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Direct User Charges
Shared-Use Paths
Safety Scans

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—

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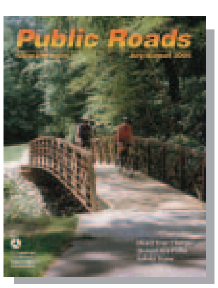

Front cover—These bicyclists are crossing a pedestrian bridge on the Crabtree Creek Greenway Connector, which is an urban, multiuse trail linking neighborhoods along a greenway system in Raleigh, NC, to one of the largest shopping malls in the Southeast. This 1,524-meter (5,000-foot)-long section of the trail includes a tunnel under U.S. 70, which is an eight-lane, high-volume arterial that is hazardous for crossing by pedestrians and bicyclists. Other design features of the trail include a 3.7-meter (12-foot)-wide bridge, lighting for nighttime use, and a centerline pavement marking. *Photo: North Carolina Department of Transportation.*

Back cover—Hot air balloons rise above the reconstructed "Big I" interchange in Albuquerque, NM, where the State's major interstates I–25 and I–40 intersect. Completed in 2002, the project replaced an outdated interchange originally constructed in 1966 to carry an average daily traffic of 40,000 vehicles. The renovated facility carries a volume of more than 300,000 vehicles per day. Streamlined environmental reviews and innovative financing helped the New Mexico State Highway and Transportation Department fast-track the project, with designs completed in 16 months and construction finished in just 23 months. *Photo: URS Corporation and New Mexico State Highway and Transportation Department.*

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Federal Highway Administration

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Guest Editorial

Financing the Increasing Cost of Highways

"We need more money for highways." This comment goes back to the earliest days of the Federal-Aid Highway Program. Each era has found solutions to funding shortages in keeping with the social, economic, and political times. In the 1950s, in step with those times, Congress rejected toll and bond financing and created the Highway Trust Fund to ensure that highway user tax revenues would be dedicated to the Eisenhower Interstate System and other highway projects. This mechanism served the Nation well for five decades.

The social, economic, and political spirit of the 21st century has raised questions about whether the Nation can rely on traditional highway user taxes alone to sustain the highway infrastructure, which is being squeezed to the limit. All levels of government—Federal, State, and local—are feeling budget pressures. Moreover, with the growing interest in fuel-efficient vehicles, such as gas-electric hybrids, traditional highway user revenues may not continue to increase as they have in the past. It is safe to assume, however, that highway needs will grow.

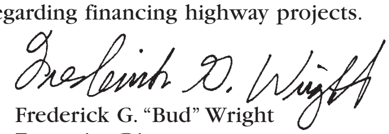
The Federal Highway Administration (FHWA) has joined with a number of State and local transportation agencies to explore alternative financing mechanisms, including tolling and public-private partnerships. These ideas were promoted for many years, but they have gained momentum since the mid-1990s with the spread of automated toll collection equipment. New tolling innovations have opened up possibilities that were not even imagined in 1956 when Congress created the Highway Trust Fund. From the high-occupancy toll (HOT) lanes on State Route 91 in California to the proposal to add HOT lanes on the Capital Beltway in the District of Columbia's metropolitan area, innovative financing concepts are being implemented from coast to coast.

This issue of PUBLIC ROADS launches a series of articles on highway financing issues and options. "Direct User Charges," the first article, explores the effects of direct user charges on the roles, relationships, and organization of network service providers, including State departments of transportation, toll authorities, and private-sector organizations. The intent of the series is to raise awareness of the choices that are available and to share some ideas that currently are being explored.

Motorists accept the notion that the gas taxes they pay are used to improve transportation. Therefore, perhaps the most surprising aspect of recent developments is the public's possible acceptance of tolls, especially when collected electronically instead of at stop-and-pay tollbooths, to provide needed service. This acceptance is enabling State and local governments to explore toll options to finance the local and interregional needs through fees that are tied more directly to specific projects or that make use of premium services, such as HOT lanes.

Another encouraging development is the growth of public-private partnerships. In some cases, the private sector contributes part of the cost for new facilities through bonds or other financing mechanisms. In other cases, private companies help reduce overall costs and enable projects to start much sooner than would have been possible using highway user taxes. FHWA is actively supporting States that want to experiment with public-private partnerships and other innovative project delivery mechanisms.

Fuel taxes have served the Nation well for many years. Federal, State, and local governments have invested billions of highway user dollars in a highway network that is essential to U.S. economic well-being, vital for national defense, and integral to the American way of life. Although the financing challenge is certainly not new, the stakes are as high as ever as the transportation community searches for innovative solutions to serve the 21st century. As complex and controversial as it might be, a new course for financing highway infrastructure will have to be charted in the very near future. Before the new reauthorization period ends. Stay tuned to future issues of PUBLIC ROADS for new strategies and ideas regarding financing highway projects.



Frederick G. "Bud" Wright
Executive Director
Federal Highway Administration

Direct User Charges

Transportation agencies are considering alternative sources of highway revenue to help build new and maintain existing highways.

by Daniel L. Dornan and James W. March

State departments of transportation (DOTs) rely primarily on Federal and State motor fuel and vehicle taxes to fund highway improvements on a pay-as-you-go basis. The combination of Federal, State, and local highway user taxes and fees, however, has not produced adequate revenues to keep pace with growth in the costs of highway programs. The biggest challenge becomes how the Nation will manage the system more efficiently and build, operate, and maintain existing and new facilities. Highway infrastructure is an asset, a continually growing asset.

(Left) Motorists from Niagara Falls to Staten Island, NY, and throughout other States in the East can travel without having to roll down a car window to pay tolls, thanks to an electronic toll collection system, E-ZPass. New York's tolling authority and NYSDOT have separate and distinct responsibilities, one of the institutional issues raised by direct user charge programs. *Photo: New York State Thruway Authority.*

According to the U.S. Department of Transportation's 2002 report, *Status of the Nation's Highways, Bridges, and Transit: 2002 Conditions and Performance Report*, revenues would have to increase by an estimated 18 percent to maintain current highway conditions and performance, and 65 percent to improve those conditions and performance consistent with the needs and expectations of a growing population and economy.

Several factors contribute to this shortfall. Taxes on motor fuel are levied on a gallonage basis, but due in part to increased vehicle fuel efficiency, taxes do not keep pace with rising highway construction costs. Also, Federal and State elected officials are hesitant to increase tax rates on motor fuel.

In response to the growing gap between highway needs and available funding, transportation policymakers may consider alternative sources of highway revenue to supplement the fuel tax. Among the alternatives are various kinds of fees that are charged directly to users of specific highway facilities. Dubbed direct user charges (DUCs), these tolls pay for the development, operation, and preservation of highway facilities. Among the variations are tolling new highway facilities, tolling sections of existing interstates that require major rehabilitation or expansion, tolling vehicles that do not meet the occupancy requirements for use of high-occupancy vehicle lanes (HOT lanes), tolling dedicated truck lanes, and congestion pricing along designated express lanes.

The introduction of DUCs creates both opportunities and challenges for State DOTs. Two of the issues involve the State's view of the purpose of tolling highways and of how DUC funds should be used. Another issue revolves around the major difference in the way that tolling entities operate compared with State DOTs in terms of mission, goals, business practices, culture, organization, and financial constraints. Still another issue is the applicability and transferability of toll authority conventions to State and local transportation agencies. Lessons learned in dealing with these institutional issues can be drawn from the experiences of transportation organizations that already are using alternative funding approaches to manage the system more efficiently and effectively.

Purpose of Direct User Charges

The principal purposes of DUCs are revenue generation and demand management. Traditionally, State and local DOTs used tolls primarily to finance specific transportation facilities. Growing congestion in many metropolitan areas and the difficulty in constructing new facilities to relieve that congestion have increased interest in a second use of direct user charges—to manage travel demand during peak periods. Because congestion tolls may generate substantial revenues, they also may be used to increase transportation capacity by funding new or expanded facilities.

When private-sector entities are involved in DUC programs, the challenge for transportation agencies is to find the balance between revenue generation and demand management purposes.

Regulation of DUC Revenues

State transportation agencies that are developing a DUC program are faced with several decisions, such as how to collect the charges and how to adjust rates over time. The regulation of DUC rates can have a significant effect on revenue generation, demand management, and the potential for attracting private-sector involvement.

One of the greatest challenges to a viable program is the inability to increase DUC rates commensurate with the costs of developing, financing, operating, and preserving the facility. The Illinois State Toll Highway Authority waited more than 20 years to obtain permission to raise its rate schedule, which severely limited its ability to finance needed improvements and affected the bond ratings it was able to obtain. Transportation agencies contemplating DUC programs must therefore understand that obtaining approval for DUCs in the first instance is only one hurdle in managing this kind of revenue program.

Cofiroute (formerly California Private Transportation Company)

The express lanes on State Route 91 in Orange County, CA, are separated from the regular lanes by the yellow plastic pylons shown here. One purpose of direct user charges is to manage congestion during peak periods.

At this eight-lane toll plaza on the Chesapeake Expressway in Virginia, barriers maintain clear separation between the high-speed electronic toll collection traffic on the left and the manual payment traffic, especially important on weekends when vacationers are using the tollway to reach North Carolina's Outer Banks. The choice of collection technologies is one of the decisions facing agencies that are considering a DUC program. *Photo: Parsons Brinckerhoff Quade & Douglas, Inc.*

Another challenge occurs when public sponsors of tolled facilities retain authority for developing and changing DUC rate schedules. This risk is greatest when ratesetting authority is vested in elected or appointed officials or requires public authorization by referendum. The Province of Ontario, Canada, recently tried to prevent its concessionaire from raising rates on Highway 407 (known as the Electronic Toll Road), just north of Toronto, but the courts ruled in favor of the concessionaire.

The imposition of a DUC program requires several regulatory decisions regarding: (1) the level of user charges, (2) the choice of whether those charges are variable or fixed, (3) collection methods and technologies, (4) criteria for determining and adjusting DUC rate schedules over time, (5) public and private responsibilities for regulating toll schedules and rates of return to assure equity and avoid perceptions of excess profits, (6) the balance between government control and the application of market forces in regulating the use of highway facilities, and (7) the effects of government regulation of DUC rate schedules and other government policies on the private sector's interest in becoming an equity partner in projects funded by DUCs.

Use of DUC Revenues

Four options for using DUC revenues are possible. The first involves dedicating the DUC revenues to developing, operating, maintaining, and preserving the specific facility where the revenues are generated. This linkage is typically made when DUC revenues are pledged to pay the debt service costs of revenue bonds issued to build, expand, or rehabilitate highway facilities, as specified in bond covenants.

The second option is dedicating the funds to the improvement of other transportation services in the corridor, especially transit services if the objective of the DUC is to manage demand and reduce highway congestion.

The third option is the development, operation, maintenance, and preservation of a system of highway facilities, all of which could be tolled facilities or a combination of tolled and nontolled facilities. This portfolio approach involves using DUC revenues to offset the costs of the overall highway system.

The last option is application of the DUC revenues to the general transportation fund to be used as needed by the State DOT to fund priority transportation projects, whether highway or other modes.

Each option will affect the potential for a private-public partnership. The more direct the relationship between the collection of DUCs and their specific use, the more public support State DOTs are likely to receive when imposing DUCs for the first time or increasing rates in subsequent years.

Authority and Responsibility for Program Functions

An important consideration before implementing a DUC program is the organizational alignment of roles and responsibilities and the relationship between DUC units and State and local transportation agencies. Currently, most State and local transportation agencies do not collect DUCs and therefore do not have units devoted to their administration. Once transportation agencies incorporate DUCs into their funding and financing approaches, the traditional organizational arrangements suited to a pay-as-you-go approach may no longer be adequate.

Collection of DUCs imposes a new set of fiscal management responsibilities, including cash collection, handling, and management; security; accounting and billing; customer service; and investment management. To accommodate these requirements, a DOT may use one of several organizational arrangements:

- A separate authority distinct from the State DOT responsible for all aspects of DUC-supported programs and projects. Many tolling entities that emerged prior to the Interstate System used this model. Examples include the turnpike and bridge authorities in Illinois, Indiana, Massachusetts, New Jersey, New York, Ohio, and Pennsylvania.
- A specialized unit within or related to the State transportation agency responsible for all aspects

This sign above the S.R. 91 Express (HOT) lanes in Orange County, CA, provides a toll-free telephone number and uses arrows to indicate "3+ Lane" and "Toll Lanes." *Photo: Orange County Transportation Authority.*

Maryland Transportation Authority

Toll plazas operated by the Maryland Transportation Authority.

of DUC programs and projects, but organizationally distinct from the rest of the agency. This model is becoming the predominant one for organizing new tolling entities. Examples include the Colorado Tolling Enterprise, Florida's Turnpike Enterprise, North Carolina Turnpike Authority, and the Texas Turnpike Authority.

- DUC program functions integrated into the State DOT as part of the responsibilities of existing functional units. Examples of this model include the New York State Department of Transportation's (NYSDOT) operation of tolls on various parkways in the State and the original model used by the Florida Department of Transportation (FDOT) to organize the functions of Florida's Turnpike after taking it over from the Florida Turnpike Authority in 1969.
- DUC programs and facilities contracted to private consortia or local or regional toll authorities, such as California's transportation corridor agencies, Florida's regional expressway authorities, and the emerging regional mobility authorities in Texas.

Independent turnpike authorities both complement and compete with their State DOT counterparts. Independent toll roads add capacity to a region's highway network and help to relieve congestion on existing facilities, whether tolled or nontolled. In some instances, however, bond covenants include so-called "noncompete clauses," which preclude the construction or expansion of parallel nontolled facilities that could attract traffic from the tolled facility. These clauses can be a major source of dispute between independent toll authorities and their State or local DOT counterparts. A case occurred in southern California when the Orange County Transportation Authority recently reacquired the State Route 91 (S.R. 91) express lanes from the private-sector concessionaire to allow highway capacity expansion in this highly congested corridor.

Tolling units within State DOTs are usually semiautonomous entities to protect the integrity of the funding mechanisms and service and preservation commitments associated with the revenue bonds and loan agreements to which the DUC funds are pledged. These units are more likely to integrate their capital planning and programming with the rest of the department than are independent authorities.

The Oklahoma Turnpike Authority is a hybrid tolling organization that incorporates elements of both the independent and semiautonomous tolling models. It operates as an autonomous turnpike agency but is closely linked to the State DOT. The authority has its own appointed board and hired staff responsible for the development, operation, and maintenance of 10 turnpikes across the State. The secretary of transportation, however, is also the transportation authority director. This arrangement ensures consistent and coordinated planning and programming.

A number of State DOTs have divisions that successfully apply DUCs to selected facilities. The Maryland Transportation Authority (MdTA), as a variation of the semiautonomous organizational model, is an independent State agency that acts on behalf of the Maryland Department of Transportation (MDOT). MdTA owns and operates all of the tolled highways, bridges, and tunnels in Maryland. The Maryland State Highway Administration is responsible for all nontolled State highways, bridges, and tunnels. Although Maryland uses the concept of a statewide transportation trust fund to pool various financial resources to fund infrastructure programs and projects across the modes, the toll revenues collected by MdTA are kept separate to support revenue bonds issued by the authority. The MdTA is authorized to issue debt to fund transportation infrastructure projects when appropriate.

Private- and Public-Sector Roles and Responsibilities

DUC programs offer the potential to form partnerships between public and private stakeholders. With the prospects of bonding against future revenues, DUCs enable the private-sector to become more involved in financing highway infrastructure. Greater opportunity is available for alternative funding approaches through the creative use of private sector equity, longer term financial arrangements, improved risk management, and additional techniques honed in other infrastructure industries such as commercial buildings, manufacturing and processing plants, and telecommunications. Contract timeframes will likely increase to reflect the private sector's willingness and ability to manage the risks associated with longer term commitments.

The potential for expanded involvement by the private sector may be constrained by U.S. tax laws that limit the duration of private management contracts for projects funded by tax-exempt debt (no more than 15 years, including extensions) and other laws.

In addition, strategic, security, economic, and mobility questions may arise regarding the appropriateness of foreign ownership and control over public-use transportation infrastructure in the United States.

DUCs, as a significant source of funding for highway projects in this country, will likely pose a number of additional challenges relating to the roles and responsibilities of traditional stakeholders and the allocation of funds.

Traditional providers of highway planning, design, and construction services are accustomed to the pay-as-you-go approach. Institutional inertia is one of the most significant potential impediments to the formation of public-private partnerships that go beyond traditional outsourcing of design and construction services. Evidence of institutional inertia is reflected by the continuing resistance to contract reform by many construction contractors, who insist on the traditional design-bid-build method. Institutional inertia based on strict adherence to business as usual, fear of change, and perceived threats to traditional business relationships and market presence represent potential obstacles to the successful implementation of DUC programs.

Mixing Traditional Tax and DUC Revenues

Motor fuel taxes are only indirectly related to the use of the highway facilities they support. The revenues from Federal motor fuel taxes are credited to the Federal Highway Trust Fund and annually distributed back to State DOTs through congressional appropriations for the formula-based programs, allocated demonstration programs, and designated earmarks. State motor fuel taxes and other highway funding sources (driver's license and vehicle registration fees) are commingled in various ways with other types of indirect revenue sources, such as sales and income taxes. The extent of commingling varies from State to State, and the relative magnitude of these other taxes and fees also vary considerably.

In each instance, the method of revenue collection separates the act of paying for highway facilities from their use, helping to create the illusion of so-called "free highways." This method of collection also has enabled State DOTs to program the use of these revenues to projects on a systemwide basis, because the proceeds of motor fuel taxes are not dedicated to the facilities where the fuel consumption occurred.

In contrast, DUC mechanisms such as tolls imply a direct linkage between the motorist's use of the facility, the toll payment, and recognition that toll revenues pay for the construction and upkeep of the facility where the fees are collected. However, motorists also are aware that their motor fuel taxes are meant to pay for highways and often resist DUCs because they believe that tolls on top of motor fuel taxes represent double taxation.

For State DOTs considering DUCs for selected highway facilities, an important institutional consideration is whether to dedicate the revenues to the facilities where they are collected or to mix DUC-based revenues with tax-based highway program funds. States can use any one of a variety of alternative models, such as segregating the DUC revenues and dedicating them to the facility where they are collected. Another option is segregating them but allowing them to be used to finance any transportation improvements in the highway corridor, including transit, or allowing them to be used on other facilities where DUCs are collected. Still other alternatives include mixing DUC revenues with highway program revenues for use on facilities regardless of whether tolls are collected on them, mixing them regardless of mode or facility type, or mixing DUC revenues with other general funds for expenditure on any public purpose.

If DUC revenues are segregated and are able to fully cover capital, operation, maintenance, and debt service costs, States can use scarce

Nathan Macek, AECOM Consult, Inc.

Coauthor Daniel Dornan (left) with FHWA Administrator Mary Peters (center) and Former Deputy Secretary of the U.S. Department of Transportation Michael Jackson (right) at a USDOT/FHWA-sponsored workshop on public-private partnerships hosted by Florida's Turnpike Enterprise and FDOT on October 6, 2004.

Federal-aid and other State highway program funds on other facilities. The agency then can avoid the additional requirements associated with the use of Federal-aid funds in developing or improving those facilities. In addition, issuing bonds is easier and cheaper if there is a clearly defined and dedicated revenue source for debt service payments.

DUCs can still be dedicated to a specific facility even if revenues from other sources are required to fully fund the facility. Traffic on many new facilities may not be adequate to allow those facilities to be financed entirely with tolls, but using DUC revenues to supplement fuel taxes and other traditional highway revenues will stretch available highway revenues and enable transportation agencies to fund more projects.

Commingling funds from a portfolio of DUC facilities provides the sponsoring agency with added flexibility in funding facilities with different revenue potentials, at different stages of maturity, or in different geographic areas. This flexibility is especially important for new facilities funded by revenue bonds since traffic in the early years may not generate sufficient tolls to cover debt service requirements. Tolling agencies with older, more mature facilities with positive cash flows can use a portfolio approach. Florida's Turnpike Enterprise uses that approach to finance its toll facilities, given the financial strength of the Florida Turnpike's main corridor. The proceeds from tolls are allocated on a geographic basis to address concerns by patrons in one area that their tolls might be used to cross-subsidize patrons in another area.

Although mixing DUC revenues with other funds such as motor fuel taxes provides the greatest financial flexibility to the sponsoring agency, this flexibility comes at the cost of having to satisfy all requirements associated with the various funding sources being used. Funding for the initial Trans-Texas Corridor projects outside Austin, which includes dedicated toll revenues, State highway program funding, Transportation Infrastructure Finance and Innovation Act (TIFIA) loans, and private right-of-way donations, is an example of a mixed financing approach. In Maryland, DUC proceeds are not included in the State's transportation trust fund to ensure that the revenues are available to service the debt and satisfy the covenants associated with outstanding revenue bonds.

Equity for Users

As an additional revenue source, DUCs are considered by many stakeholders as double-charging for surface transportation facilities since users continue to pay motor fuel taxes. Defenders of DUCs point to higher service levels on tolled facilities as value for the added costs resulting from the imposition of DUCs.

Tolling of vehicles that do not meet the occupancy requirements for using high-occupancy vehicle (HOV) lanes (HOT lanes) and congestion-based variable pricing of express lanes have raised questions about equity for different socioeconomic groups. The higher the DUC, particularly when used as part of a variable pricing approach aimed at better managing travel demand and the resultant congestion, the greater the potential burden on lower income users. Some critics have dubbed HOT lanes "Lexus lanes" out of concern that the wealthy disproportionately benefit from these facilities. According to a 2000 study at California Polytechnic State University by Edward Sullivan, *Continuation Study to Evaluate the Impacts of the SR 91 Value-Priced Express Lanes Final Report*, however, express lane users come from all income levels.

Another equity concern is whether certain States or regions will benefit disproportionately from the ability to apply DUCs because they have the greatest potential for success in generating revenues and managing system congestion in more densely populated urban areas. Potentially, fast-growing and higher income areas of the Nation will have a distinct fiscal advantage in funding their transportation needs through the application of DUCs as compared to more rural areas.

Patrons of DUC facilities where proceeds are diverted to pay for other transportation programs, projects, services, or modes may perceive such diversions as inequitable. In certain areas of the country, these users have convinced their elected officials to institute measures to ensure that the DUC proceeds remain within the community in which they are generated.

Daniel Dornan, AECOM Consult, Inc.

Florida's Turnpike Main Line uses a portfolio approach to implement direct user charges. This sign marks the entrance to the turnpike in Dade County.

Cultural Challenges Within Agencies

The introduction of DUCs by State DOTs will inevitably affect the evolution of those agencies, in terms of their program orientation, culture, policies, practices, accountability, and critical success factors. Changing the status quo is inherently difficult for organizations that have become used to a certain way of doing business, particularly if the status quo has a long history of success.

For the first 35 years of the interstate highway program, the Federal Highway Trust Fund provided such a high proportion of the revenue for building interstates that States were eager to participate and quite willing to model their programs after Federal rules, regulations, policies, and procedures. During this period of highway development, the Federal-aid program became a reliable source of program guidance and project funding. Over time, a signifi-

Hubert H. Humphrey Institute

Officials from several States are shown here participating in an FHWA workshop to promote exchange of lessons learned from their efforts to implement value pricing for toll facilities.

cant private highway construction industry developed. Later, as the highway program continued to grow and mature, State DOTs began to outsource more and more of their project design work as well. With the parameters of the program fully defined and the roles of stakeholders specified, an institutional framework evolved that produced a culture of standardized processes. As a result, the highway programs in many States are largely characterized by projects that meet Federal transportation and environmental planning criteria, receive at least partial funding through annual appropriations from the Federal Highway Trust Fund, are financed on a pay-as-you-go basis as Federal-aid funds became available, and are delivered through a highly controlled and rigid design-bid-build contracting process.

Given the nature of the funding mechanisms, State transportation agencies pay particular attention to two factors: committing the full allocation of Federal-aid funding appropriated each year and making sure that contracts for all planned construction projects are awarded on schedule. These two factors ensure that no available Federal-aid funds for which the State is eligible are left unclaimed and that the bulk of the highway program for that year is committed so that the highway construction industry can commit its resources with assurance. As funding has become more constrained relative to needs, State transportation agencies are paying more attention to such performance factors as schedule and budget conformance.

Toll authorities have a somewhat different culture as a direct result of their reliance on DUCs as their primary funding source. Debt-based financing mechanisms cause the tolling entities to be more accountable for the operation, maintenance, and preservation of their facilities due to the requirements contained in bond covenants. These covenants are intended to protect the interest of the bondholders by ensuring that the funds derived from the tolls are used to keep the toll facility operating at a high level of performance to promote use by patrons who have a

Metropolitan Transit Development Board

Tolls are charged electronically on the I–15 HOT lanes, using a special lane with readers suspended overhead from gantries like those shown here.

choice of tolled and nontolled facilities. Bond covenants also require that certain reserve funds be maintained to ensure that the tolling agency has sufficient financial resources to weather periods of higher expenditures or lower revenues due to changes in the economy and other causes beyond the control of the agency.

One impact of DUCs on tolling agencies is the importance of completing projects on schedule and adhering to the budget. Delayed projects defer the collection of toll revenues, while escalating project costs make it more difficult for the sponsoring agency to satisfy the various requirements of the bond covenants. Both factors can jeopardize the financial feasibility of a project relative to its revenue-producing capability, particularly in the early startup years. Bond rating agencies might downgrade the project or agency bonds, which would increase the cost of bonded debt, further exacerbating the financial consequences of project delays and overruns.

Transportation agencies with a long history of DUC use consider the users of their facilities as customers who require added value through the condition and operation of the toll road, bridge, or tunnel to justify the added costs of using these facilities. "We offer transportation value in the form of safety, service, and convenience," says Jim Ely, executive director and chief executive officer of Florida's Turnpike Enterprise. "In the years that I've been the director of Florida's Turnpike, I have yet to meet a person who likes paying a toll. They do like what user-financed transportation offers—that is, better mobility for all." Toll facility operations are much more locally focused, and accountability is directly to the customers, bond holders, and the communities they serve.

In recent years, the older toll agencies have transitioned from being merely caretakers of debt-financed facilities, whose tolls were slated to be eliminated once the debt was paid off, to enterprising engines for capital investment in highway facilities that promote economic development in the areas they serve. This change has produced a culture of entrepreneurs who have become empowered to adopt more innovative approaches to improve cost effectiveness, to manage greater risks to achieve greater outcomes, and to take a longer term view that focuses on products over process.

Daniel Dornan, AECOM Consult, Inc.

Operations Center for Florida's Turnpike Enterprise, Pompano Beach, FL.

The application of DUCs by more traditional transportation agencies can promote a transition to a more customer-centered, production-driven, service-oriented, and accountable highway program. Agency leadership must consider that "business as usual" does not apply when DUCs are introduced. The whole notion of collecting fees directly from users poses design, engineering, operational, logistical, and financial management challenges to an agency not used to handling or managing these kinds of funds. State DOTs might be able to learn much from their counterparts in the tolling community.

In the near term, DUCs will not likely become the predominant revenue source for State or local transportation agencies. Even a modest percentage of DUC-based funding, however, will have profound effects on a State's entire highway program. Those State and local DOTs considering applying DUCs to selected highway facilities need to understand the cultural changes likely to occur with the imposition of DUCs, the nature and source of opposition to those changes, strategies for managing the transition, and the absolute necessity to develop added capabilities in such areas as financial management, operations, asset management and preservation, and performance tracking.

Public Acceptance

The prospect of new revenue sources has many stakeholders excited about the opportunity to recharge highway capital budgets and address transportation infrastructure needs that would otherwise take years, if not decades, to realize under the pay-as-you-go approach. As noted by Ely of Florida's Turnpike Enterprise, "I'm not a toll nut—I'm a transportation nut. If we had sufficient funding to meet the growing demand for mobility in our State, I would be the first in line to bulldoze all our toll plazas. That isn't the case today and won't be in the foreseeable future."

Many State DOTs are legitimately concerned about the institutional challenges and are cautious about the public's willingness to accept DUCs. Electronic tolling technology and the ability to provide open road tolling without tollbooths or toll collectors can remove a significant

OOCEA

In Florida, the Orlando-Orange County Expressway Authority (OOCEA) converted the University Boulevard Plaza on S.R. 417 from a traditional main line barrier plaza to the express lanes concept by which E-PASS customers can pay their tolls electronically at the posted highway speed.

impediment to public acceptance. "People are more willing to pay DUCs if they receive value for their toll dollars and do not have to wait in line to pay the toll," says Patrick Jones, executive director of the International Bridge, Tunnel, and Turnpike Association.

Leaders in the highway design and construction industry also support DUCs when they recognize that tolls provide a means to expand and expedite highway improvement programs without jeopardizing traditional fuel tax-based programs.

The entire highway infrastructure industry and market is in a state of flux, with major changes already happening and even more significant changes on the way. As noted in the Fitch Ratings report of 2003, *Redefining Toll Roads: An American Challenge*: "U.S. toll roads are now entering into a remarkable period of redefinition, involving an active debate on how toll roads are organized, with whom they partner, and even how they perceive their identity."

The same can be said about the Federal-aid highway program and the State and local transportation agencies that administer the program. In both institutional arenas, the need for change is being driven by the widening gap between transportation infrastructure needs and the resources available to address those needs. DUCs may help State and local transportation agencies reduce and potentially close this widening gap, provided these agencies create an institutional environment that embraces new ways of meeting the transportation accessibility and mobility needs of America. "While the challenges are great and the needed changes may appear ominous, the risks of not changing are much greater with the Nation's economic viability at stake," says Ken Philmus, vice president and national director of toll services, DMJM Harris, and former director of the Tunnels, Bridges, and Terminals Division of The Port Authority of New York and New Jersey.

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This article is the first in a series on innovative financing that will run in the next few issues of PUBLIC ROADS. One of FHWA's priorities is encouraging the use of innovative financing.

Making Trails

by Ann H. Do, Joseph E. Hummer, Jennifer L. Toole, and Nagui M. Rouphail

A new tool will help designers evaluate the level of service on shared-use paths.

"If you build it, they will come," says Chuck Flink, president of Greenways Incorporated in Durham, NC. Originally uttered by the actor Kevin Costner in the movie, "Field of Dreams" (1989), Flink used the quote to describe the growing demand for new trails and footpaths in the United States. Shared-use paths, defined as paved offstreet travel ways for nonmotorized traffic, attract bicyclists, pedestrians, inline skaters, roller skaters, skateboarders, equestrians, wheelchair users, and others for purposes ranging from commuting to leisure and recreation.

As the popularity of shared-use paths grows, trail usage and mileage are increasing steadily. In fact, some urban trails attract hundreds or even thousands of users per hour during peak periods, and many are experiencing morning rush hours on weekdays and traffic jams on weekend afternoons. According to a survey conducted in 2000, the Capital Crescent Trail in the Washington, DC, metropolitan area handles an average of 400 to 500 users per hour during peak periods. And the Pinellas Trail, stretching from Tarpon Springs to St. Petersburg in Florida, attracts an estimated 90,000 users per month, according to the Florida Department of Environmental Protection.

"The potential for conflict, overuse, and misuse is growing as more and more people are using the trails," says Dan Cross, project manager of Trailnet, a nonprofit organization based in St. Louis, MO, that is dedicated to promoting bicycle and pedestrian activities. "When you have a diverse group of users all using the same facility at the same time, it's almost like having a tennis game going on in the middle of a baseball game. The walkers don't like the bike riders because they go too fast, inline skaters get upset with pedestrians for walking two abreast, and the bike riders complain because inline skaters use too much of the trail when swinging their arms back and forth with each glide."

When creating a shared-use path, designers and planners often begin with the question, how wide should the pathway be? That question nearly always raises more questions: Will the path ever need to be widened? Should different types of users be separated from one another? If designers specify trails that are wider than future use justifies, they potentially waste money that could have been used to construct more trail miles. If the trails are too narrow, user conflicts and the potential for collisions may lead to dissatisfaction among users and the need to consider expensive trail-widening projects.

In 2000 researchers at the Federal Highway Administration (FHWA), North Carolina State University, the Toole Design Group, and the University of North Carolina initiated a study, Evaluation of Safety, Design, and Operation of Shared-Use Paths, to develop a simple tool and guidance to help trail managers and planners optimize their designs for shared-use paths. The research involved four primary efforts. The first task was to develop theoretical equations with which to estimate users'

A woman with young children is easily passed by a cyclist going the opposite direction on the new waterfront trail system in Portland, OR. *Photo: Robert S. Patten, Toole Design Group.*

Jennifer L. Toole, Toole Design Group

A separate structure carries this shared-use path across the Allegheny River in Pittsburgh, PA. While a pair of bicyclists takes a break to enjoy the view, a family of pedestrians passes behind them. The generous path width and broad curvature improve sight distance and enhance safety.

passing and meeting events on shared-use paths. Passing events occur when a bicyclist either overtakes or is overtaken by other path users while traveling in the same direction. Meeting events are when a bicyclist encounters trail users traveling in the opposite direction. Next, the research team collected field data on path operations to calibrate and validate the equations for conditions in the United States. The third task involved collecting data on the perceptions of path users and developing a model relating those perceptions to operational and geometric variables. Finally, the researchers developed a computer-based tool to estimate the level of service (LOS) on new or existing shared-use paths.

The Need for a New Model

The fourth edition of the Transportation Research Board's *Highway Capacity Manual 2000 (HCM)* represented the first attempt to offer a procedure model for analyzing LOS for shared-use paths on a large scale in the United States. The model estimates the number of passing and meeting events encountered by a test bicyclist traveling at the mean speed of bicyclists on a test trail. Collecting data from the perspective of a bicyclist is analogous to collecting data on traffic volumes on a highway using a moving vehicle.

A number of limitations, however, make it difficult for designers to use the *HCM* procedure to resolve problems in path design. First, the procedure is based in part on field data from the Netherlands. U.S. paths typically are wider than those in Europe, and bicyclists in the United States tend to ride more often for recreation and not for commuting. Therefore, the team determined that a new model needed to be calibrated and validated for U.S. conditions, especially the weighting used for criteria in passing and meeting events.

Second, the *HCM* procedure does not consider passive passing events, which occur when a faster path user passes the test bicyclist. Also the old procedure assumes that path users do not impede one another's movements, meaning that there is always adequate room for one bicyclist to pass another with no change in speed or lateral positioning. This is true only if the path is wide enough or the bicyclist encounters no opposing traffic during the passing maneuver. If passing is restricted, overtaking events will be delayed.

Another limitation is that the current LOS procedure accounts for pedestrians and bicyclists only. Today, shared-use paths accommodate runners, inline skaters, skateboarders, and other users. Further, the current procedure is based on single statistical values of bicyclist and pedestrian mean speeds. Designers working in areas where bicyclists and pedestrians may travel faster or slower need to have the ability to incorporate that information into their LOS estimates.

Finally, the *HCM* method is limited to analyzing two- and three-lane paths, where two-lane paths are specified as 2.5 meters (8 feet) wide and three-lane paths as 3 meters (10 feet) wide. No guidance exists for designers considering other widths and numbers of lanes. "Our rule of thumb has been to build 12-foot [3.6-meter]-wide trails," Trailnet's Cross says, "with no rhyme or reason, or research to back it up. It looked and felt more comfortable for users."

Flink, who has been in the business of designing trails for more than

Robert S. Patten, Toole Design Group

Joggers like these are frequent users of the Schuylkill River Trail in Philadelphia, PA.

Robert S. Patten, Toole Design Group

This trail features separate paved lanes for users to spread out or segregate themselves according to travel speed.

20 years, agrees, adding that a new LOS tool will help remove much of the guesswork. "In the past, we relied on the AASHTO [American Association of State Highway and Transportation Officials] guidance that calls for 10-foot [3-meter]-wide trails," he says, "but field experience says that's often not wide enough. Some people go with 12 feet [3.6 meters], while others choose 14 feet [4.3 meters]. But that's not based on scientific fact, just observation. Anything that applies more science and math to the topic will help us out a lot."

Considering these limitations, FHWA and its partners set out to develop a new LOS procedure and produce a tool that designers can use to evaluate the operational effectiveness of shared-use paths, given various traffic volumes or forecasts and a few geometric parameters.

Collecting Data

The theoretical framework for estimating meeting and passing events on a shared-use path is based on the theory of supply and demand from the perspective of a bicyclist traveling at the average speed of bicyclists on the path. The project team developed equations from basic traffic flow principles to estimate the frequency for meetings, active passes (passing a trail user moving in the same direction), passive passes (being passed by another trail user moving in the same direction), and delayed passes (being unable to pass a trail user moving in the same direction because of oncoming traffic or encountering trail users traveling two or three abreast).

Next the project team identified a method to collect data on meeting and passing events to validate the models. The chosen solution involved mounting a video camera to a bicycle helmet to record data as a team member peddled through selected segments of shared-use paths. The video camera recorded the number of meetings, the number of passes accomplished, and the number of delayed passes. At the same time, another team member counted the number of users of each mode in each direction moving past the midway point of the segment. This exercise provided the necessary volume data. The day before conducting the moving bicycle study, the team determined the desired mean speed for bicycles by recording a sample of speed observations manually using a stopwatch.

Selecting Test Sites

The project budget limited data collection to 10 U.S. cities, and the team used a number of criteria to select candidate sites. First, the team sought paths that represent the diversity of regions in the United States. To reduce travel costs, it selected cities with two or more sites. In addition, the sites needed to contain a variety of geometric characteristics, moderate to high traffic levels at least sometimes, and 0.8-kilometer (0.5-mile)-long segments with no intersections or turnouts, assuring uninterrupted flow.

The team assembled a preliminary list of 37 cities with paths that meet some or all of the criteria and submitted a questionnaire to path managers to help determine the suitability of their respective sites. Based on the responses, the researchers identified 10 cities that provided the best possible chances to satisfy the criteria. The final list of 15 trails represents cities in all regions of the United States and many of the best-known trails in those areas. The trails are located in urban and suburban environments that include parks, lakes, beaches, highways, and downtown areas. Trail widths range from 2.4 to 6.1 meters (8 to 20 feet), and some paths were marked with centerlines.

Robert S. Patten, Toole Design Group

Signs like this one encourage pedestrians and slower users to stay to the right, allowing faster users to pass them safely on the left.

Locations and Trail Names

Location	Trail Name
Marin County, CA	Mill Valley-Sausalito Pathway
Santa Monica, CA	South Bay Trail
Washington, DC	Capital Crescent Trail
Dunedin, FL	Honeymoon Island Trail (Dunedin Causeway)
Dunedin, FL	Pinellas Trail
Chicago, IL	Lakefront Trail
Arlington, MA	Minuteman Bikeway
Boston, MA	Dr. Paul Dudley Bike Path
St. Louis, MO	Forest Park Trail
St. Louis County, MO	Grant's Trail
Raleigh, NC	Lake Johnson Trail
Dallas, TX	White Creek Trail
Dallas, TX	White Rock Lake Trail
Vienna, VA	Washington and Old Dominion Trail
Redmond, WA	Sammamish River Trail

This table shows the location of the 15 trails in 10 cities where the project team collected data on bicycle passing and meeting events. *Source: FHWA.*

The team collected data primarily on weekends from July 2001 to March 2002. In total, the researchers completed 771 runs with an average of about 60 runs at most trails.

Analyzing the Data

The two main objectives of the data analysis were to develop average and default values for key parameters that the team could use in a procedure for estimating LOS and to validate the theoretical framework developed earlier. The average and default values collected included speeds, volumes, mode splits (the breakdown of different types of users), a peak hour factor, percentages of user groups occupying two lanes, and distances needed by bicyclists to make passes. To validate the theoretical framework, the researchers compared the number of meeting and passing events recorded on the trails against the numbers predicted using the model.

The team recorded speeds using a stopwatch. The goal was a sample of at least 30 free-flowing bicyclists and as many other path users as possible during the time the researchers were recording the test bicyclist's speeds.

Based on up to 8 hours of observation at relatively busy times on 15 paths, the team estimated an average volume of just over 400 users per hour. Adult bicyclists made up an average of 56 percent of the users, with pedestrians averaging about 18 percent, runners about 13 percent, skaters about 10 percent, and child bicyclists about 3 percent. Although some trail professionals who use the model may have detailed counts or forecasts for the volume of users by mode on their paths, most will need to rely on default values.

The peak hour factor is an important consideration in capacity and LOS calculations to adjust for peaking of traffic within the hour of interest. The team determined the peak hour factor by dividing the hourly volume by four times the volume of users in the peak 15-minute time period within that hour. It is important that designers consider a peak hour factor for trails because pedestrian and bicyclist peaks tend to be higher than motor vehicle peaks. Therefore, a trail may feel more crowded to its users than a raw volume count or forecast would convey, and designers need to account for that.

Another default value necessary as an input in the delayed passing procedure was the proportion of users moving along the path while occupying two lanes. Usually, a group of two users moving together will occupy two lanes. In many cases, however, a group of two or more users occupy one lane because they move in single file, or one user walks or rides off the path, or the users walk or ride side by side but very close to each other. To collect these data, the team reviewed

www.pedbikeimages.org, Dan Burden

These four pedestrians are walking side by side down a shared-use path in Santa Barbara, CA. The researchers found that in 36 percent of the cases studied, pedestrians occupied two lanes, potentially causing a faster user, such as a bicyclist, to slow down and delay passing.

21 hours of videotape from the helmet camera and observed that pedestrians most often occupied two lanes, followed by runners, skaters, and bicyclists.

The distance needed by a bicyclist to pass another trail user is another key factor. To collect these data, the team reviewed 50 runs for which high-quality video with passing maneuvers was available on five paths. The overall average for the case of the test bicyclist passing a pedestrian was 18 meters (60 feet) when the bike was traveling from 18 to 23 km/h (11 to 14 mi/h).

After comparing the meeting and passing data collected in the field to the predictions from the models, the team determined that the estimates from the models proved to match the field data reasonably well. The next step was to gather input from trail users.

User Perceptions

Although current LOS criteria are based on the expert opinions of the Transportation Research Board's Highway Capacity and Quality of Service Committee, the team chose to solicit user perceptions to enhance the credibility of the new model. The purpose was to develop a measure of bicyclists' perceptions of hindrance in terms of their sense of comfort and freedom to maneuver on the trail.

To gather user perceptions, the team recruited 105 volunteers from bicycle and trail user groups from the Raleigh, NC, and Washington, DC, metropolitan areas. The volunteers viewed 36 video sequences from 10 of the 15 trails and rated their perceptions of the facility conditions based on four characteristics: lateral spacing (side-to-side maneuvering room), longitudinal spacing (front-to-back maneuvering room), ability to pass, and the overall perception of comfort and freedom to maneuver. The 60-second clips represented video segments that spanned the range of geographic locations, trail widths, and geometries. To rank the qualitative responses, the project team created a five-point scale, where 1 is bad, 2 is poor, 3 is fair, 4 is good, and 5 is excellent.

Based on the participants' feedback, the project team logged a total of 15,000 observations and used the data to determine the trail characteristics (operational, geometric, or contextual) that factored significantly into the bicyclists' perceptions of the four freedom-to-maneuver characteristics noted above, and to what degree. Analysis of the respondents' comments showed that the variables related to path operations and trail width strongly affected the overall quality of the users' experiences. The recommended model for overall rating therefore included variables for path width, the number of meeting and passing events, and the presence of a centerline.

Developing the LOS Procedure

A review of the literature enabled the project team to evaluate existing LOS tools from the standpoints of ease of use, accessibility of the format, inputs required, nature of the outputs, type of scale used, and other factors. "A primary goal of the project was to produce a tool that is easy for a variety of practitioners to use, even if they do not have a background in transportation or engineering," says Michael F. Trentacoste, director of the FHWA Office of Safety Research and Development. "Trail designers, landscape architects, and park planners should be able to enter data and interpret the outputs as effectively as a transportation engineer."

Robert S. Patten, Toole Design Group

The researchers found that the presence of a solid or dashed centerline stripe, like the one shown here, appears to make bicyclists feel less comfortable overtaking slower users. This finding supports the intent of providing a centerline, which is to clearly delineate two opposing travel lanes and encourage increased caution in making passing maneuvers.

In addition to overcoming the limitations of existing methods, the researchers established a number of other objectives for the bicycle LOS procedure. The tool would use an A–F grading scale and be applicable to trails with widths ranging from 2.4 to 6.1 meters (8 to 20 feet), the full range of the study trails.

Below is the equation for the final model that predicts the overall LOS rating on a scale of 1 to 5, where "E" means weighted events (meetings plus 10 times the active passing events) per minute, "RW" is the reciprocal of path width (that is, 1 divided by path width, in feet), "CL" is equal to 1 if the trail has a centerline or 0 if the trail has no centerline, and "DPF" stands for an adjustment for the delayed passes factor.

$$\text{Bicycle LOS Score} = 5.446 - 0.00809(E) - 15.86(RW) - 0.287(CL) - (DPF)$$

The variables in the model correspond to the framework of the existing LOS method in the *HCM*, except for the centerline variable, a heavier weight on passing events, and the delayed passes factor. The scores generated fall in the same range as the perception ratings provided by the respondents: 1 equates to "bad" with 5 equal to "excellent." The equation requires only four inputs from the tool user: one-way user volume per hour, mode split percentages for the five common path user groups, path width, and the presence of a centerline.

The researchers programmed the model into a Microsoft® Excel®

Robert S. Patten, Toole Design Group

Shared-use paths accommodate a variety of users, including bicyclists, pedestrians, inline skaters, strollers, and wheelchair users. These bicyclists and inline skaters are sharing a path on the Schuylkill River Trail in Philadelphia, PA.

spreadsheet. A one-page user interface links the necessary inputs with the factors in the equations and displays the equation outputs as LOS results. The user interface provides the LOS calculation based on the volume, mode split, and width of the typical study trail. Four additional rows provide space for developing separate scenarios for comparison purposes. Designers can easily save and print the results.

An accompanying user's guide provides practitioners with an overview of the research, a discussion of LOS procedures, instructions on how to use the spreadsheet and interpret the results, and two fictional case studies.

Practical Applications

The model is applicable to a variety of problems related to trail planning and design, including overcrowding and accommodating diverse user groups. It can be especially useful for planning and design tasks where trail managers need quantitative measures to augment qualitative criteria to strengthen the basis for making decisions about trail design.

Potential uses include planning appropriate widths and cross sections for new trails, evaluating the LOS provided on existing trails, guiding the design of improvements for existing trails where additional capacity is needed, determining how many additional users a trail may be able to serve given a minimum LOS threshold, and evaluating LOS for specific timeframes, such as weekday morning or evening periods when commuting trips are heaviest. Practitioners also can use the tool to determine LOS at a particular location on a trail, such as at a narrow pinch point, in an area with unusually high volume, or in an area experiencing many reported user conflicts. "This study will come in handy for determining the best planning to accommodate all trail users comfortably," Trailnet's Cross says.

Finally, the data gathered on the 15 study trails provide examples of peak user volumes and mode splits from a variety of urban trails. These data may prove helpful to practitioners who want to forecast future use of shared trails.

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Joseph E. Hummer, Ph.D., P.E. is a professor of civil engineering at North Carolina State University. He has researched and taught transportation operations, safety, and design for 16 years. He was a member of the first class of FHWA graduate research fellows in 1984. Hummer has a Ph.D. from Purdue University and M.S. and B.S. degrees from Michigan State University.

Jennifer L. Toole is the president of Toole Design Group, a planning and engineering firm that specializes in multimodal transportation. Toole has more than 15 years of experience serving as an expert consultant on bicyclist and pedestrian projects throughout the United States. She served three terms as president of the Association of Pedestrian and Bicycle Professionals.

Dr. Nagui M. Rouphail is the director of the Institute for Transportation Research and Education at North Carolina State University. Rouphail's previous work on pedestrian and bicyclist LOS has been adopted in the 2000 *Highway Capacity Manual* procedural chapters on signalized intersections, pedestrians, and bicyclists. He currently serves on the team leading National Cooperative Highway Research Program (NCHRP) Project 3-78 on providing crossing solutions for visually impaired pedestrians at roundabouts and high-speed turn lanes.

The final report, Shared-Use Path Bicycle Level of Service Calculator: A User's Guide, *and a spreadsheet containing the LOS calculation tool will be available in fall 2005 at www.tfhrc.gov. For more information, please contact Ann Do at 202-493-3319 or ann.do@fhwa.dot.gov.*

Preventing Roadway Departures

Effective solutions are ready for deployment today, as these State examples show.

by Harry W. Taylor

Of the 42,643 people who died on the Nation's highways in 2003, more than 25,000 deaths (or 59 percent) occurred when vehicles left their lanes or ran off the road (ROR) and crashed. Although gradual improvements in infrastructure have helped keep the numbers from increasing, research by the Federal Highway Administration (FHWA) shows that higher traffic volumes have counteracted any real reductions in the number of deaths. The statistics lead to one conclusion: Strategies to prevent or lessen the effects of lane and roadway departures are important steps toward improving the safety of the Nation's roads.

Vehicles depart from a lane or road for a variety of reasons, including the environment (weather or animal crossings), human factors (inattention or drowsiness), design factors (locations with substandard curves, unimproved shoulders, or travel lanes that are too narrow), or a combination of several factors. Lane and roadway departure countermeasures must be designed to keep the motorists in lanes and on the roads, enable the drivers to recover and safely return errant vehicles to the roadway, and keep vehicle occupants from greater harm if a vehicle does leave the roadway.

A critical look at the Nation's roadways can suggest strategies for systematically dealing with crashes caused by known factors. Many strategies and low-cost countermeasures are available today or offer promise for the future. Six countermeasures with demonstrated benefits, or which show great promise, are signage/markings, rumble strips/stripes, median cable barriers, the safety edge, road widening, and raised median islands.

Signage and Markings

When compared with interstate highways, rural roads exhibit a higher ROR crash rate, especially on sections of roadway with horizontal curves. According to FHWA data, although horizontal curves make up only a small percentage of roadway length, nationally about 23 percent of ROR crashes occur on this kind of curve. Because many small secondary roads were constructed originally to follow property lines, their curves often are not up to current standards in terms of the degree of curvature. Some secondary roads on those old systems have no shoulders, no centerline stripes, and no road edgelines. Some have curves that start with one radius and end with another. Given these conditions, plus local economic constraints that limit reconstruction to change alignments, correctly placed and consistently employed signs may be the most effective strategy to save lives at a relatively low cost.

In Missouri in the past 3 years, 1,205 of the State's 3,539 traffic fatalities occurred at horizontal curves. Of those, the majority—17 percent—took the lives of young drivers aged 15 to 20. To address this challenge, Missouri is looking at improving and increasing signage on rural roads.

"We're using chevron signs extensively to mark horizontal curves with a high [crash] history," says Kevin Irving, transportation engineer and safety programs engineer for FHWA's Missouri Division. According to the Missouri Department of Transportation's (MoDOT) *Traffic Sign Manual*, chevrons may be used in "locations where there is [a crash] history, evidence of drivers losing control on a curve or turn, or a sharp change in alignment not readily visible to the driver."

For example, on Route F in Laclede County, MO, a curve in the northbound direction exhibited a high crash history. According to MoDOT, ROR crashes at this location appeared to be caused by motorists simply not realizing there was a curve ahead. Additionally, motorists negotiating this curve have just exited I–44, where they have potentially grown accustomed to the 113 kilometers per hour (kph) (70 miles per hour, mph) speed limit. Further complicating the location is the fact that the curve is concealed by a pronounced vertical curve, and there are about 30.5 meters (100 feet) of tangent past this crest before the point of curvature of the horizontal curve. To improve safety at this site, MoDOT installed signage including a "curve right" sign (visible while approaching the crest of the hill northbound) and chevrons.

For another State that has reduced its ROR crashes by improving signage on rural roads, see the successful, low-tech program established by Mendocino, CA. ("Signs Show the Way to Cost-Effective Rural Safety," PUBLIC ROADS, January/February 2005). In addition, improvements to road signs to increase visibility have become common in recent years. MoDOT recently increased the size of the familiar black-on-yellow chevrons to make them more visible.

Rumble Strips and Stripes

For a number of years, FHWA has actively endorsed the use of rumble strips as a way to reduce ROR crashes. Several varieties of rumble strips (see "Rumbling Toward Safety," PUBLIC ROADS, September/October 2003) have evolved over the past decade. The spacing between rumbles may vary, and rumble strips may be raised, formed, or—more commonly—milled, and can be used on the shoulder, travel lane, edgeline, or centerline. When used to supplement pavement markings as a low-cost delineation tool, rumble strips can present an effective deterrent to ROR incidents. This countermeasure relies on noise and, in the FHWA-recommended milled design, vibration to attract the attention of an unaware driver who has left the travel lane. In many cases, the rumble strips alert the driver in time to take corrective measures before leaving the road, potentially averting a road departure entirely.

States that have implemented extensive rumble strip programs include Kansas, Michigan, Minnesota, Mississippi, Oklahoma, and Pennsylvania, among others. Michigan, for example, has a successful track record with installing rumble strips. Research by the Michigan Department of Transportation (MDOT) revealed that the milled-in rumble strip demonstrates a design advantage by allowing vehicle tires to partially drop into them, providing a vibration to the vehicle that translates up to the steering wheel.

MoDOT

This "curve right" sign is visible while approaching the crest of this hill on Route F in Laclede County, MO.

Whereas rolled and concrete intermittent designs can provide some outside noise to alert a drifting driver, the milled design produces a louder noise and adds a vehicle vibration that most certainly increases the potential for alerting a drowsy or distracted driver.

MDOT reports that milled rumble strips installed on Michigan roadways have reduced drift-off-the-road crashes by 40 percent, through the entire range of traffic volumes studied. For more information on the Michigan study, see "Rumbling Toward Safety," PUBLIC ROADS, September/October 2003.

Minnesota also began exploring rumble strips as a potential solution to high crash rates on the State's rural roads. Today, the State has instituted a comprehensive policy that mandates placing edgeline rumble strips on all rural multilane and two-lane highway projects where shoulders are constructed, reconstructed, or overlaid, and where the posted speed limit is 80 kph (50 mph) or greater and shoulders are 1.8 meters (6 feet) or greater in width.

According to Gary Dirlam, District 3 traffic engineer for the Minnesota Department of Transportation (Mn/DOT), the department reviewed several reports, including the 1999 FHWA summary report, *Safety Evaluation of Rolled-In Continuous Shoulder Rumble Strips Installed on Freeways* (FHWA-RD-00-032), which estimated that approximately one single-vehicle, run-off-the-road incident (at an average cost of $62,200)

Improved signage on rural roads is an effective countermeasure for run-off-the-road crashes. These chevron signs installed along a rural road in Missouri help delineate the curve and call attention to a new intersection alignment. *Photo: MoDOT.*

could be prevented every 3 years based on an investment of $217 to install continuous shoulder rumble strips for 1 kilometer of roadway.

"Our crash statistics revealed a significant run-off-the-road crash problem that followed national trends," Dirlam says. "Shoulder rumble strips on two-lane highways were slow to be implemented due to concerns that a driver could overcompensate and veer into oncoming traffic. Eventually, the success of shoulder rumble strips in reducing run-off-the-road crashes overcame the fear of a one-car crash becoming a two-car crash."

In the late 1990s, an average of 17 head-on and sideswipe crashes occurred annually on rural roads in Mn/DOT District 3. "But the centerline rumble strip was considered experimental at best," says Dirlam. Since then, Mn/DOT conducted further research geared toward finalizing a draft policy on implementing centerline strips throughout the State. In October 2003, District 3 installed multiple sections of centerline strips, totaling 274 kilometers (170 miles), across 13 counties. The project doubled the number of miles of in-State centerline strips, which now totals more than 483 kilometers (300 miles).

With national statistics showing that about half of all ROR incidents occur at night, many States, including Mississippi and Pennsylvania, also are applying paint to rumble strips to increase their visibility after dark. A painted rumble strip is referred to as a "rumble stripe." Because the vertical edges of the strips are painted, the paint line is more visible at nighttime and during wet conditions.

Rumble strips are not without their challenges. During the winter months, sand and salt can get caught in the strips, and because of difficulties navigating around them, roadway sanders may have to apply more material to achieve a thorough application of sand on icy roads. Painting crews as well have noted difficulties with their guide wheels bouncing over centerline strips. And some members of the bicycling public have criticized edgeline rumble strips for making cycling more difficult. Bicyclists prefer to ride along the edgeline—safely out of the travel lane and generally free of the debris that may collect farther back on the shoulder. As a compromise, some State highway departments are now placing breaks in continuous edgeline rumble strips to make an intermittent rumble strip that is more bicycle friendly.

In the future, Minnesota plans to research midlane rumble strips, which run down the center of each lane and take effect when a vehicle's wheels veer to the right or left from the travel lane. Already installed at the Minnesota Highway Safety & Research Center at St. Cloud State University, midlane strips hold the promise of eliminating concerns for snowplowers, striping crews, and bicyclists.

All current rumble strip installations have met largely positive response from Mn/DOT's customers. "We hear a number of compliments on the new strip installations, especially from people who have had to drive in whiteout conditions," Dirlam says.

Median Cable Barriers

Median cable barriers constitute yet another countermeasure that is slated for increased and expanded use in many States. A median cable barrier is a system in which three (or four in some designs) strands of tensioned heavy-duty wire are strung between steel posts and installed in the median to keep vehicles from crossing into oncoming traffic and causing head-on crashes. Cable barriers and rumble strips are two of FHWA's priority technologies, which are a compilation of innovations that have proven benefits and are ready for deployment. (See www.fhwa.dot.gov/rnt4u/pti.htm for more information.)

The North Carolina Department of Transportation (NCDOT), for example, conducted research studies

Choosing the Right Tools

Beginning with the 1997 National Cooperative Highway Research Program (NCHRP) Strategic Plan for Improving Roadside Safety (NCHRP Project 17-13), FHWA, in cooperation with the American Association of State Highway and Transportation Officials (AASHTO) and others, began developing and deploying a plan for implementing countermeasures to improve road departure safety.

Picking the appropriate countermeasure for a particular type of road departure is critical. State DOTs can obtain assistance in determining the safety tools relevant for their particular circumstances by implementing the AASHTO *Strategic Highway Safety Plan* (Project 17-18), Tools for Life program, a jointly sponsored State and Federal program that involves FHWA, AASHTO, the Governors Highway Safety Association, National Highway Traffic Safety Administration (NHTSA), Transportation Research Board (TRB), and NCHRP. Using guidance on road departure crashes from NCHRP 17-18, the Tools for Life program provides implementation guides to assist State and local DOTs in employing strategies to reduce fatalities. Guides currently available (see http://safety.transportation.org) cover run-off-the-road crashes, horizontal curves, head-on collisions, and trees, among others.

FHWA also created a sample strategic action plan for lane departure countermeasures that can be used as a starting point for DOTs that are developing their own strategic plans to reduce ROR crashes. The *Lane Departure Strategic Action Plan: Sample Plan* can be found at http://safety.fhwa.dot.gov/roadway_dept/docs/lanedeparture, but an excerpt is provided here to show the level of practical detail included in the document.

Shoulder and Edge Rumble Strips

- Initially limit to rural highways on the State system where there is a history of ROR crashes that can be reduced by the installation of shoulder or edge rumble strips, or similar sites where there are no concentrations of homes that may be affected by noise issues.
- Receive input from the State pedestrian and bicycle coordinator.
- Use bicycle-tolerable rumble strips.
- Where the State pedestrian and bicycle coordinator anticipates moderate to high bicycle traffic, defer placement of edge or shoulder rumble strips on paved shoulders less than 1.8 meters (6 feet) in width until a 1.8-meter (6-foot paved) shoulder can be placed adjacent to the pavement as part of a 3R (resurfacing, restoration, and rehabilitation) project.
- Limit applications to hot-mix surfaces that are fewer than 4 years old. However, edge rumble strips may be placed on older pavements with the pavement design engineer's approval.
- Only apply edge rumble strips on pavement structures of sufficient strength to deter edge breakup.
- May place edge rumble strips on narrow pavements between 5.5 and 6.7 meters (18 and 22 feet) in width with a history of ROR crashes.

Mn/DOT District 3

As part of its aggressive effort to reduce roadway departures, the Minnesota Department of Transportation (Mn/DOT) recently installed these centerline rumble strips on Highway 371 near Pine River.

in 1993 and 1998 and subsequently installed protective median barriers that dramatically reduced cross-median crashes. By installing median cable barriers on divided roads, and especially those with narrow medians, the department nearly cut in half the number of fatalities from cross-median crashes from January 1999 through December 2003, saving hundreds of millions of dollars in fatal crash costs alone. Many of the cross-median crashes that occurred during this time were on stretches of highway that were slated to receive median barriers but had not yet had them installed. To date, the installation of median barriers in North Carolina has resulted in an estimated 90-percent reduction in freeway cross-median crashes, approximately 25 to 30 lives saved each year, and hundreds of injuries prevented or reduced in severity.

South Carolina also installed cable barriers to reduce crossover crashes. The South Carolina Department of Transportation (SCDOT) recently began implementing this countermeasure along with establishing a reduced speed limit for urban interstate sections and launching a 1-year program to restrict truck traffic on six-lane highways to the outside two lanes.

"The engineers were seriously concerned about reducing crashes and were studying the potential causes [in addition to] the effectiveness of using median barriers," says South Carolina Department of Transportation (SCDOT) Executive Director Elizabeth S. Mabry. "When the State Infrastructure Bank made funding possible, [FHWA South Carolina Division Administrator] Bob Lee and I announced that we would immediately begin placing barriers. Not only were the barriers installed, but [also] when the barriers are hit, we get them put back within a matter of hours. We've had well over 6,000 hits on the median barriers in the past 3 years."

South Carolina has installed more than 644 kilometers (400 miles) of

Centerline Rumble Strips

- Initially limit to rural highways on the State system where there are no concentrations of homes and a history of head-on or opposite direction sideswipe crashes.
- Limit applications to hot-mix surfaces less than 4 years old. However, edge rumble strips may be placed on older pavements with the pavement design engineer's approval.
- If centerline rumble strips are perceived to be a problem in passing zones for passing maneuvers, consideration may be given to reducing the depth of rumble strips from 1.3 centimeters (0.5 inch) to 0.95-centimeter (0.38-inch) milling to reduce the impact on passing maneuvers and still provide a warning system for drowsy and inattentive drivers who begin to drift across the centerline. If the 0.95-centimeter (0.38-inch) milling is used, test sections of both depths will be initially installed, and an evaluation of the impacts of both depths made before wide use of the 0.95-centimeter (0.38-inch) depth.
- Centerline rumble strips will be limited to those pavements 6.7 meters (22 feet) or greater in width.

Advanced Curve Marking Systems

- Only apply on hot-mix surfaces less than 4 years old.
- Install on curves where drivers have to reduce speed by about 16 kph (10 mph) or more, horizontal curves superimposed on vertical curves, and curves that pose an unusual driving situation.

Tree Removal

- Limit to rural areas.
- Receive input from the DOT State environmentalist on avoiding any endangered species, removal conditions, and any other environmental requirements.
- If trees are off the right-of-way, discuss the hazard with the property owner and endeavor to obtain written permission to remove the trees. Replacements in a safe location and/or storage of the wood may be offered to the property owner as appropriate.
- Avoid sensitive areas where the trees have substantial aesthetic value.
- In sensitive areas where trees cannot be removed and pose a night safety concern, install tree delineation on an experimental basis.
- Include stump removal, minor regrading, sodding of the affected area, and removal of any other adjacent fixed objects.

Guardrail (Guiderail) Upgrade

- Limit to obsolete guardrail (guiderail) (strong post cable), replace blunt end sections and turned-down ends, connect unattached approach rail to bridge rail, and protect unprotected bridge parapets.

median cable barrier, which Mabry and Lee believe has significantly reduced this type of fatal crash. The statewide program in place today has become a centerpiece of the South Carolina safety program and the State's long-term negative fatality trend is beginning to reverse. Total fatalities have dropped each year since 2000, resulting in more than 300 lives saved thus far.

In Missouri, where head-on collisions claimed 480 lives and caused 2,433 disabling injuries from 2001 through 2003, MoDOT is nearing completion of cable barriers or other median barrier installations on its entire I–70 corridor, about 403 kilometers (250 miles). And Missouri plans to begin installations on other interstate routes in the near future.

For more information on successful median cable barrier programs in the United States, see "The Many Faces of Safety," PUBLIC ROADS, March/April 2005; "Low-Cost Solutions Yield Big Savings, PUBLIC ROADS, November/December 2003; and "Keeping Traffic on the Right Side of the Road," PUBLIC ROADS, January/February 2005.)

The Safety Edge

A pavement edge where there is a dropoff of more than 10 centimeters (4 inches) and the angle of the road to the shoulder is 90 degrees is considered unsafe, according to R.A. Zimmer and D. L. Ivey in a paper, "Pavement Edges and Vehicle Stability—A Basis for Maintenance Guidelines," in *Transportation Research Record 946*. An estimated 11,000 injuries and 200 deaths per year may be attributed to unsafe dropoffs. Once a vehicle has crossed from a paved surface onto an unimproved shoulder, the driver's reaction often is to overcorrect to get back on the road. In the process, the rear wheel may catch on the shoulder edge and spin the vehicle around. In many instances, drivers attempting to return to the road often veer into the adjacent lane, cross into opposing traffic, or leave the opposite side of the roadway and become an ROR statistic.

"An easily traversable transition provides a countermeasure to help an errant vehicle reenter the travel lane from the unpaved shoulder," says Chris Wagner, pavement and materials engineer with the FHWA Resource Center. The safety edge is

A worker uses a hand level and ruler to measure a new asphalt shoulder where a safety edge was not installed.

A shoulder with a safety edge installed.

an angled asphalt fillet of 30 to 45 degrees that creates a tapered edge between the paved travel way and the unpaved shoulder.

In 2003, the Georgia Department of Transportation (GDOT) conducted a pilot project incorporating the safety edge into a 21-kilometer (13-mile) asphalt overlay on Georgia State Route 88, a rural, two-lane, undivided highway. Adding the safety edge was "a concept that appealed to Georgia as a simple way to provide safe roadway conditions during and after a roadway resurfacing project," says Bryant Poole, who served as GDOT State maintenance engineer during the test project and is currently Atlanta metro district engineer.

of the hot-mix designs. An added benefit noted by GDOT: The safety edge is a useful temporary fix for dropoffs that occur after a pavement overlay is placed, but before earth shoulders can be reconstructed flush with the travel way.

According to Wagner, "Field observations after 1 year of service show that the safety edge has no visible signs of deterioration." GDOT's experience showed three important facts: the safety edge can be placed on any type of roadway facility as an integral part of the asphalt preventative maintenance paving process, it has no impact on production, and it represents less than 1 percent of additional material costs.

"We've been very pleased with the success of the test project," says GDOT's Poole, pointing out that the project met with success "from the beginning to final application of the safety edge, including long-term results." The test project was so well received, Poole adds, that "in Georgia, starting in March 2005, the safety edge is now required for any preventative maintenance resurfacing projects let to construction by GDOT." Since the test project's conclusion, GDOT has worked with representatives of the Georgia Highway Contractors Association, Inc., to ensure that the new safety edge requirement can be put into practice easily. "As a road departure countermeasure, the safety edge provides an easy-to-implement, low-cost measure," Poole says.

William D. Lawson, Texas Tech

This 4.9-meter (16-foot)-wide road east of Blossom, TX, was originally constructed out of concrete but has since been extensively blade-patched with hot-mix. Note the broken pavement edge and the original concrete beneath the seal coats.

To enhance safety, TxDOT is widening narrow Texas roadways like this one, which has dropoffs where the roadway is crumbling at the edgeline.

"Six areas where dropoffs tend to occur were identified during the preconstruction investigation of the research test sections," says FHWA's Wagner, who worked closely with GDOT. "These six areas were at horizontal curves, near mailboxes, turnarounds, shaded areas, eroded areas, and asphalt pavement overlays."

The test section's 3.8-centimeter (1.5-inch) asphalt overlay was paved with two hot-mix asphalt designs that are typically specified in resurfacing low-volume roadways in Georgia. Two devices—a steel wedge fabricated by GDOT and the Safety Edge Maker™ from TransTech Systems, Inc.—were used to create a 30-degree safety edge. Both devices produced a durable edge with each

Road Widening

To enhance safety, the Texas Department of Transportation (TxDOT) is widening roads with a paved surface of less than 7 meters (24 feet) in width that have an average daily traffic volume of more than 400 vehicles. Although today's roadway design criteria place the minimum width of new roadways in Texas at 8 meters (26 feet), "Texas has more than [51,520 kilometers] 32,000 miles of State-maintained roads that are classified as rural two-lane roads with a paved surface of less than [7 meters] 24 feet wide," says David Bartz, technical assistance team leader and safety coordinator for FHWA's Texas Division. "Some of these roads are so narrow," adds Bartz, "that there isn't even room for an edge stripe. Crash statistics show

City of Des Moines, WA

This urban arterial in Washington State allows unrestricted left-turn access that may increase the potential for head-on collisions when vehicles in the two-way left-turn lane approach from opposite directions.

that the crash rate for similar categories of incidents is three times greater on [5.5- to 5.8-meter] 18- to 19-foot-wide roadways than on [7-meter] 24-foot-wide roadways."

Bartz also points out that the benefit-cost ratio of shoulder widening is an impressive 4.5:1. Using 2001 data from the National Safety Council's (NSC) report, *Estimating the Costs of Unintentional Injuries, 2003,* this figure is calculated by taking the annual safety benefits (estimated lives saved and injuries prevented over the 20-year service life of this type of improvement, using the NSC societal costs) and dividing them by the estimated pavement widening and edge striping cost. "Bringing these roadways up to [7 meters] 24 feet wide makes a huge difference and really does pay off quite a bit," says Bartz.

William D. Lawson, P.E., Ph.D., a TxDOT researcher who is also a senior research associate and faculty member at Texas Tech University's Center for Multidisciplinary Research in Transportation (TechMRT), recently presented findings on best practices for pavement edge maintenance at TRB's 2005 annual conference.

"Among the more rigorous of approaches," Lawson says, "road widening is perhaps the best long-term solution to the pavement edge dropoff problem because it takes care of some of the fundamental issues that cause dropoffs in the first place. Dropoffs are very strongly correlated with narrow roads and the lack of a shoulder. If you add a shoulder, you widen the road."

From a systems perspective, Lawson points out that policymakers need to realize that "increases in vehicle size, speed, and traffic level reveal that older, narrow roads in the highway system are being overloaded. Narrow roads without shoulders consistently have the most serious and most prevalent edge problems, and road widening is a reasonable solution to this problem. Widening may not always be the immediate answer because it's no small thing," he says, pointing to cost, right-of-way issues, environmental regulations, and a host of other potential policy, design, resource allocation, and methodology issues, "but it is helpful to think in terms of approaching the ideal."

Lawson's TxDOT research effort looked at 3 years of available data from the Texas Maintenance Assessment Program (TxMAP), which evaluates a statistical sample of all State roads for pavement condition, traffic operations, and roadside features. Among the observations that emerged: The maintenance district with the best statistics has two-lane roads that are 9.8 meters (32 feet) wide, as opposed to a State average of about 6.7 meters (22 feet). "The TxMAP data showed a strong correlation between those districts with good edge conditions and good roadway performance in general," Lawson says. "This suggests that a good edge maintenance strategy is necessary for good roads and is perhaps the key element of a successful highway maintenance program."

Raised Median Islands

Sometimes too much of a good thing can be a liability. Trees can be an aesthetic delight, but when growing too close to a road at locations where run-off-the-road crashes are likely to occur, they often are involved in driver and passenger deaths. In 2003, 452 fatalities involving trees occurred on urban principal arterials, minor arterials, and collectors. A desirable balance between a community's need for both safety and aesthetics is to plant trees in the median and then shield motorists from them. FHWA, through the National Crash Analysis Center, has funded computer modeling of various protective barrier shapes, and State DOTs have developed, crash-tested, and installed the technology.

"In Washington State, we've installed low-profile barriers of 18 to 20 inches [46 to 51 centimeters] tall in a handful of urban locations where the speed limit is less than 45 mph [72 kph]," says Richard Albin, assistant State design engineer for the Northwest Region of the Washington State Department of Transportation (WSDOT). These raised median islands consist of an elevated area in the middle of a roadway with a low-profile traffic barrier that surrounds landscaping elements such as shrubs and trees. Several low-profile traffic barriers have been approved that meet NCHRP Report 350: *Recommended Procedures for the Safety Performance Evaluation of Highway Features* Test Level 2 criteria of impacts at speeds of 70 kph (45 mph) and 25 degrees.

WSDOT officials are evaluating the safety and effectiveness of the raised median island in cities like Des Moines, WA, and SeaTac, WA, where two-way left-turn lanes have been replaced with a planting strip on portions of State Route 99. WSDOT worked with these cities to develop median solutions that would limit left-turn access and

This raised median island in Des Moines, WA, limits left-turn access while protecting motorists from the potential hazards posed by landscaping and other fixed objects in the median.

City of Des Moines, WA

reduce the potential for head-on collisions between vehicles in a two-way left-turn lane approaching from opposite directions. The project also will revitalize the area through the use of attractive landscaping and minimize the potential hazards posed by fixed objects.

Raised median treatments often are associated with traffic calming and speed reduction. But Albin notes, "The research on the effectiveness of these treatments for reducing speeds is inconclusive." WSDOT's inservice evaluation will monitor these design elements over the next several years. According to Albin, "We're going to compare data to see if there's any speed reduction, reduction in pedestrian collisions, or an increase in fixed-object impacts. From that, we're hoping to develop better design criteria and identify roadside safety issues for urban areas like these."

The raised median islands along Washington's State Route 99 are an attempt to provide a context-sensitive solution that simultaneously meets or enhances safety and capacity needs, environmental goals, and community revitalization desires. Albin explains, "We see this as an optimization of tradeoffs." By monitoring raised median islands and watching for associated crash rates, WSDOT should be able to determine the effectiveness of more widespread use of the median design throughout the State or alter the solution, if needed.

"In the interim, if a correlation is noted between increased collisions and fixed objects like newly planted trees in median islands where there is no barrier, the trees will be removed or mitigated in some other way," says Albin. "The sections with barriers will be studied for comparison purposes." While monitoring this group of context-sensitive solutions, Washington State aims to develop new median designs for urban areas. WSDOT will incorporate identified solutions, where appropriate, into a new design manual.

Roadside Safety Opportunities

Every opportunity for intervention presents an opportunity to save lives. Safety measures designed to keep the driver on the road or to minimize the consequences of leaving the road are the goal. To attain this vision, the vehicle and roadside must be designed to work together to protect vehicle occupants and pedestrians from serious harm. Which of the safety measures available today can help save lives on your roads?

Harry W. Taylor is the road departure safety team leader in the FHWA Office of Safety Design. He has been involved in highway and roadside safety work for more than 25 years. He has participated on numerous NCHRP panels and industry-government roadside safety groups. Taylor is also one of two U.S. observers to the European Committee for Standardization (CEN), Technical Committee 226, Working Group 1, Road Equipment-Safety Barriers. He has a bachelor's degree in civil engineering from Tennessee State University and a master's in engineering administration from The George Washington University.

For more information, contact Harry Taylor at harry.taylor@fhwa.dot.gov.

Motivating Teens to Buckle Up

Researchers in Rhode Island are promoting increased seatbelt use among high school students.

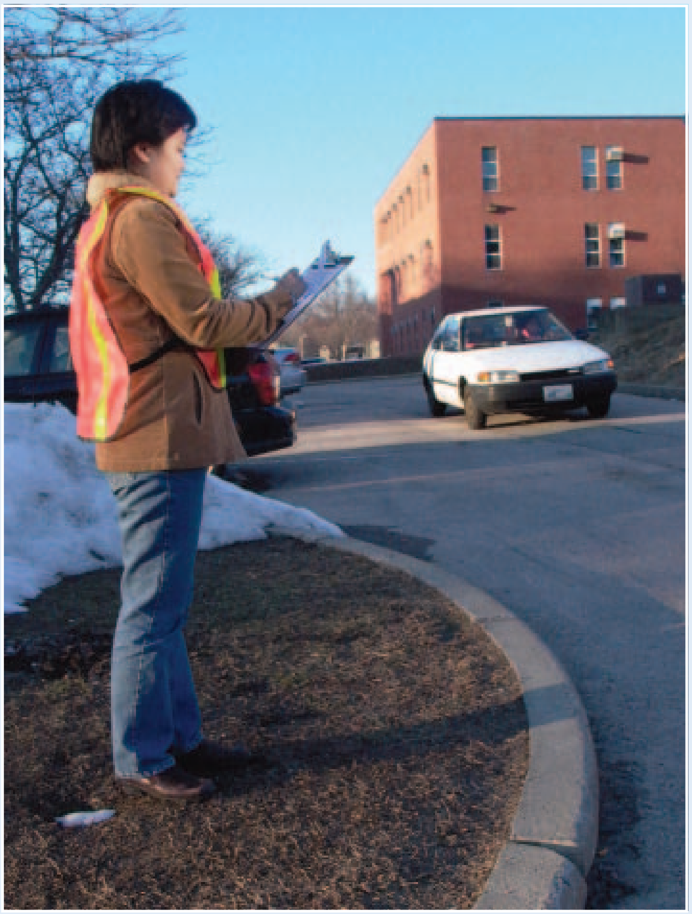
by Daniel Berman

According to the U.S. Department of Health and Human Services' Centers for Disease Control and Prevention, motor vehicle crashes are the leading cause of death for 15- to 20-year-olds in the United States. The U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA) reports that teenagers have the highest fatality rate in motor vehicle crashes of all age groups. In 2001 teens accounted for 10 percent of the U.S. population, but 13 percent of motor vehicle deaths.

One of the simplest steps that teens can take to prevent this needless loss of life is to fasten their seatbelts, whether they are passengers or drivers. A 2004 survey conducted by NHTSA found that the seatbelt usage rate for 16- to 24-year-olds was 77 percent (up from 69 percent in 2002), compared to the national average of 80 percent. Research on passenger cars has shown that seatbelts reduce the risk of fatal injury to front-seat occupants by 45 percent and the risk of injury by 50 percent.

Finding effective ways to encourage teenagers to buckle up was the impetus for a recent study on seatbelt use among high school students in Rhode Island. The State's overall seatbelt use rate was 74 percent in 2003 (as reported to NHTSA for national survey data), up from 63 percent in 2001, but still below the national average. One problem was a lack of data on students' seatbelt use and attitudes toward buckling up among Rhode Island teens.

"We had very little information about seatbelt use among high school students," says Dr. Jerome Schaffran, a professor of human development and family studies at the University of Rhode Island. "Because Rhode Island is small, we decided to see if we could gather enough surveys to develop good baseline information about seatbelt use among teens and begin to develop interventions to raise the rate."



URITC

A URITC researcher counts cars with drivers and front-seat passengers wearing their seatbelts.

Conducting the Survey

Armed with a grant from NHTSA, representatives from the University of Rhode Island Transportation Center (URITC), the Rhode Island Department of Transportation, and the Federal Highway Administration (FHWA) collaborated to conduct a survey of seatbelt use among high school and college students in Rhode Island.

The URITC researchers developed a survey tool based on the one that NHTSA uses nationally to collect data on seatbelt use. Building the survey on the NHTSA model would facilitate a loose comparison between the Rhode Island responses and those at the national level. (Note: The Rhode Island observation survey used a different sampling strategy than the NHTSA survey, which used randomly selected locations across a range of demographics and road types.)

URITC

At North Kingstown High School, shown here, researchers from URITC conducted student surveys and observational behavior studies to assess seatbelt usage among Rhode Island teenagers.

Between February and April 2004, the survey team obtained more than 15,000 completed paper surveys from students at 29 high schools, representing about one-third of the State's high school population. Homeroom teachers handed out the eight-question survey, and the students spent an average of 1 minute answering the multiple-choice questions. The teachers returned the completed surveys to URITC for processing. The survey team also received more than 3,200 similar electronic surveys from students at five Rhode Island colleges.

Rhode Island Seatbelt Survey

We are conducting an anonymous study of high school seatbelt usage. The survey is completely confidential.

1. What grade are you in?
- ❑ 9th grade
- ❑ 10th grade
- ❑ 11th grade
- ❑ 12th grade

2. What is your gender?
- ❑ Male
- ❑ Female

3. When driving/riding in a car (truck or van), do you wear your seatbelt?
- ❑ Yes
- ❑ No

4. When was the last time you did not wear your seatbelt when in a car (truck or van)?
- ❑ Today
- ❑ Within the past week
- ❑ Within the past month
- ❑ Within the past 12 months
- ❑ A year or more ago/I always wear it

5. Are you more likely, less likely, or just as likely to wear your seatbelt when driving with friends as compared to driving alone?
- ❑ More likely
- ❑ Just as likely
- ❑ Less likely

6. Why are you less likely to wear your seatbelt when there are others in the car?
- ❑ I'm worried what my friends will think
- ❑ I'm only driving a short distance
- ❑ There are not enough seatbelts in the car
- ❑ I ride in the back seat
- ❑ I always wear a seatbelt

7. In the past 12 months, has your use of seatbelts increased, decreased, or stayed the same?
- ❑ Increased
- ❑ Decreased
- ❑ Stayed the same

8. What will increase your usage of a seatbelt? (Check all that apply)
- ❑ Becoming more aware of safety issues
- ❑ Becoming aware of the seatbelt law
- ❑ Fear of getting a ticket
- ❑ Getting a seatbelt ticket
- ❑ Someone you know was in a crash
- ❑ Other people encouraging you to use a seatbelt
- ❑ Other

Source: University of Rhode Island Transportation Center.

To verify the results of the paper surveys, researchers conducted observational studies in parking lots at 13 high schools during the morning arrival period between February and April 2004. Pairs of observers recorded shoulder belt use for drivers and front-seat passengers. They also noted the vehicle type and the gender of the driver and passenger. Researchers also conducted an observational survey at one college.

Analysis of the Survey Data

The researchers concluded that 69.5 percent of Rhode Island high school students actually wear seatbelts, factoring in full- and part-time users.

Overall, 83 percent of the students indicated on the self-report survey that they use their seatbelts. But on a followup question, 13.5 percent of reported seatbelt users said they did not wear a seatbelt that day. Reducing the reported usage rate by the percentage for "today's nonuse," the researchers established the State average for teens at 69.5 percent.

The reported use rates were similar among males (82.9 percent) and females (83.6 percent). Results from the observational surveys, however, found that male drivers scored significantly lower than females in seatbelt use, ranking 68.4 percent and 79 percent, respectively.

At the high schools where researchers conducted observational studies, the average observed rate for seatbelt use was 73.7 percent, 9.1 percent less than the reported rates at those schools. When the study team compared the observed rate to the reported rate (minus the percentage for "today's nonuse") or 71.9 percent, the rates differed by about 2 percent.

Specific Results

Juniors reported the highest percentage of seatbelt use among high school students at 85.6 percent. In Rhode Island, the junior year is when most students take driver's education and apply for a driver's license.

"We were surprised that younger kids reported not buckling up as often as juniors," Schaffran says. "We thought that freshmen and sophomores would buckle up more because they come to school with their parents."

Three of the survey questions were about the effect of peer pressure on students' seatbelt use. When asked if they are more likely, less likely, or just as likely to wear a seatbelt when driving with friends compared to driving alone, 67.6 percent reported that they are just as likely to buckle up. Only 11.9 percent said they would be less likely.

Just as older students are more likely to wear their seatbelts in general, peer pressure seems to affect usage less as students advance in grade. Although 63.3 percent of ninth graders reported that they were just as likely to fasten their seatbelts when friends are in the vehicle, the number rose to 72.8 percent for 12th graders.

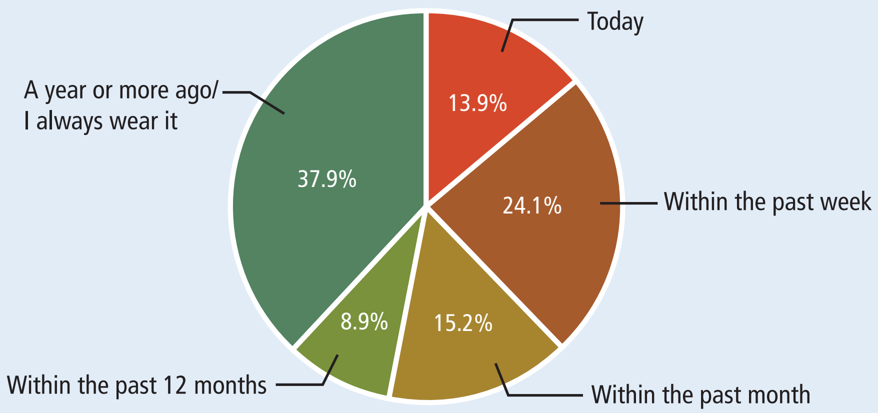
Students reported that the number one reason that they are less likely to wear a seatbelt is if they are traveling a short distance (17.5 percent of respondents). When the same information was evaluated by grade, ninth graders were the most likely to cite that reason, with a response rate of 22.6 percent.

When asked what would increase their seatbelt use, 44 percent reported that knowing someone in a crash would influence them. Thirty-seven percent answered that fear of getting a ticket for not buckling up would be enough reason to wear a seatbelt. A statewide "Click It or Ticket" campaign, which informs motorists that failure to buckle up could result in a substantial fine, was ongoing during the survey.

The URITC researchers surveyed college students as well, because they, like high school students, are in a major stage of social development. The researchers found that 90 percent of the students who responded to the electronic survey reported that they wear seatbelts. The actual average observational usage rate—determined from a study at the University of Rhode Island—was only 70.5 percent.

Similar to the high school students surveyed, college students' seatbelt use improves as they age and mature. Freshmen reported the lowest use at 80 percent, while graduate students reported 97 percent usage. College students also cited driving a short distance as their top reason for not wearing a seatbelt.

Seatbelt Nonuse Patterns



In the Rhode Island survey, 83 percent of high school students reported wearing seatbelts. When asked about the last time they had not worn a seatbelt, the largest percentage of students (37.9 percent) reported that it was a year or more ago or that they always wear it. Nonuse on the day of the survey was 13.9 percent. *Source: URITC.*

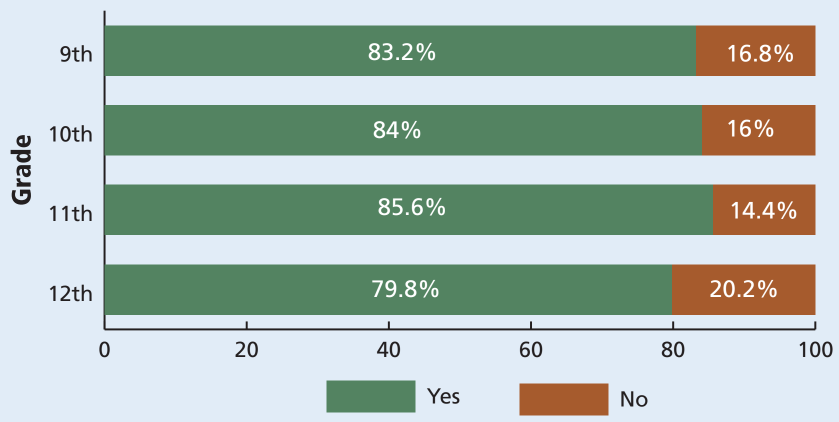
When asked what would encourage them to increase their seatbelt use, 25.4 percent of college students said knowing someone in a crash. Although that response garnered the highest percentage rate among college students, it was significantly less than the 44 percent reported by high school students.

Promoting Behavioral Change

The next step for the URITC researchers is to design and test initiatives that schools can use to promote healthy behavioral changes. "Now that we have some information, we can begin to develop interventions," Schaffran says.

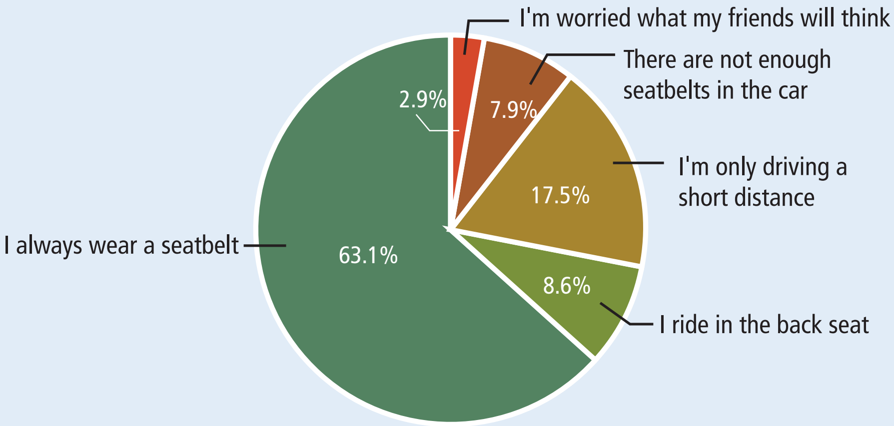
To plan effective initiatives, the researchers are applying what is known as the Transtheoretical Model of Change, which describes how people modify a problem behavior or acquire a positive behavior by going through stages of change. Developed in the 1980s by Dr. James O. Prochaska and his colleagues with the Cancer Prevention Research Center at the University of Rhode Island, the model has served as the foundation for developing interventions to encourage a variety of behavioral changes, including quitting

Seatbelt Usage Rates by Grade Level



As shown in this graph of seatbelt usage rates by grade level, high school students in Rhode Island reported the highest percentage of seatbelt use during their junior years. *Source: URITC.*

Reasons for Seatbelt Nonuse



When asked why they would be less likely to wear a seatbelt when others are in the car, the top reason students cited was that they were only driving a short distance (17.5 percent). *Source: URITC.*

smoking, losing weight, or using sunscreen to prevent skin cancer.

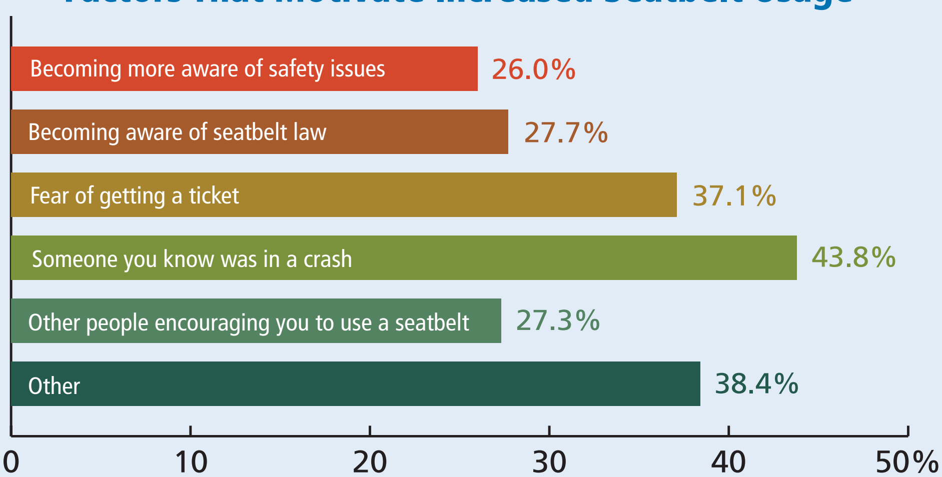
The model's central feature is the identification of stages that define where individuals are in the continuum of the change process. The stages are precontemplation, contemplation, preparation, action, and maintenance. In the case of seatbelt usage, those in the earliest stage—precontemplation—are unaware or unconcerned about the benefits of using seatbelts. Students in the next stage, contemplation, are aware that not using a seatbelt is a risk, but still do not buckle up.

In the preparation stage, students acknowledge that they want to change their behavior but do not wear seatbelts regularly. Students in the action stage report themselves as seatbelt users and only rarely fail to buckle up. At the maintenance stage, the students have adopted a consistent pattern of seatbelt use.

By applying the model to the data from the Rhode Island survey, researchers found that the highest percentage of students—36.1 percent—fell in the preparation stage, although 18.2 percent were still in the precontemplation stage.

The model can be applied to individual schools to identify the various stages of behavior change necessary to develop an effective program for interventions. If a high percentage of a school's ninth graders are in the precontemplation stage, for example, then a seatbelt initiative could be developed for use in freshman health classes.

Factors That Motivate Increased Seatbelt Usage



The survey found that knowing someone in a crash (43.8 percent) and fear of getting a ticket (37.1 percent) are the top motivators for encouraging seatbelt use among Rhode Island teens. *Source: URITC.*

Researchers are conducting focus groups at several schools to determine the types of interventions that would be most effective in influencing teens at various stages of change. "Since this is a choice behavior—buckling up or not buckling up—we want to find out what would tip them over the edge to buckle up more," Schaffran says.

Eventually, the research team plans to develop a program that schools can adopt to conduct their own focus groups and design targeted interventions. Student organizations, such as Students Against Destructive Decisions (SADD), student councils, and volunteer clubs, would conduct the focus groups and sponsor interventions.

"We want to help student advocacy groups generate ideas and initiate them the first year, and then let them take over from that point, with some adult supervision from teachers or counselors," Schaffran says.

Piloting Student Initiatives

So far, URITC researchers have worked with two high schools on pilot initiatives. At North Kingstown High School, students produced videos and showed them over the school's closed-circuit television system.

Teacher Aaron Thomas requires students in his advanced communications class to do a community service project, and producing a 1-minute video on seatbelt use is one of the options. Before developing concepts for their videos, the students met with URITC researchers to learn about the survey.

"The kids were shocked at some of the survey results and the reasons [their peers] weren't using their seatbelts," Thomas says.

One video created by the students focuses on the chief reason teens do not wear seatbelts. In it, two students jump in a car and drive off without buckling up because they are going just a short distance. The screen fades to black with the sound of a car crash.

Another video features a North Kingstown police officer stopping a speeding car and noting that the fine will be even higher because the

URITC

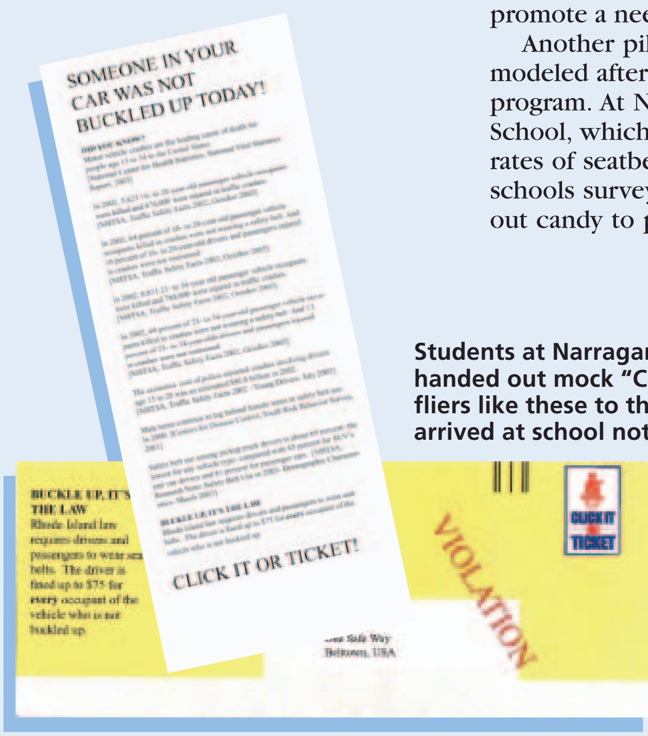
These two students are buckled up, representing community role models for consistent seatbelt usage.

occupants are not wearing seatbelts. A video shown before the school's winter break includes a montage of students clicking their seatbelts in time to lively holiday music.

Although no followup surveys were conducted, Thomas reports that the videos appeared to have made students more conscious of the importance of seatbelt use. "If you see an ad on TV that isn't about anyone you know, you don't take it as seriously as one that has facts about your town and your State. It really hits home," he says.

Thomas believes the concept of making videos encouraging seatbelt use could translate easily to other schools. "Most schools have some type of video program," he says. "The kids like to see their work used, and it's a great way to learn how to do a public service announcement and promote a needed message."

Another pilot intervention was modeled after the "Click It or Ticket" program. At Narragansett High School, which had one of the lowest rates of seatbelt use among the schools surveyed, students handed out candy to peers arriving at school wearing seatbelts and fake tickets to those who failed to buckle up. Followup surveys showed that the incentive increased seatbelt use by 20 percent—but only for a short time, indicating the need to repeat successful approaches regularly.



URITC

Students at Narragansett High School handed out mock "Click It or Ticket" fliers like these to their peers who arrived at school not wearing their seatbelts. Those who were buckled up were rewarded with candy.

A Model for Other States

The survey established baseline information that other researchers can use in ongoing efforts to develop targeted initiatives to increase seatbelt use among Rhode Island teens. By working with student groups to strategize ways to increase seatbelt use, the URITC research team—and eventually the schools themselves—can capitalize on students' abilities to influence their peers and encourage behavioral changes.

The research team also developed a model survey that other States or organizations could use to measure seatbelt use among teens and develop targeted initiatives to increase usage rates. "[Others] can certainly adapt the survey instrument we used," Schaffran says. "Once they have that baseline, they can start their own interventions and begin influencing behavioral change."

Ultimately, the goal in Rhode Island is to increase seatbelt use among teens to 90 percent or more, an accomplishment that would significantly lessen students' risk of death or serious injury on the State's roadways.

Daniel Berman, assistant division administrator for the FHWA Rhode Island Division, collaborated on the seatbelt study as an executive in residence at URITC in 2004. During his 30 years at FHWA, Berman has worked in transportation engineering, planning, and management. In 1995, he won FHWA's Superior Achievement Award for his work as project manager for the Central Artery/Tunnel Project in Boston, MA. He has a bachelor's degree in civil engineering from Lamar University in Texas.

To view the report, Safety Belt Usage Rates at High Schools and Colleges in Rhode Island, *visit www.uritc .uri.edu/media/finalreportspdf /2004_000318.pdf.*

Safety Scans—A Successful Two-Way Street

by John Baxter, Michael L. Halladay, and Elizabeth Alicandri

International tours glean best technologies and practices from around the globe, and U.S. departments of transportation apply those lessons and offer their own successes.

Roadway safety is an international challenge, with an estimated 1.2 million people killed and 20 to 50 million injured in road crashes every year. The World Health Organization (WHO) and the World Bank cite these statistics in a 2004 joint publication titled, *World Report on Road Traffic Injury Prevention*, which lists road traffic injuries as the "ninth leading contributor to the global burden of disease and injury" today. By 2020, WHO expects them to be the third leading contributor.

Of this number, the United States experiences approximately 42,000 fatalities and millions of injuries on roads each year. The Fatality Analysis Reporting System (FARS) indicates that progress on improving highway safety has taken place since the 1960s when fatality rates were more than three times what they are today. Despite the gains, the United States has much work ahead, and it plans to address safety challenges through aggressive programs in the four "E's" of safety—engineering, enforcement, education, and emergency medical services.

Like other Nations that look to the United States and one another for solutions and information sharing, the United States also benefits from technology and information exchanges with transportation safety neighbors around the world.

(Above) A cable median guardrail kept this truck from crossing over the median on a Florida highway, possibly preventing a fatal head-on crash. *Photo: Florida Department of Transportation.*

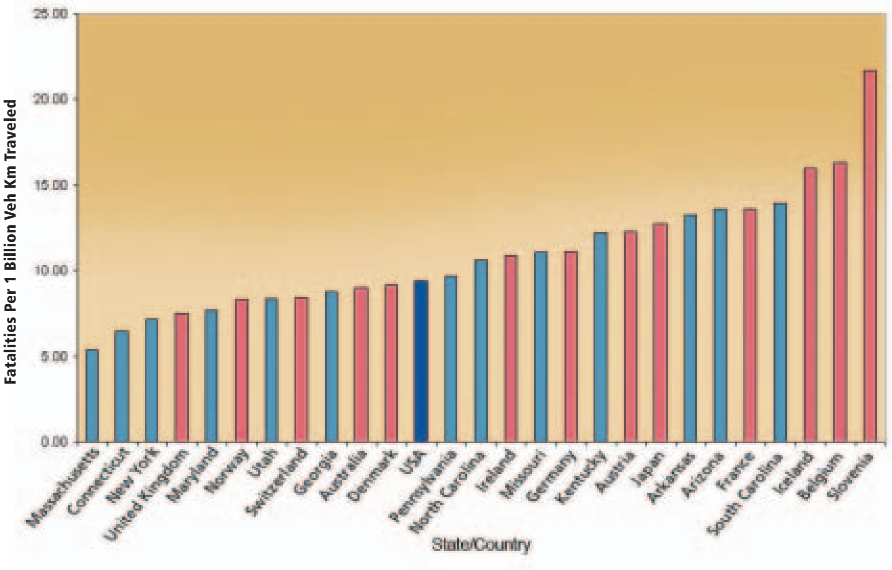
Vehicles for Sharing Knowledge

One method for information exchange is the International Technology Scanning Program, funded by the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO). Scan tours visit "best-in-class" (benchmarking term for a best practice in a specific category) countries to explore and evaluate innovative technologies and practices that could significantly benefit U.S. highway transportation systems.

The scanning program enables the United States to adapt and implement advanced technologies more efficiently by re-creating advances already developed by other countries. FHWA and AASHTO have sponsored a number of scan tours related to safety, visiting countries with the most impressive highway safety records. (See "Selected Safety-Related Scan Tours" on page 33.)

Another avenue for learning from the best-in-class is through the involvement of U.S. transportation professionals in the road safety technical committee of the World Road Association (also known as PIARC), a nonpolitical and nonprofit international association with headquarters

International and U.S./State Highway Fatality Rates, 2002



Source: International Road Traffic and Accident Database.

Using exposure rates—the most common measure used in the United States—the rankings of these 27 countries and U.S. States range from a low of 5.39 for Massachusetts to a high of 21.7 for Slovenia.

cess is a two-way street. U.S. successes can be applied internationally to improve highway safety in other countries as well.

The first of the five lessons is that a top-down commitment (or national priority) by a country's leaders is essential to making a difference in reducing fatalities. Terecia Wilson, director of safety at the South Carolina Department of Transportation (SCDOT) says, "Top-down leadership commitment is vital because it provides clear direction to the agencies responsible for highway safety, establishes national goals for fatality reduction, ensures accountability for meeting those goals, and gives the necessary support for allocation of resources."

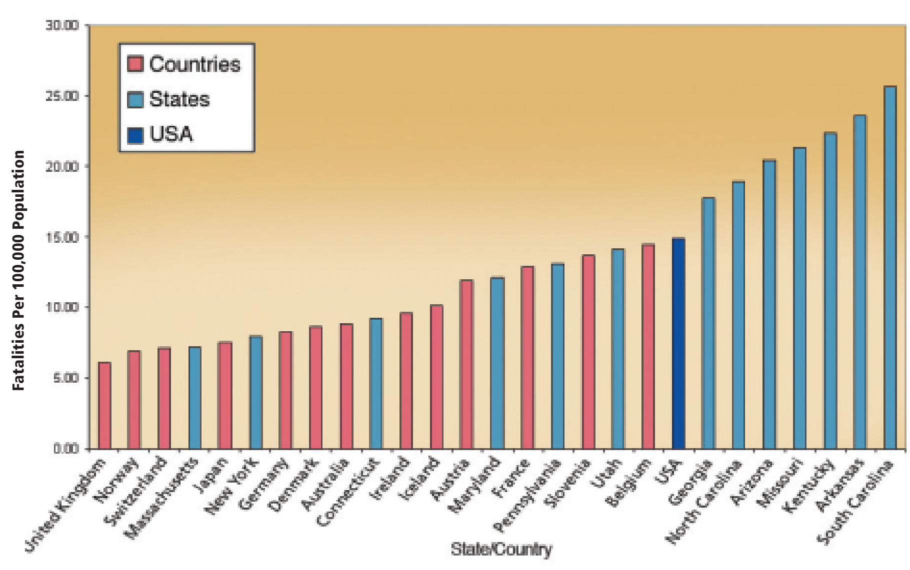
An example of top-down safety prioritization is Sweden's "Vision Zero," a law passed by the Swedish Parliament, which establishes zero traffic fatalities as a national goal. Vision Zero is based on the philosophy

in Paris, France, devoted to the analysis and discussion of the full spectrum of road transport issues. One aspect of the World Road Association's mission is the identification, development, and dissemination of best practices, including cost-effective investments in road safety, improved road design, and intelligent vehicles and infrastructure technologies that improve road safety.

Safety Prioritization At Top Levels

Through recent scans (particularly those within the past 3 years) and World Road Association activities, the international community offers the United States a number of overarching lessons on highway safety. Five of these lessons are highlighted here. Applications of these lessons by U.S. States can help improve the Nation's highway safety record. In fact, for each of the five lessons, examples are available that show how the lessons already are being applied in the United States. And the learning pro-

International and U.S./State Highway Fatalities By Population, 2002



Source: FARS.

When countries and U.S. States are ranked by fatalities per 100,000 population—the most common measure used in other parts of the world—the rankings differ considerably.

that highway fatalities are morally unacceptable. The new law implies that roadway users will not be killed or seriously injured in a crash if they wear seatbelts, follow road rules such as speed limits, and avoid driving under the influence of alcohol.

In another European example of high-level prioritization, the current president of France made road safety one of the three major national initiatives for his 5-year term. The result? A 25-percent decrease in traffic fatalities from 5,731 killed in 2002 to 4,220 killed in 2003. Thus, fatalities decreased by 1,511 lives, concurrent with a national intolerance for poor driver behavior, supported politically and judicially with aggressive enforcement strategies.

In the United States, Secretary of Transportation Norman Y. Mineta has set an aggressive national goal of reducing fatalities to a rate of 1.0 per 100 million vehicle miles traveled by 2008. A number of key national organizations support this goal. National conferences such as the Safety Leadership Forum in June 2003, held in Lexington, KY, help solidify leadership support. AASHTO hosted a followup forum, Safety Leadership Forum II, at its May 2005 meeting. These forums facilitated discussion of the safety issue and established commitments to continue advancing highway safety nationally and at State and local levels.

In another top-down leadership effort to support increased leadership commitments in safety, AASHTO, with support from FHWA, the National Highway Traffic Safety Administration (NHTSA), the Governors Highway Safety Association (GHSA), and the National Cooperative Highway Research Program (NCHRP), hosted a 2-day peer exchange in Overland Park, KS, in October 2004. The sponsors organized the meeting to facilitate the development and implementation of effective statewide highway safety plans. Representatives from 47 States attended.

In a similar effort, the AASHTO Lead States are assembling plans for deploying effective safety countermeasures in the emphasis areas identified in AASHTO's *Strategic Highway Safety Plan* (NCHRP Project 17-18). According to AASHTO, the goal for the Lead States initiative is for "State transportation agencies that have gained early and extensive experience with the technologies developed or evaluated under the Strategic Highway Research Program to share their practical, real-world experiences with others." The concept behind the program is to set a leadership model in technology deployment.

This meeting on safety information systems took place in the Netherlands. Presentations and open discussions with foreign officials on a wide range of topics explored safety programs and implementation issues.

Selected Safety-Related Scan Tours

Pedestrian and Bicyclist Safety in England, Germany, and the Netherlands 1994

Highway Safety Management Practices in Japan, Australia, and New Zealand 1995

Speed Management and Enforcement Technology: Europe and Australia 1996

Road Safety Audits: Japan, Australia, and New Zealand 1997

Innovative Traffic Control Technology and Practice in Europe 1999

Methods and Procedures to Reduce Motorist Delays in European Work Zones 2000

Commercial Vehicle Safety, Technology, and Practice in Europe 2000

European Road Lighting Technologies 2001

Signalized Intersection Safety in Europe 2002

Managing and Organizing Comprehensive Highway Safety in Europe 2002

Traffic Information Systems in Europe and Australia 2004

Survey of Roadway Human Factors and Behavioral Safety Research and Implementation Practices . 2004

Safety Applications of ITS Systems 2005

Transportation Performance Measures in Australia, Canada, Japan, and New Zealand 2005

Safe Systems Approach

The second overarching lesson from the international community is the value of a "safe systems" approach, which involves identifying the causal factors of crashes so that specific strategies can be implemented in response. The *World Report on Road Traffic Injury Prevention* discusses a system in the following manner:

The traditional view in road safety has been that road crashes are usually the sole responsibility of individual road users despite the fact that many other factors beyond their control may have come into play, such as the poor design of roads or vehicles. But human error does not always lead to disastrous consequences. Human behavior is governed not only by the individual's knowledge and skills, but also by the environment in which the behavior takes place. Indirect influences, such as the design and layout of the road, the nature of the vehicle, and traffic laws and their enforcement affect behavior in important ways. For this reason, the use of information and publicity on their own is generally unsuccessful in reducing road traffic collisions.

Understanding and managing the interactions between the driver, vehicle, and road is the underlying concept behind this approach, along with a philosophy of shared responsibility for system failures. In Sweden, for example, Vision Zero provides a multidimensional framework and multidisciplinary solutions focused on vehicle crashworthiness, occupant restraints and their use, and vehicle speed.

Sweden has been investigating all fatal crashes individually since 1997. Analysts divide fatal crashes into three groups, defined by which component of the roadway environment failed. The first group is the "beyond system" group in which the driver violated road rules (for example, speeding, driving under the influence of alcohol). Suggested countermeasures include aggressive enforcement and, in some cases, limiting access to the system.

The second group is "excessive risk," where the roadway user was killed because of a lack of personal protection (for example, seatbelts). Countermeasures include strict laws and education programs.

International Cultural Differences

Although the United States and the scan tour countries often differ culturally, the differences do not prevent U.S. transportation professionals from learning new safety technologies and best practices developed by those countries. Partly because of cultural differences, however, these countries may be more successful than the United States in implementing certain behavioral practices, such as seatbelt usage or prevention of impaired driving. Expectations about implementation may need to be adjusted because some countries can adopt practices at a national level that can be implemented only at a State or local level in the United States. Similarly, the political context in the United States may inhibit adoption of certain technologies that are more readily accepted in other countries, such as speed enforcement cameras. Nevertheless, exploration of technologies and practices provides an opportunity to advance necessary discussions of their potential adoption or adaptation in the United States.

The third group is "excessive force," where a combination of speed, roadway infrastructure, and vehicle safety capabilities contributed to the fatality. Countermeasures include improving roadway infrastructure and vehicle crashworthiness, and reducing the energy released in a crash through physical separation of opposing traffic. For example, Sweden's 2+1 roadway design provides three lanes of traffic with alternating passing lanes and physical separation between opposing traffic.

Given the concept of shared responsibility, suggested solutions are often multidisciplinary, such as driver education on seatbelt use combined with roadside design improvements. These types of solutions require comprehensive coordination and communication among safety agencies.

In the United States, the National Transportation Safety Board (NTSB) investigates selected highway crashes that highlight safety issues of national significance. Most selected investigations involve commercial vehicles, but in some cases private vehicle crashes are investigated as well. All causal factors are analyzed, and recommendations for industry improvement are developed using an overall system approach. FHWA and other organizations work closely with NTSB to resolve resulting recommendations by making systematic improvements to safety through modified policies, training, and technological advances.

Comprehensive planning also helps ensure a safe systems approach to safety by involving all major stakeholders of safety in the planning process, and by considering safety from the vehicle, driver, and user perspectives. A number of States are advancing comprehensive safety plans.

The Collaborative Process

The third overarching lesson from the international community is the importance of a collaborative process that reaches out to all agencies. In the Netherlands, the Dutch government determined the goals and contents of its national transportation plan through a process called the "Polder" model, a negotiation that builds grassroots buy-in. This approach requires thorough and close consultation among all highway agencies to reach agreement on a national plan. This process of all-inclusive agreement and coordination often takes longer than other approaches but results in alignment of plans from the national to local levels.

Another example of collaboration is the more than 500 multidisciplinary, locally based "accident commissions" in Germany that are responsible for a high level of safety coordination and communication. Institutionalized by the German government in 1971, the local accident commissions include police officers, representatives of roadway authorities, and others in the communities who have knowledge of roadway crashes. The commissions are required to investigate and suggest

In addition to top-level commitment to enforcement efforts, a number of European countries actively manage speeds based on traffic flow and lane occupancy, as shown in this installation in the Netherlands.

solutions for high-risk locations within their jurisdictions. They review crash data to identify safety black spots, which are locations with five similar crashes in a year or locations with three fatalities or five serious injuries in the past 3 years. An ongoing training program provides commission members with new ideas and techniques.

Australia also has a strong local government outreach, providing grants to local agencies for safety initiatives. The State of Victoria's VicRoads Saferoads initiative is a partnership between various agencies that support municipalities in identifying safety issues and implementing safety programs to address identified issues. Community Road Safety Councils serve as key advocates and educators for road safety practices in local communities and create strong linkages between police and local government. A typical council has 10 to 20 members, representing Government, police, businesses, community members, and civic groups. The councils are eligible to receive funding to deliver road safety programs.

In a U.S. example of the collaborative process, more than 150 safety partners developed Missouri's comprehensive highway safety plan, *Missouri's Blueprint for Safer Roadways*. The Missouri Department of Transportation's (MoDOT) chief engineer, Kevin Keith, notes that highway safety "is an area that touches a lot of people," including representatives of the four E's of highway safety. Engineering, enforcement, education, and emergency services are multijurisdictional and therefore are the domain of multiple agencies. "No one person, group, or agency can control the outcome," he notes, "so you have to get the right folks committed to doing something."

Missouri had been working to develop a coalition of safety partners for years, and this effort was accelerated when MoDOT volunteered for AASHTO's Lead States initiative to develop a comprehensive highway safety plan. "We used that as a way to refocus our safety coalition," says Keith. The coalition agreed on a safety goal of reducing the State's fatalities to less than 1,000 by 2008, which will represent nearly a 20-percent reduction from the 2003 number of 1,232. "This gives all these agencies with separate missions, budgets, and constituencies a common focus so they can use their existing resources to help us achieve that goal."

A coalition of Minnesota agencies recently completed development of a comprehensive highway safety plan, which explicitly recognizes the need to provide local agencies with funding, training, and technical assistance to improve highway safety in the State. In fact, the plan includes a "safety toolbox" that is specifically designed to provide local agencies with guidance in developing, prioritizing, and implementing safety projects. The toolbox includes both general and specific information on how localities can improve safety, ranging from descriptions of the initiatives in the comprehensive highway safety plan to specific contact information regarding crash data and formulas for determining crash rates. To provide a means to implement the strategies in the safety toolbox, Minnesota developed a two-tiered funding plan that provides for central solicitation, selection, and guidance for decisionmaking in the local planning process. In both cases, the local road authorities are partners and their safety projects are eligible for funding.

Business Approach

As the fourth lesson from the international community, countries like the United Kingdom base their highway safety strategies on a business approach, which supports strategies that are data driven and results oriented. The United Kingdom implemented an approach that emphasizes comprehensive safety improvements along extended

EuroRAP is mapping road networks based on the fatal and serious crash rates per billion vehicle kilometers. So far, EuroRAP has produced risk maps for Britain (the one pictured here shows trunk and primary roads), Ireland, the Netherlands, Spain, Catalonia, and Sweden.

sections of highway or within specific areas rather than just at black spots. This approach is data driven from an overall system perspective. Corridor-level safety measures include high-performance marking and signing, new and more consistently applied speed limits from village to village, splitter islands (islands placed to slow traffic speed, to direct vehicles into the circle at the correct angle, or to prevent vehicle movement against traffic), speed cameras, flashing fiber-optic signs, higher friction and colored pavements, guardrails, passing lanes, and improved bicycle and pedestrian facilities.

The United Kingdom also uses performance-based financial incentives to local governments to encourage safety results. Here is how it works: The national government provides all funds in a block amount to the local governments, and each locality prioritizes the spending of funds as it sees fit. The amount provided is based on a locality's measured performance. Financial incentives are available for meeting a number of goals, including safety or transportation performance. As reported in the FHWA scan trip report, *Managing and Organizing Comprehensive Highway Safety in Europe*, about three-quarters of the local governments in the United Kingdom have chosen safety as one of their performance measures for obtaining the financial incentives.

In the United States, the comprehensive highway safety plans being developed or that already have been developed in many States are based on a business model approach that requires sound data, risk assessment, and quantifiable results, enabling safety to compete against other transportation priorities for resources. Fiscal accountability—keeping one's word to the public—requires that agencies responsible for improving safety spend funds wisely, as with any business.

Another example of the performance-driven business approach emerged in 2004 when the Maine Department of Transportation (MaineDOT) recognized that it needed a change in its organizational structure to elevate safety throughout the department. At the direction of MaineDOT's Chief Engineer John Dority, members of the executive staff and bureau directors were nominated to participate in a review of the department's existing safety programs. The Safety Office Review Team (SORT) was empowered to conduct interviews, gather necessary information, and develop an implementation plan that would achieve the objective of raising awareness of the State's transportation safety challenges. SORT interviewed key players in all program areas, and, as a result of the team's efforts, an organizational restructuring has occurred that places a greater emphasis on safety. Today, the MaineDOT leadership incorporates a performance-based, resource-balanced business model into its daily decisionmaking process. This internal reorganization is currently being augmented by the formation of a multiagency cabinet-level safety steering committee that includes representation from FHWA and NHTSA. This committee will ensure that safety priorities receive the highest consideration and that the Governor and State Legislature are kept aware of the needs and results of the State's transportation safety initiative.

Innovative Concepts

The fifth lesson from the international community is that there are many new, innovative concepts that offer opportunities for broader application in the United States. One such innovation is a systematic road assessment program called EuroRAP, standing for the European Road Assessment Programme. Motoring organizations and road authorities throughout Europe developed EuroRAP to evaluate the safety of roads. The road assessment is based on a two-part protocol: color-coded risk maps based on a synthesis of available crash statistics and a star rating system based on a safety review of design features, both of which are designed to describe the relative safety risk by road segment.

EuroRAP safety ratings inform motorists of the level of safety on the roads they travel. The ratings also provide road engineers and planners with vital benchmarking information that will demonstrate how well, or poorly, their roads are performing compared with others, both in their own and other countries. A number of countries have generated initial risk maps, including Britain, Ireland, the Netherlands, Spain, and Sweden, and several others have pilot programs underway, including Australia. Work to expand and refine the technical protocols continues.

This innovation has a counterpart in the United States, the AAA Foundation for Traffic Safety's (AAA FTS) United States Road Safety Assessment Program (USRAP), a pilot program to test the technological and political feasibility of instituting a road assessment program in North America. The pilot will examine various technological barriers, such as whether appropriate data are available, and, if available, how those data should be aggregated. The pilot test also will examine political barriers and liability concerns. Sufficient assessment will be completed in a test jurisdiction to demonstrate not only the feasibility but also the utility of such a program.

"By providing the public with a simple, graphic measure of risk that is based on good science," says J. Peter Kissinger, president and CEO of AAA FTS, "I believe the pilot can energize a national debate on road safety. This type of dialogue should help to create public support for more funding to upgrade data systems and lead to additional road safety improvements."

A second innovation is the "self-explaining roadway," or "self-organizing roadway," which refers to roads with characteristics that clearly show drivers what is expected of them. The objective is not simply to reduce speeds, but rather to provide a roadway planned and designed in such a way that motorists achieve and maintain an appropriate speed. Instead of enforcement by police, the emphasis is on controlling speed through the design and characteristics of the roadway.

In the United States, some traffic calming techniques apply the self-explaining philosophy and potentially can be used more broadly. Roundabouts are self-explaining features as the road geometry requires the driver to select a lower speed to maneuver.

The Future of Safety

In the United States, many States have adopted the national goal of reducing highway fatalities to 1.0 per 100 million vehicle-miles traveled by 2008 and are exploring opportunities to contribute to achieving that goal. Many States also have completed a safety planning process, and many others have adopted safety innovations such as cable guardrails for medians, road safety audits, roundabouts, and intelligent transportation systems.

"To further that progress, FHWA will continue to support collaboration with our international colleagues," says FHWA Associate Administrator for Policy Charles D. Nottingham, "We need to work together and learn from one another to reduce the death toll on all roadways in the United States and abroad."

John Baxter is director of the FHWA Office of Safety Design in Washington, DC. He leads a multidisciplinary staff in developing and implementing strategies and policies that affect highway safety performance. Before joining the Office of Safety, he was the FHWA division administrator in Indiana. Baxter holds a bachelor's degree in civil engineering and a master's degree in transportation engineering from Clemson University in South Carolina. He is a registered professional engineer in Utah.

Michael L. Halladay is director of the FHWA Office of Safety Program Integration and Delivery, part of the leadership team for safety. He leads a staff that advances highway safety strategic planning, research, technology programs, training and education, safety data, outreach, and other topics. Halladay has a civil engineering degree from Duke University and is a registered professional engineer in Virginia.

Elizabeth Alicandri is director of the FHWA Office of Safety Programs. She leads a staff that develops and administers multidisciplinary programs for the safe operations of roadways with an emphasis on coordinating with partners and stakeholders in engineering, enforcement, and education. Before joining the headquarters Office of Safety in 2000, she spent more than 15 years working in and managing the Human Factors Laboratory in FHWA's Office of Research, Development, and Technology. She has a B.S. in psychology from Georgetown University and an M.S. in transportation engineering from the University of Maryland.

For more information on transportation safety, see http://safety.fhwa.dot.gov. Cable median guardrail is an FHWA priority, market-ready technology, and innovation. See www.fhwa.dot.gov/rnt4u for more information.

Where the Dowel Bars Are

A new quality-assurance tool could help engineers improve the performance of concrete pavements.

by Shreenath Rao

Due to daily and seasonal fluctuations in temperatures, concrete slabs contract and expand, but the joints in the pavements serve to absorb these movements. The dowel bars embedded in concrete pavements transfer the load across the construction joints. When aligned properly, they help reduce faulting and improve the pavement's performance.

For more than 30 years, the Federal Highway Administration (FHWA) has recommended using large-diameter dowel bars for all jointed concrete pavements subjected to high volumes of heavy truck traffic to help avoid roughness caused by faulting. Implicit in this recommendation, however, is the assumption that the dowel bars will be placed in proper three-dimensional alignment.

Misplaced or misaligned dowel bars can adversely affect the performance of concrete pavements. Misaligned dowel bars can lock up the joints and prevent them from opening and closing freely, which may result in the opening and deterioration of midslab cracks, as well as spalling (chipping) and cracking near the joints. Because of the difficulties in determining the position of dowel bars in hardened concrete, misplaced dowel bars went largely undetected in the past, until it was too late and problems started to develop.

Until recently, engineers had few practical options for verifying the position and orientation of dowel bars. Probing manually or taking core samples is invasive and can be time consuming. Ground-penetrating radar is another option, but analyzing the data can be difficult, and the variations in material properties along sections of pavement can introduce significant errors in results. A new state-of-the-art, nondestructive testing device known as MIT Scan-2 offers a faster, easier, and more accurate means for measuring the three-dimensional position of dowel bars embedded in concrete.

MIT Scan-2 is the first device of its kind created specifically for measuring the alignment of dowel bars. Developed by Magnetic Imaging Tools (MIT) of Dresden, Germany, MIT Scan-2 was designed to be simple to operate and to provide accurate, real-time results in the field.

"MIT Scan-2 holds the promise of greatly improving the quality of concrete pavement construction, as well as providing significant cost savings by preventing costly errors in dowel placement," says Sam Tyson, FHWA's technical representative for a project to evaluate the device. "Evaluating dowel positions in real time will afford the opportunity to identify problems during construction when onsite corrections can be made."

How the Device Works

The MIT Scan-2 system consists of a sensor unit encased in a green box, an onboard computer that controls the testing process and records data, and a special plastic rail system that guides the unit along the joint to be scanned. During testing, the device emits a weak, pulsating magnetic signal and detects a transient magnetic response signal induced in the metal dowel bars. Employing the methods of tomography, the user is

(Above) A worker is pulling the MIT Scan-2 scanning device across a joint in a new pavement to measure the alignment of the dowel bars in the concrete. *Photo: Applied Research Associates, Inc. (ARA).*

able to determine the position of a bar by taking a cross section mathematically to obtain useful information such as the bar's orientation in the vertical and horizontal planes.

To use the device, an engineer enters pavement information, such as the type of dowel, slab thickness, and other data, into the onboard computer. The engineer then places the rails along the joint and slowly pulls the unit by hand over the length of the joint. The testing takes about 1 minute per joint, and up to three lanes can be tested at a time. In an 8-hour day, a two-person crew can test 200 or more joints. In addition, the tool can run continuously for up to 8 hours on one battery charge.

MIT Scan-2 tests the entire joint in one pass, providing results for all dowel bars placed in the joint. The field data analysis is fully automated, and the results can be printed using the onboard computer.

"This device shows promise because of its built-in software, its portability, and the speed with which it can be used on hardened concrete," says Tyson.

The field results are accurate for the following dowel placement conditions:

- Mean dowel depth of 150 +/- 40 millimeters (6 +/- 1.5 inches)
- Maximum vertical misalignment +/- 20 millimeters (0.79 inch)
- Maximum horizontal misalignment +/- 20 millimeters (0.79 inch)
- Maximum lateral position error (side shift) <50 millimeters (2 inches)

For other conditions, engineers can use the accompanying PC-based software to conduct a more comprehensive analysis. The results include a graphical output that shows a contour map of the induced magnetic field, which is the response signal to the active, pulsating, electromagnetic signal. A darker red color indicates a stronger signal, meaning that the object is closer to the surface. A graphical illustration of the results shows the specified bar location and the placement tolerance, represented by rectangles with the actual bar positions shown as gray bars.

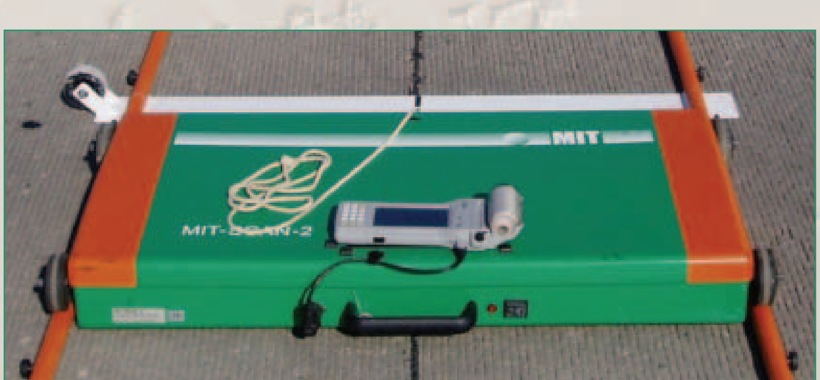
The accuracy of the results depends on the position and orientation of the bars. The device provides the most accurate results when the bars are placed within typical placement tolerances. For bars within the dowel placement conditions listed above, the overall standard deviation of measurement error is about 2 millimeters (0.08 inch) for horizontal and vertical misalignments (maximum error of about 4 millimeters or 0.16 inch).

The results obtained are precise because of the meticulous calibration of MIT Scan-2 to each type of bar to be detected using the device. During calibration, measurements are taken over the entire range of bar positions and orientations to correlate the response signals to known bar positions and orientations. As the final step in calibration, the results are verified at the testing facility at the manufacturer's lab by comparing the MIT Scan-2 results to manual measurements.

Because MIT Scan-2 operates on an electromagnetic field, the presence or absence of nonconducting material does not affect the results. Thus, the results for tests conducted in the open air are the same as those conducted with concrete or any other cover material. Nor will the presence of water on the pavement surface or changing moisture content in the concrete as it cures affect the results. In fact, the testing can be conducted in the rain, if necessary.

Field Trials in California

Since December 2002, the California Department of Transportation (Caltrans) has been conducting trial



ARA

(Above) A closeup of the MIT Scan-2 resting on a new concrete pavement.

(Right) The field output shown here summarizes the essential information about the joint being analyzed, including the location, date and time measured, concrete thickness, and the type, spacing, and orientation of the bars. "Bar Loc." refers to the offset of the individual bar from the edge of the pavement. "Bar Spc." indicates the spacing between individual bars. "Depth" indicates the depth of the center of the bar from the top of the pavement. "Side shift" refers to the shift of the bar to the right (positive) or left (negative) of the middle of the bar over the joint. Alignment (horizontal or vertical) indicates the deviation of one end of the bar from the other end in plan view of the pavement (horizontal) or side view of the pavement (vertical).

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Date         : 15/4/2004
Time         : 10:16
File g:\04_04_15\15041016.hdf
-----------------------------------
Highway      : I20
Station No.: 0+31
Bar Spacing          : 300 mm
Concrete Thickness : 300 mm
Bar type     :  456 x 32.4 mm
-----------------------------------
Bar  Bar   Bar  Depth  Side Alignment
     Loc.  Spc.        Shift Hor. Vert.
No.  mm    mm    mm     mm    mm    mm
-----------------------------------
 1   266   297   130   -33    6     0
 2   563   304   136   -20    1    -4
 3   867   315   139   -15    1     0
 4  1182   296   150     1   -4    24
 5  1478   303   135    -8    0     9
 6  1781   305   140   -19    1    10
 7  2086   307   134   -15    2     3
 8  2393   297   138    -3    0     4
 9  2690   315   143   -42    2     6
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An engineer calibrates measurements at the MIT GmbH laboratory.

tests using MIT Scan-2. Instrumental in bringing the technology to the United States, Caltrans has used MIT Scan-2 to detect numerous problems associated with dowel bar and tie bar placement on existing pavements. The agency has found the tool valuable for quality assurance and quality control tests during construction of concrete pavements.

Examples of problems that Caltrans identified using MIT Scan-2 include the following:

- On one project using a dowel bar inserter (DBI), MIT Scan-2 results showed that the dowel alignment on the project was so poor that the joints were practically cross-stitched.
- On another DBI project, the MIT Scan-2 results showed that the dowel bars were dropped to the bottom of the slab over the 2.4 kilometers (1.5 miles) of the project.
- On another project, an equipment problem caused tie bars across the centerline joint to be placed too shallowly. MIT Scan-2 successfully identified the fact that the majority of the bars were cut when workers sawed the longitudinal joint.
- And on a project using dowel basket construction, MIT Scan-2 results showed that the majority of dowel baskets were either shoved or had burst open. As a result, construction stopped while the contractor used additional pins to secure the dowel baskets. Comparing the concrete placed before and after this adjustment showed a striking improvement. Before the adjustment, nearly 100 percent of the joints had at least one severely misaligned dowel bar. After the fix, 100 percent of the bars satisfied the specification requirement.

According to Tom Pyle, chief engineer of rigid (concrete) pavement materials and structural concrete with Caltrans, the device holds promise for allowing early detection of these types of problems and helping agencies avoid compounding costly errors. "MIT Scan-2 is the only machine that we have found that provides information on the location of every dowel bar with such accuracy," he says. "One of the biggest challenges we have now is to figure out how to manage the large amount of data it produces."

Pyle adds, "The next big step for us is to determine how we will roll the information into a useful test method for dowel bars. With coring, we can only check a few slabs and have to wait until the concrete can support a drill rig. With MIT Scan-2, we can scan about one joint per lane every minute and do so after only a modest strength gain since we carry [and then drag] the device. Therefore, we will be able to check trial slabs quickly and thus help contractors get off to a good start in terms of the accuracy of their dowel bar placement."

MIT GmbH

A dowel bar alignment is set up for a field validation at the testing facility.

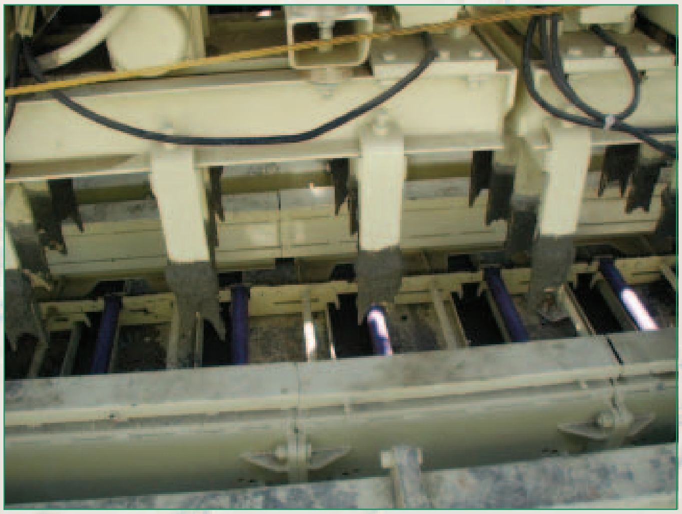
DBI Versus Dowel Baskets

Researchers recently used MIT Scan-2 to study the relative effectiveness of using dowel baskets versus DBI systems during construction. Dowel bars are either placed manually before concrete placement using dowel baskets or during construction using automatic DBI equipment. Concerns about possible problems with dowel bar misalignments are one of the reasons why DBIs are not widely used in the United States, even though they can expedite construction and reduce costs.

Experience using MIT Scan-2, however, shows that using dowel baskets does not guarantee good dowel alignment. Testing conducted by FHWA and several State departments of transportation (DOTs) using MIT Scan-2 showed that excellent results can be obtained by using a dowel bar inserter.

The study compared dowel alignments for five DBI projects and seven basket projects located in six States across the United States. The findings showed that comparable results can be obtained using either method of construction, as long as care and attention are given to the many details required to achieve accurate dowel bar alignment.

For dowel baskets, the most critical factor appears to be the manner in which the baskets are secured on the subbase prior to paving. If the baskets are not adequately pinned down, they may be shoved, rotated, or pulled apart during paving, resulting in extreme misalignments. The baskets also



(Left) This closeup shows a dowel bar inserter. (Right) A construction crew is using a dowel bar inserter on this highway paving project. *Photos: Guntert & Zimmerman Construction Division, Inc.*

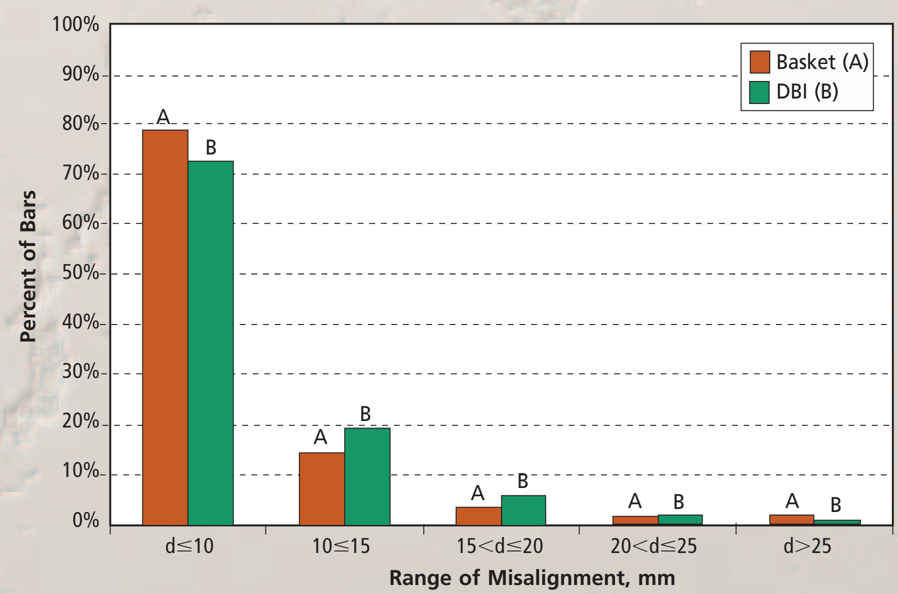
may bend during handling or concrete placement if walked on.

Because MIT Scan-2 is essentially a metal detector, the presence of any metallic objects within about 1 meter (3 feet) of the bars being scanned interferes with the measurements. Therefore, dowel baskets could interfere with the measurement results. Regardless, reasonably accurate results can be obtained for dowel baskets if the following conditions are met: (1) the dowel bars used with the baskets are epoxy coated, and (2) the transport ties on the basket are either cut or removed. If these conditions are met, the results for horizontal and vertical alignments are typically within +/- 5 millimeters (0.2 inch) of their true alignment. In addition the manufacturer recently developed analysis software to improve on the accuracy. With careful construction practices and inspection, testing is needed only to verify that the basket has not moved or burst open during paving. With specific calibration for the type of basket used, the accuracy can be improved further.

Even without specific calibration, however, MIT Scan-2 is still a useful screening tool for identifying problem areas because it can easily detect the results of displaced or burst baskets. For example, engineers can easily identify problems in the bar placement or sawcut locations visually by looking at the images generated by MIT Scan-2. In a signal intensity plot generated by the device, areas with severe vertical misalignments will show up in an asymmetrical alignment rather than a parallel configuration.

For DBI construction, the critical factors are the proper adjustment of the equipment and concrete mix design. When using a DBI, the portland cement concrete (PCC) mix must be stable enough to hold the bars in place without displacing them during the paving operation.

Comparison of Alignment in DBI and Dowel Basket Projects



The bar chart compares the dowel alignments in projects featuring (A) dowel baskets and (B) dowel bar inserters (DBI). The comparison is based on the MIT Scan-2 results of five DBI projects and eight dowel basket projects located in seven States across the United States. The results demonstrate that with careful attention to paving details, comparable results can be obtained using either method of construction. *Source: Yu, Thomas,* Dowel Bar Alignments of Typical In-Service Pavements, *American Concrete Pavement Association, Skokie, IL, 2005.*

Field Trials in the Carolinas

On a reconstruction project on I–95 in South Carolina, the contractor elected to use the DBI construction method, which posed a significant concern for the State because it had no prior experience with this paving system. However, using MIT Scan-2, engineers from the South Carolina Department of Transportation (SCDOT) were able to monitor the dowel bar alignment to their satisfaction.

"MIT Scan-2 provided us with considerable peace of mind that the

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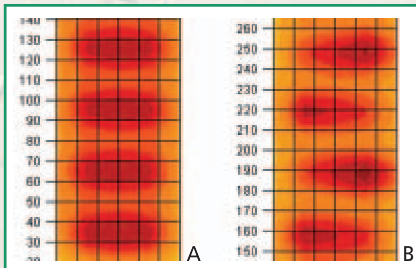
Workers prepare to use MIT Scan-2 to evaluate the dowel alignment in a new pavement joint.



These two signal intensity plots illustrate how easily an engineer can use MIT Scan-2 to see the difference between properly aligned dowel bars (A) and severely misaligned bars (B). A good alignment is characterized by uniformity and symmetry in the intensity of the magnetic signal. A poor alignment shows an asymmetrical magnetic signal, which is a telltale sign that the dowel basket was pulled apart and the alternating ends of successive bars were dropped. *Source: ARA.*

insertion process was working properly on I–95," says Andrew Johnson, State pavement design engineer with SCDOT. "Although more research is necessary to understand exactly what tolerances are acceptable, we feel like the vast majority of inserted dowels were appropriately located. We would not have had this assurance without MIT Scan-2."

Johnson adds that the scanning data led to the replacement of several defective joints that would not have been caught otherwise. One joint problem the State encountered was that tie bars were being placed at dowel locations. Although this in itself is not a major problem, tie bars can displace the dowel bars as they are inserted. MIT Scan-2, however, can easily detect problems like this. "I am certain that the use of the device led to higher quality on our project," Johnson adds.

In North Carolina, a contractor performing work on a U.S. 64 bypass project used MIT Scan-2 to gain approval to use the DBI construction method for a substantial savings in construction costs. On that project, the North Carolina Department of Transportation (NCDOT) used the device to monitor the dowel alignments to optimize the concrete mix design. When the PCC mix was optimized with assistance from the DBI manufacturer, an FHWA study showed that the resulting dowel bar alignment is among the best observed on any project, whether using a DBI or a dowel basket.

Further Testing

For both dowel basket and DBI methods of construction, MIT Scan-2 can be instrumental in fine-tuning the construction process. For baskets, MIT Scan-2 can be used to determine whether the planned method of securing the dowel basket is adequate. For DBIs, MIT Scan-2 can help optimize the PCC mix design and detect any equipment adjustment needs. By

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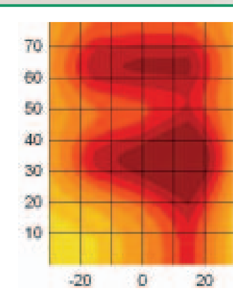
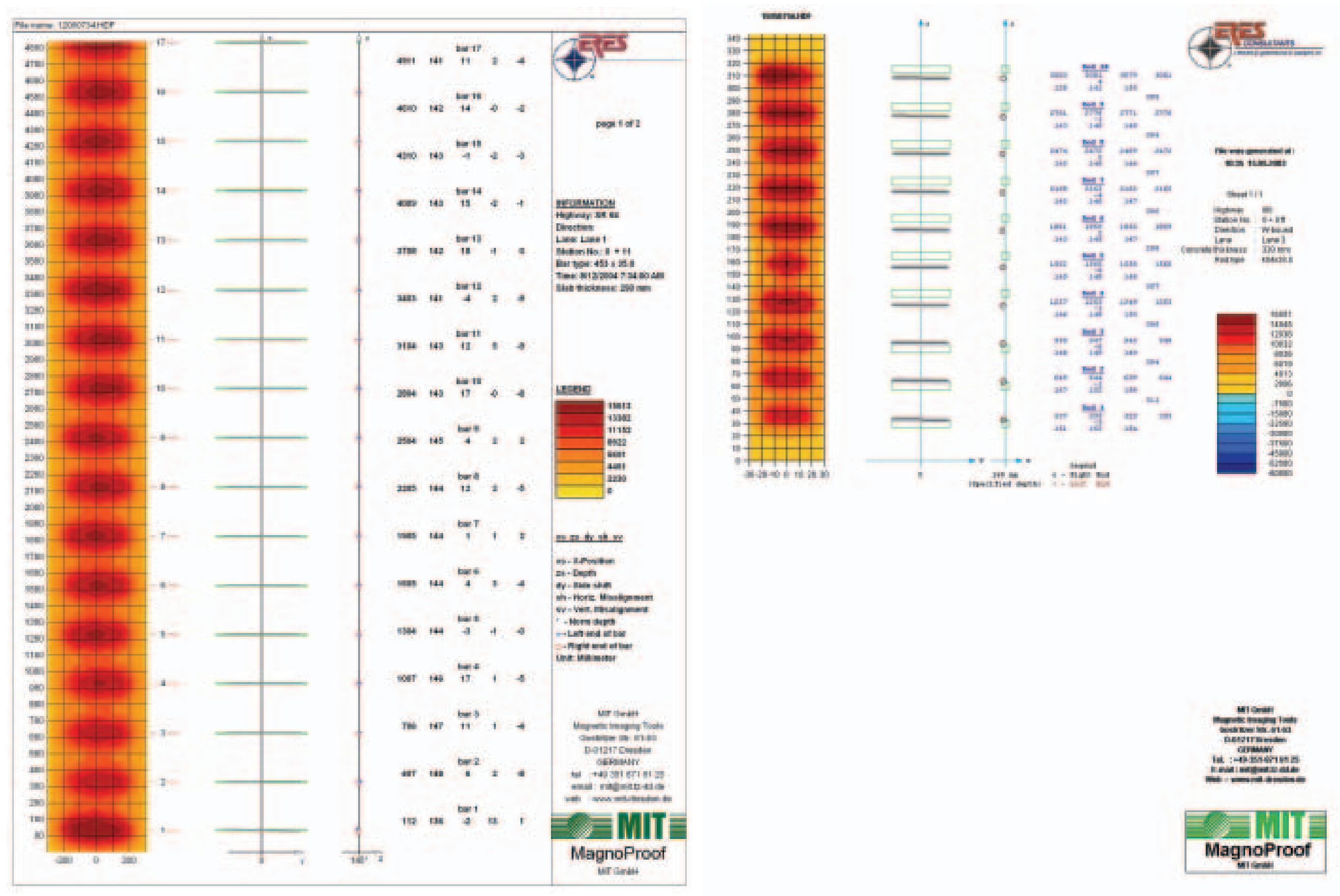
Three workers are using MIT Scan-2 on a U.S. 64 bypass construction project in Knightdale, NC.



This signal intensity plot shows that a tie bar was placed too close to a dowel location. The dowel bars are indicated by the red elliptical regions oriented horizontally. The presence of the tie bar is indicated by the vertical dark red region near the right end of the bars. *Source: ARA.*



These readouts show the typical graphical output from the scanning device. The plots consist of three types of information: (1) signal intensity plot (on the left); (2) a schematic illustration of the analysis results (center), which shows the specified dowel location with placement tolerance and the actual measured dowel position; and (3) numerical results (right) that show the bar location, depth, lateral placement error, horizontal misalignment, and vertical misalignment. The readout on the left shows an example of very good dowel bar alignment, while the one on the right shows poor alignment. *Source: MIT GmbH.*

providing a practical means of verifying dowel alignment, MIT Scan-2 already has enabled contractors to use DBIs in States that had no previous experience with them. The ability to quantify and document quality also sets the stage for the development and implementation of performance-related specifications regarding dowel alignments.

Results of the MIT Scan-2 testing indicate that many inservice pavements may contain at least a few bars that do not satisfy the current specification requirements, even on well-performing pavements with no signs of any distresses. One consequence of not having had a practical means of measuring dowel alignment in the past is that the existing specifications on dowel placement tolerances are largely untested. As a result, no clear consensus exists on what specifications would lead to the most durable pavements. In addition, the actual field performance data that could be used to determine what is needed do not exist.

A comprehensive review of the existing specifications is critical, and the National Cooperative Highway Research Program (NCHRP) recently launched a study for a review. NCHRP Project 10-69—"Guidelines for Dowel Alignment in Concrete Pavements" kicked off in March 2005.

FHWA recently acquired an MIT Scan-2 device for its Mobile Concrete Laboratory. "The measurement of dowel locations in existing concrete will enable FHWA to review current guidelines and specifications for dowel placement tolerances and recommend best practices for construction," says FHWA's Tyson. "Equally important is the ability to use the device to measure dowel positions in newly placed concrete a short distance behind the paving train. These measurements, in three dimensions with a printout for immediate review and electronic storage of all data, make this one of the more useful devices to be added in recent years to the toolbox for constructing high-performance concrete pavements."

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Trans-Texas Corridor

by Antonio Palacios

The Lone Star State is pioneering innovative approaches to developing and financing major transportation projects.

Texans pride themselves on doing things in a big way, and the proposed Trans-Texas Corridor is no exception. The 6,400-kilometer (4,000-mile), multiuse transportation system, projected to take 50 years to develop, is the State's most ambitious transportation project to date.

The proposed system will be a network of transportation corridors (routes) incorporating separate lanes for passenger vehicles and trucks, rail lines for high-speed passenger and freight rail, and a dedicated utility zone. Components in the system may incorporate existing and new highways, railways, and utility rights-of-way where practical. Up to 366 meters (1,200 feet) wide in some places, the corridor is designed to move people and freight faster and more safely through Texas, from Mexico to the Oklahoma border.

(Left) The Trans-Texas Corridor is designed to accommodate expanding transportation demands resulting from population growth, particularly in the State's urban areas. This photo shows a traffic backup on Interstate 35 heading into downtown Austin. *Photo: TxDOT.*

TxDOT

The concept for the Trans-Texas Corridor, shown here in an artist's rendering, calls for separate lanes for cars and trucks; rail with separate lines for passenger, high-speed freight, and commuter traffic; and a utility zone.

Transportation officials expect the project to improve the existing Texas transportation network and provide congestion relief for the State's busy metropolitan areas. The Texas Department of Transportation (TxDOT) plans to use public-private partnerships to finance much of the development of the corridor, which has an estimated price tag of $145.2 billion to $183.5 billion.

The Trans-Texas Corridor joins two other Texas projects on the Federal Highway Administration's (FHWA) list of megaprojects—the $2.7 billion, 37-kilometer (23-mile) Katy Freeway from Katy to Houston and the $2.5 billion, 193-kilometer (120-mile) Central Texas Turnpike near Austin (this estimate is for Phase I only, with Phase II now known as U.S. 183A, and no current estimate for Phase III)—making the State one of a handful with experience in developing multiple major projects.

Megaprojects are major transportation projects that cost at least $1 billion or attract a high level of public attention or political interest because of their impact on the community, environment, and State budgets. The Trans-Texas Corridor qualifies for the designation on both counts, because of its size and potential long-term impact on the State and its residents. (See the July/August 2004 special issue of PUBLIC ROADS, which highlights the challenges and complexities of megaproject development and management with examples from across the Nation.)

"The Trans-Texas Corridor is an innovative concept for moving freight and people, as it incorporates unique public-private partnerships in financing and offers an excellent opportunity to use a collaborative environmental review process," says Highway Engineer Jim Sinnette with the Major Projects Team at the Federal Highway Administration (FHWA).

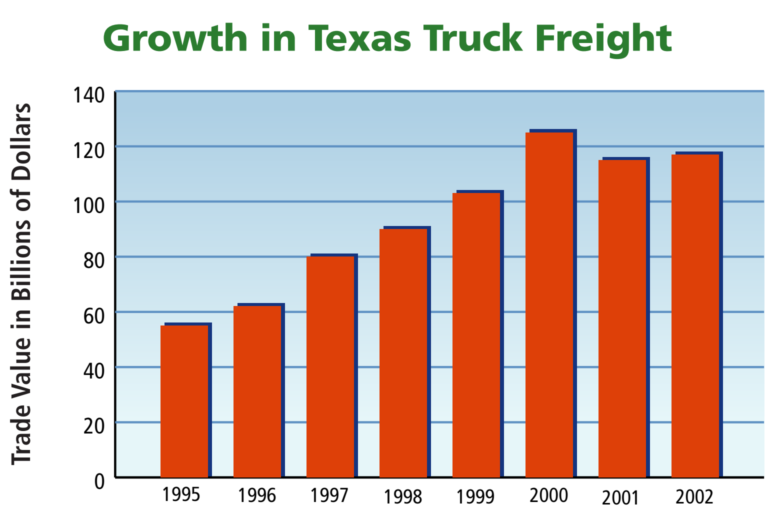
Meeting Tomorrow's Needs

TxDOT has not determined specific locations for the Texas Corridor, but the proposed routes would generally parallel interstate routes. As currently envisioned, each corridor will include as many as six lanes for passenger vehicles and up to four lanes for large trucks. Corridors also will have up to six rail lines for high-speed passenger rail between cities, high-speed freight, and conventional commuter and freight transit.

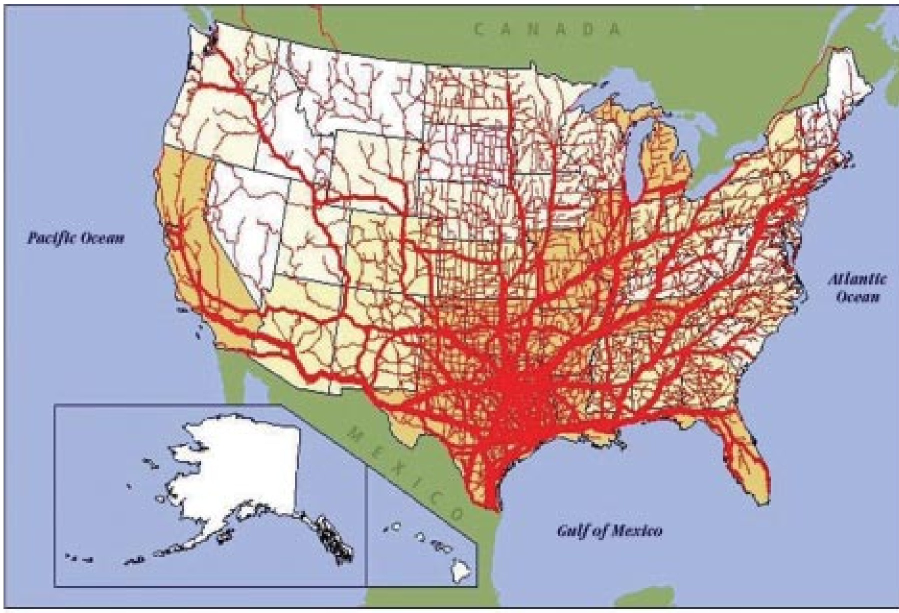
Another unique component of each route will be a 61-meter (200-foot)-wide dedicated utility zone for water, oil, and gas pipelines, and transmission lines for electricity, broadband, and other telecommunications services.

"We need a transportation system that meets the needs of tomorrow, not one that struggles to keep up with the needs of yesterday," Texas Governor Rick Perry said in announcing the corridor concept in 2002. "[The Trans-Texas Corridor] is a plan to ease traffic congestion and increase the safety and security of Texans living in crowded cities and suburbs, near congested border crossings, and in our smallest communities in rural Texas."

Plans call for developing the Trans-Texas Corridor in phases over the next 50 years, in contrast to the typical 25-year timeframe for planning



The Trans-Texas Corridor is designed to accommodate continued growth in truck freight traveling through the State as a result of the 1994 North American Free Trade Agreement. *Source: TxDOT.*



This map of the United States shows the heavy volume of freight shipped through Texas, a major trade gateway from Mexico and South America, as red lines branching out from the heart of the Lone Star State. *Source: FHWA.*

and developing large transportation systems, with routes prioritized according to the State's transportation needs. TxDOT will oversee planning, construction, and ongoing maintenance, but private firms will provide financing and be responsible for much of the daily operation of the transportation system, recovering their investment by charging tolls.

Says Gaby Garcia, TxDOT spokesperson, "We're looking ahead to the future of State transportation needs and, with a limited amount of money, figuring out how to plan systemwide roads and rails together in one corridor."

Projected increases in the Texas population and freight traffic triggered development of the Trans-Texas Corridor concept. Forecasters expect the State's population of 22 million to grow to 36 million by 2030. The majority will live in urban areas, where limited room and high costs make it difficult to expand existing highway systems to accommodate growing transportation demands.

Most U.S. imports from Mexico and South America travel through Texas, as do most exports to Mexico and South America. In fact, 79 percent of U.S.-Mexico trade passes through Texas ports of entry, and trade flows are expected to increase in the coming years as a result of the North American Free Trade Agreement (NAFTA).

Keeping Texans Moving

Transportation officials expect the corridor project to improve the mobility of the growing Texas population by adding additional capacity. By routing passenger and freight traffic around metropolitan areas, the corridor should relieve urban traffic congestion, improve air quality by reducing emissions, and keep hazardous materials out of populated areas by providing transportation alternatives. "Overall, we'll have a more efficient and reliable transportation system," Garcia says.

So far, environmental studies are underway for two sections of the corridor. TxDOT expects to identify and study other potential sections in the future.

The first study, begun in early 2004, focuses on the section from Oklahoma to Mexico and the Gulf Coast, known as Trans-Texas Corridor 35 (TTC–35) because it roughly parallels Interstate 35 (I–35). The proposed 1,290-kilometer (800-mile) section extends from north of the Dallas/Fort Worth metropolitan area, through central Texas, to the Rio Grande Valley and possibly the Gulf Coast.

Today, nearly 9.5 million people—about 45 percent of all Texans—live within 80 kilometers (50 miles) of I–35. Forecasters project this population group to increase to more than 15 million by 2025, putting even more demands on this heavily congested interstate corridor.

The second section under study, I–69/TTC, extends from northeast Texas to the Mexican border, incorporating about 1,600 kilometers (1,000 miles) of the planned I–69 corridor. Although part of a national project, I–69/TTC is being developed in Texas under the Trans-Texas Corridor master plan. I–69 is a 2,570-kilometer (1,600-mile) national highway that, once completed, will connect Mexico, the United States, and Canada. Other States involved in the I–69 project include Arkansas, Indiana, Kentucky, Louisiana, Michigan, Mississippi, and Tennessee. The planned location for I–69, designated by the U.S. Congress in the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), was chosen because of the economic opportunities that could be created along the north-south corridor, specifically those related to increased trade resulting from NAFTA.

Public-Private Partnership

To pay for the Trans-Texas Corridor, TxDOT is looking at a variety of financing methods. The agency expects public-private partnerships, such as those that tap into funding resources from the private sector in return for toll revenues, to play a key role in financing and constructing the system. Other options include right-of-way leasing and State and Federal funds.

"We don't have enough revenues from the State fuel tax and other traditional sources to meet all of our transportation needs, so we need infusions from other sources," Garcia says. "In looking to the private sector, we see investors who are willing to put money up front to give us the infrastructure we need and let it be a State-owned project."

For the TTC–35 corridor, FHWA is partnering with Texas to plan and develop the route through an innovative contracting agreement. This corridor qualified Texas for a special experimental project (SEP-14/SEP-15), allowing the State to reach a comprehensive development agreement with a developer before the environmental analysis—Tier 1 of the environmental impact statement (EIS)—is completed.

SEP-14 permits States to evaluate project-specific innovative contracting practices that have the potential to reduce the life-cycle cost of projects while maintaining product quality. The objective of SEP-15 is to evaluate and document public-private partnership approaches that advance the efficient delivery of transportation projects while protecting the environment and taxpayers.

The approval under SEP-14 cleared the way for TxDOT to proceed with the arrangements for contracting a private developer who will assist the department in planning, designing, constructing, financing, maintaining, and operating projects in the TTC–35 corridor. Without SEP-14, Texas would not be able to use Federal funds on the comprehensive development agreement until after the environmental process is complete. According to Garcia, the agreement sets the general framework between TxDOT and the developer. The agency and the developer will produce a master development and financial plan that will outline the phasing, planning, and construction of TTC–35.

"Because of the size and scope of the project, we need to develop a strategy or master plan of how to go about implementing it, subject to environmental clearance," Garcia says.

Although the agreement permits TxDOT to develop the master plan concurrently with federally required environmental studies of the corridor area, Garcia emphasizes that the agreement does not circumvent or shortcut the environmental review process. The developer has no influence in route selection and cannot begin construction until the environmental review process is complete and FHWA has approved a route. The comprehensive development agreement does, however, allow the developer to provide support services to the National Environmental Policy Act (NEPA) process.

The benefit of the agreement is having a development plan ready once environmental work and route selection are complete, instead of waiting until the environmental process is finished to start planning, which may add years to the corridor's overall development process. "We're looking to save time on a process that can be quite lengthy," Garcia says.

Construction of the proposed Oklahoma-to-Mexico section of the Trans-Texas Corridor would ease congestion on nearby Interstate 35, including this heavily traveled section in Austin shown here with a high volume of traffic in each lane.

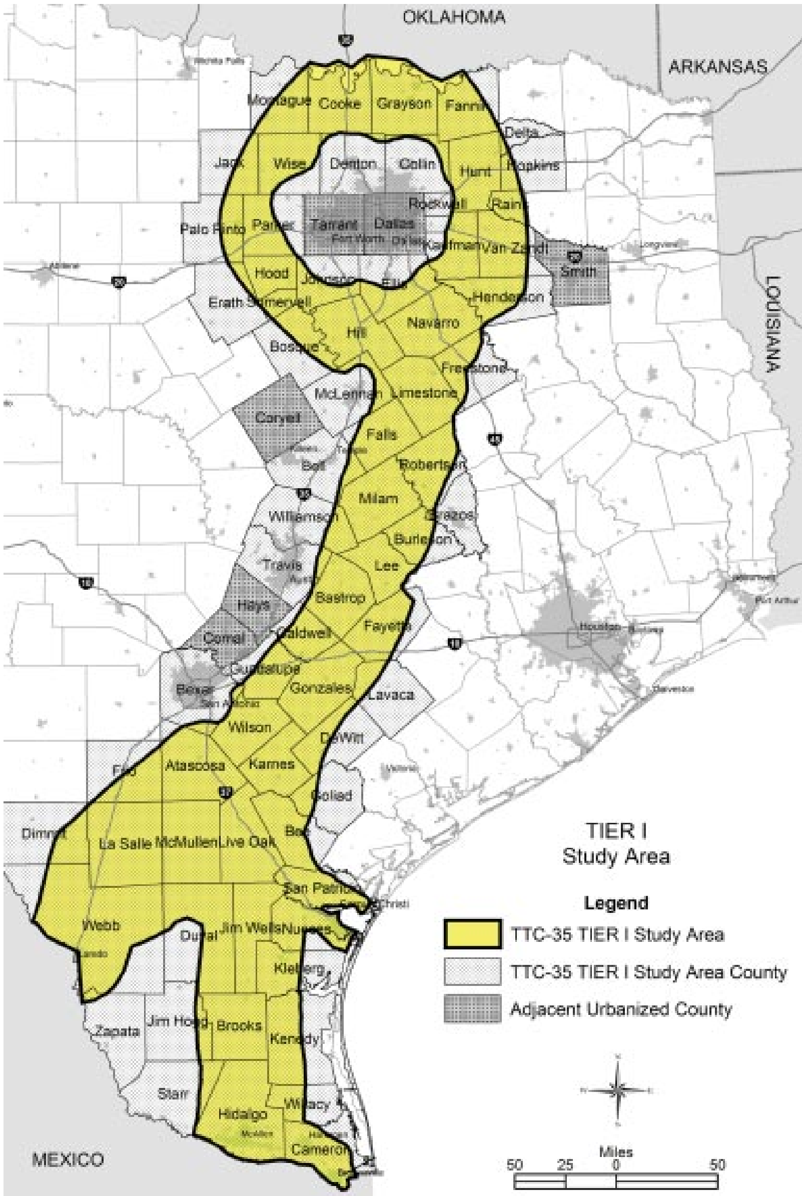
Planning the Oklahoma-to-Mexico Corridor

After soliciting proposals from private consortia on how to develop the TTC–35 section of the corridor, in December 2004, the Texas Transportation Commission chose a $7.2 billion proposal from an international group of engineering, construction, and financial firms. An evaluation, review, and selection committee of TxDOT staff recommended the proposal, one of three submitted for developing the TTC–35 corridor, as the best long-term value for the State.

The selected proposal contains plans to invest $6 billion in developing a number of projects between Dallas and San Antonio and to contribute $1.2 billion to the State for additional transportation improvements between Oklahoma and Mexico, in return for the right to operate and maintain the system and collect tolls for 50 years. Although the developer may perform the proposed projects itself, TxDOT retains the right and expects to develop projects for the corridor by traditional means outside of the agreement with the developer.

"This is a historic change in the way major transportation assets are built and paid for in Texas," says Ric Williamson, chairman of the Texas Transportation Commission. "Private investment, not taxpayer dollars, will be where we look first for funding."

The first phase of the 50-year proposal calls for developing $6 billion in new roadways roughly paralleling I–35 to ease congestion on that route. This includes building 509 kilometers (316 miles) of new



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The map shows the Tier 1 study area (highlighted in yellow) for the section of the Trans-Texas Corridor that runs south from Oklahoma to Mexico and the Gulf Coast, roughly paralleling Interstate 35.

four-lane divided highway from Dallas to San Antonio.

The proposal also includes funding options for a route connecting southeast San Antonio to State Highway 130 and for relocating the existing Union Pacific Railroad between San Antonio and Austin.

Future projects include separate lanes for cars and trucks on State Highway 130, a congestion-relief route around the west side of Fort Worth, a TTC–35 route from San Antonio to the Rio Grande Valley, and rail between Dallas and San Antonio.

TxDOT plans to use a public-private arrangement to develop the I–69 portion of the corridor as well. “The private sector is willing and able to invest in transportation improvements to reduce congestion, improve safety, provide economic development, and protect our quality of life,” says Williamson.

Two-Tiered Environmental Process

The Trans-Texas Corridor project is being developed using a tiered EIS process, which streamlines documentation for extraordinarily large projects required under NEPA. NEPA directs Federal agencies, when planning projects or issuing permits, to conduct environmental reviews to consider the potential impacts of their proposed actions on the environment.

The tiered process involves breaking up a complex study into a series of steps or tiers to address broad issues first and consider more detailed, location-specific issues in subsequent steps.

The environmental studies on the two Trans-Texas Corridor sections now under consideration include two tiers. Tier 1 consists of an EIS for each corridor to consider broad issues, such as general location and areawide air quality and land use issues, while Tier 2 will consist of a series of studies addressing site-specific details on project impacts, costs, and mitigation efforts.

Tier 1 for TTC–35 began in early 2004 with the preparation of a corridor study report that assessed an area 32 to 160 kilometers (20 to 100 miles) wide to reduce it to 6 to 16 kilometers (4 to 10 miles) wide. A final route for the corridor will not be selected at this phase. The purpose of the Tier 1 EIS is to help agencies make a decision between alternatives with significant impacts. A no-build option could be identified at any time in the process or if the environmental impacts were so severe that it would not be a prudent decision to move forward with the project, even though there might be a need.

When the team identifies a preferred corridor, a second tier consisting of numerous environmental studies will help determine alignments for specific facilities, such as rail lines and lanes for trucks and vehicles. Tier 2 studies will begin only if the team rejects the no-action alternative in the Tier 1 EIS. It may take decades to complete the Tier 2 studies for all the individual projects that comprise the TTC–35 corridor.

TxDOT officials hope to identify sections of the final routes for the two proposed corridors sometime between 2007 and 2010. Once all required Federal studies are completed and the Tier 1 EIS has identified a final alignment for the proposed corridor, Tier 2 studies will be prepared before construction of projects selected by TxDOT and the developer can begin.

TxDOT

When the Trans-Texas Corridor is completed in about 50 years, it will include up to six rail lines for high-speed passenger rail between cities, high-speed freight, and conventional commuter and freight transit. This freight train traveling on an existing rail line in rural Texas might reach its destination faster upon completion of the corridor.

"The two-tiered process is designed to allow us to make decisions at appropriate times," says Sandra Allen, I–69 environmental manager for FHWA. "It allows us to work in stages. If we were to try to do a [1,610-kilometer] 1,000-mile project using the standard NEPA process, it would be much harder to reach a decision."

The environmental review for TTC–35 covers an area about 1,290 kilometers (800 miles) long and 80 to 96 kilometers (50 to 60 miles) wide and includes 77 counties. Expected to be complete by spring 2006, the Tier 1 EIS will result in a preferred corridor about 16 kilometers (10 miles) wide or a no-build alternative.

The initial environmental study for I–69/TTC covers an area about [1,600 kilometers] 1,000 miles long and includes 46 counties in Texas and 2 parishes in Louisiana. Planned for completion in the winter of 2006, the study will result in a preferred corridor about 6.5 kilometers (4 miles) wide or a no-action option.

As part of the environmental study process, TxDOT is conducting a series of public meetings to solicit input on the two corridors. The meetings, more than 100 of which have been held so far, enable interested citizens and organizations to review preliminary corridor alternatives, ask questions, and submit official comments for the record.

Streamlining the Environmental Review

Because projects on the scale of the Trans-Texas Corridor take years to complete, involve many stakeholders, and cost billions of dollars, ensuring that the process is efficient and effective is very important. As directed by Section 1309 of the Transportation Equity Act for the 21st Century, FHWA is committed to using environmental streamlining to ensure timely delivery of transportation projects while protecting the environment.

Environmental streamlining requires transportation and environmental resource agencies to establish realistic timeframes to develop projects, and then work together to adhere to those timeframes. A key element of environmental streamlining is communicating with and gathering input from the public and other stakeholders.

To facilitate environmental streamlining on the I–69 project, TxDOT and FHWA created an I–69/TTC steering committee, which includes executives from the Federal and State transportation and resource agencies involved in the project. The project team also formed a technical advisory committee involving TxDOT, FHWA, State and Federal resource agencies, and metropolitan planning organizations affected by the project.

An important function of the technical advisory committee is to review project deliverables, such as required environmental documentation, at key points in the project and make recommendations to the steering committee.

"Gaining input from all participating agencies during the early stages of the project development and NEPA documentation processes will save time and eliminate the need to revisit certain issues at later stages," says FHWA's Allen.

The technical advisory and steering committees began meeting in late 2001 to formulate an overall approach. In October 2003, after months of work, the committees approved a key to streamlining the I–69/TTC project, the *I–69/Trans-Texas NEPA and Project Development Process Manual*.

The manual, which is undergoing periodic adjustments as the project proceeds, provides guidance for each step of the project development process, including how to manage working relationships effectively between many agencies. It is modeled after the *Mid-Atlantic Transportation and Environmental Streamlining Process—A Framework for Change in the 21st Century*, a guide developed in 2000 by Federal and State transportation and environmental agencies in the Mid-Atlantic Region.

Trucks, such as these lined up in Laredo, carry much of the growing freight traffic through the Lone Star State and would have the option of a corridor all their own.

TxDOT

A Closer Look at the Tiered Environmental Process

The Trans-Texas Corridor project uses a tiered environmental review process to facilitate transportation decisions that are functionally and environmentally sound, in a timely and cost-effective manner. The process involves two tiers and four stages covering 14 steps, 6 of which are concurrence points when decisions are made on whether to move to the next step in the process.

The Tier 1 process involves identifying a corridor that will accommodate all of the proposed modes, including highway lanes for automobiles and trucks, multiple rail lines, and major utilities. Tier 2 studies will address environmental impacts and design details for specific segments of the corridor.

Each stage represents a narrowing of the range of alternatives or areas to be studied and an increase in the level of detail. Each step represents the completion of a series of tasks by the various agencies involved in developing the project.

Six of the steps will conclude with a recommendation from the technical advisory committee, followed by approval from the steering committee and FHWA. These concurrence points represent the critical decision points in the project development process.

The I–69/TTC manual emphasizes that collaboration will not infringe on any agency's individual jurisdictional responsibilities, and clarifies that the process requires flexibility and will evolve as the project moves forward.

Decisionmaking Framework

To meet the streamlining goal, the I–69/TTC process manual contains a framework for making decisions, addressing organizational structure, providing evaluation methodology and processes, resolving conflicts, and developing an EIS.

The section on organizational structure explains the roles and responsibilities of the steering committee, which provides policy-level oversight, and the technical advisory committee, which is involved in the technical aspects of the review process.

The technical advisory committee reviews the information available at each concurrence, or decision point, and develops a written recommendation on whether to advance the project to the next stage. The steering committee reviews the recommendation and either approves it or returns it to the technical advisory committee for reconsideration. FHWA, as the lead Federal agency involved in the project, makes the final decision on proceeding to the next step in the development process.

The decisionmaking process section provides an overview of concurrence points, which include the purpose and need for the project, evaluation criteria that will be used, and an analysis of corridor alternatives. The section also explains the type of written statement that members of the technical advisory committee should provide if they do not concur with a committee recommendation, such as stating that a recommendation appears to conflict with the regulations or policies of a participating agency.

Finally, the section on conflict resolution describes procedures to follow if the steering or technical advisory committees cannot develop a consensus. The chair of the technical advisory committee, for example, can appoint a working group to try to reach a resolution on an issue and report back to the full committee. If the working group is unable to resolve an issue, the steering committee can assign its own working group to study the problem and make a recommendation, or it can redefine the problem and send it back to the

The I–69/TTC section of the Trans-Texas Corridor, highlighted in yellow on this map of the southeastern segment of Texas, incorporates part of the planned Interstate 69 that will connect Mexico, the United States, and Canada.

TxDOT

Seventy-nine percent of U.S.-Mexico trade passes through Texas ports of entry, contributing to congestion on the State's highways. Here, trucks are backed up at a border crossing.

TxDOT

technical advisory committee for reconsideration.

The process manual also provides specific instructions for developing a tiered EIS. The process is broken down into stages, and for each stage a detailed flowchart outlines all of that stage's requirements. Each stage is broken into smaller steps, and for each step a user-friendly table denotes each agency's responsibilities at that step.

As outlined in the process manual, the team will use technological tools in Tier 1 of the environmental streamlining process for I–69/TTC. One tool is the Geographic Information System Screening Tool (GISST), which the U.S. Environmental Protection Agency developed to identify and rate priority areas according to their degree of environmental concern.

The technical advisory committee will combine the functionalities of the GISST with the Texas Ecological Assessment Protocol—a tool that evaluates natural resources by diversity, rarity, and sustainability to identify the most ecologically important areas across Texas—and geographic information system (GIS) software to develop a map of a preferred corridor that avoids substantial environmental impacts.

"Using all of these tools enables us to identify and avoid [negative impacts on] important resources as we develop a corridor-level map," Allen says.

The benefits of using the manual in the environmental streamlining process, she says, are that it encourages early involvement by stakeholder agencies, helps build interagency relationships, and ensures that all participants are committed to working together to review and concur on key decision points.

Another advantage, particularly on a long-term project like I–69/TTC, is that future participants will be able to review and refer to key decision points. "Everything is documented, so when new agency staff people come onboard, we don't have to revisit old decisions," Allen adds.

Although the I–69/TTC project is still in the early stages, the team expects the manual to help save both time and money over the long term. A similar manual will be used in developing the TTC–35 project.

Nationwide Interest

Several aspects of the Trans-Texas Corridor make this megaproject unique: size and scope; 50-year outlook; multiuse corridor concept with zones for cars, trucks, trains, and utilities; public-private partnerships to finance project elements with investors' dollars; and the tiered environmental review process to narrow down corridor options for future development.

As a result, the project is generating a good bit of interest outside of Texas. In particular, the project has attracted the attention of other States faced with similar challenges of traffic congestion, population growth, and limited budgets for developing new transportation infrastructure.

"We're getting requests for presentations on how we're developing this project from DOTs that might want to put some of these concepts into practice in their own States," Garcia says.

By building on and sharing its successful practices and lessons learned, the Lone Star State is leading the way in planning major transportation projects of this type.

Antonio Palacios, an engineer in FHWA's Texas Division, oversees development of the TTC–35 element of the Trans-Texas Corridor for FHWA, including the procurement process for selecting the developer and management of the environmental review processes. Palacios has been with FHWA since 1974, working in engineering positions in Pennsylvania, Texas, and West Virginia. He has a bachelor's degree in civil engineering from the University of Texas at El Paso.

For more information, visit www.keeptexasmoving.com. To learn more about environmental streamlining, visit http://environment.fhwa.dot.gov/strmlng/index.asp.

Multistate Endeavor to Address Premature Pavement Distress

by Jim Grove,
Mark Anderson-Wilk, and
Marcia L. Brink

Iowa is leading an effort aimed at increasing the long-term performance and durability of concrete roadways.

Concrete research often is conducted using mixes developed in a lab. When road crews mix concrete on a paving project in the field, however, the amount of mixture is much larger in quantity, and weather and other conditions are less controllable. As part of a study called Material and Construction Optimization for Prevention of Premature Pavement Distress in PCC Pavements (MCO), researchers are determining which conditions affect the quality of these new concrete mixtures.

"In some of the States, we heard concerns about the quality of concrete, and we found that part of the issue was the fact that materials were changing," says Gordon Smith, president of the Iowa Concrete Paving Association. "For example, we have admixtures that we didn't use 30 years ago. Then we used portland cement only, whereas today we may use portland cement, fly ash, and ground, granulated blast-furnace slag. Instead of just having one cementitious material, there may be three. As we mix these changing materials today, we are finding that some of the things we used to do in the past do not always work now. The industry needs to have a better understanding [about] how those materials work together."

To identify possible solutions to common problems like this, in 2003 the Federal Highway Administration (FHWA), Iowa State University, and other partners launched a 5-year pooled fund study known as the MCO project. In the study, researchers are evaluating conventional and new technologies and procedures to help State departments of transportation (DOTs) prevent premature distress in concrete pavements. Ultimately, the research will lead to the development of a suite of tests that will enhance the long-term performance of concrete pavements.

Pooling Resources

Federal, State, regional, and local transportation agencies, academic institutions, foundations, and/or private firms jointly fund studies through the Transportation Pooled Fund Program, with the focus of the research on solving problems of widespread interest within the transportation community.

Researchers and Missouri Department of Transportation personnel work together outside the Mobile Concrete Research Lab to cast specimens for testing the development of maturity curves and strength gain from age. *Photo: Jim Grove, Iowa State University.*

The Midwest Concrete Consortium (MC^2), a group of Midwestern States that has been gathering biannually for the last 8 years to share experiences and concerns about concrete and concrete pavements, initiated the MCO study through the Transportation Pooled Fund Program. The States in MC^2 decided to work together through a pooled fund study to improve the group's collective understanding of the materials its members were using in concrete mixes, and the consortium then recruited additional States and partners to join the effort.

FHWA, 17 State DOTs, the American Concrete Pavement Association (ACPA), and State and regional concrete paving associations are sponsoring the MCO study. The Iowa DOT serves as the lead State for the project, and the Center for Portland Cement Concrete Pavement Technology (PCC Center) at Iowa State University is responsible for management and execution.

The study consists of three phases. In Phase 1, now complete, researchers collected data, developed testing procedures, and implemented pilot projects. In Phase 2, now underway, researchers are further developing the test procedures and conducting field demonstration projects. An additional aspect of this phase involves dispatching teams of engineers to help States evaluate problems that arise on concrete paving projects. During Phase 3, expected to begin in 2006, the researchers will focus on technology transfer and help States implement successful testing programs. The MCO project will wrap up in 2008.

"There's a tremendous value in doing this type of research through a pooled fund because you've got a group of interested investors at the very beginning of the project," says Smith. "And if we're coming up with answers about how to do something better, I truly believe that those States and contractors involved in the study will respond more quickly to lessons learned than if we'd tried to tell the story later. There's real ownership."

Focusing on Durability

The realization that pavements need to be durable rather than simply strong is partially responsible for a change in how projects are contracted, and the MCO study will likely advance this trend.

In the past, concrete pavement specifications usually were based on the strength and thickness of the pavement. But today that is not enough. "You can make a concrete that is strong but not durable," says Shannon Sweitzer, P.E., State roadway construction engineer at the North Carolina Department of Transportation (NCDOT). "For instance, if you don't have the appropriate air entrainment, the concrete doesn't have an air void structure that will resist freezing and thawing cycles. Therefore, the concrete pavement will likely deteriorate, and you'll be replacing it in a short period of time."

New and improved procedures for evaluating the durability of a concrete mixture will help. "We'll be able to shift emphasis from prescriptive specifications to performance-based specifications," says Seamus Freyne, Ph.D., a civil engineer at the Oklahoma Department of Transportation (ODOT) and an adjunct professor at the University of Oklahoma.

"The method specifications that we've lived by for years and years were developed when there wasn't a lot of variation in sources or types of materials," adds the Iowa Concrete Paving Association's Smith. Those specifications required the contractor to produce concrete by mixing specified materials in definite proportions with predetermined types of equipment and placing methods.

"But the method specifications didn't address the fact that some of those materials might react differently when combined as a concrete mix," he continues. "What we're really trying to do with the MCO study is to look at the holistic aspect of concrete by determining what materials work best together."

This may be particularly important for contractors who increasingly are asked to expand their roles in paving projects. "There's a shift in philosophy today that makes the contractor more responsible for the quality of the material," Smith says. "While contractors today are still being required to meet specifications by mixing certain ingredients and following certain procedures, they also are being encouraged to assure that the pavement works and performs to expectation when the project is complete. And this study will help to reduce the risk to contractors by helping them to better understand how these materials work together."

Mobile Concrete Research Lab

In 1988, FHWA first used the concept of a mobile concrete laboratory to demonstrate new concrete technologies to personnel in field offices

Jim Grove, Iowa State University

Participants in the Midwest Concrete Consortium, the group that initiated the MCO pooled fund study, met in Detroit, MI, and are shown here touring the Mobile Concrete Research Lab on September 21, 2004.

Mobile Labs

In 1988 FHWA introduced its first Mobile Concrete Laboratory. Technicians traveled across the country helping States test their pavements. According to lab technicians, the first FHWA mobile lab served the agency's needs well, but the extensive travel caused sufficient wear and tear that it eventually had to be replaced. The original lab now serves as a stationary facility at the FHWA Turner-Fairbank Highway Research Center.

FHWA's Mobile Concrete Laboratory is shown parked along the shoulder of the I–90 project in Wisconsin in 2002.

In the early 1990s, FHWA created its second, larger mobile concrete lab, measuring 15 meters (48 feet) long. With several years of experience under its belt, FHWA designed the second lab with improved functionalities. The newer lab is large enough to serve as a small classroom on wheels, traversing the country to introduce Federal, State, and local transportation personnel to state-of-the-art concrete materials and technologies and to conduct field and laboratory testing. Lab technicians continue to update the facility as new technologies become available.

FHWA's Mobile Concrete Laboratory has three main goals: to advance technologies and procedures for long-life pavements, to conduct nondestructive testing, and to assist States with implementing the *Mechanistic-Empirical Pavement Design Guide*, developed through the National Cooperative Highway Research Program. (For more information about the guide, see "Designing Tomorrow's Pavements" in the September/October 2004 issue of PUBLIC ROADS.)

The lab accomplishes these goals by visiting concrete pavement laboratories and project sites and conducting technical demonstrations. "We tailor what we do for each State depending on what it needs," says Suneel Vanikar, concrete team leader at FHWA. "This may include training on equipment or software. Sometimes we conduct training seminars not on the site of the trailer but in a DOT building." The FHWA lab also loans equipment to States and contractors so they can try the equipment before purchasing it.

"We help industry associations and contractors by showing them the latest advances in testing," Vanikar says. "Contractors play a key role because ultimately they implement a lot of these new technologies."

The notion of having a mobile lab is catching on within the States. Missouri, for example, recently created its own lab, albeit smaller than the FHWA prototype at 5 meters (16 feet) long. "It's a mushroom compared to FHWA's trailer," says Patty Lemongelli, director of research, development, and technology at the Missouri Department of Transportation (MoDOT).

According to Lemongelli, necessity was the mother of invention for MoDOT's lab. "We found ourselves out in the middle of nowhere, as we often do with field testing, and we needed to shuttle specimens to the nearest testing facility," she says. "It was extremely inconvenient, and also dangerous to the specimens to transport them at such early ages."

This mobile concrete lab owned by MoDOT was previously an equipment-hauling trailer. The lab provides a convenient way to conduct maturity testing and other research-related activities in the field. *Photo: MoDOT.*

In response to this need, a couple of resourceful technicians at MoDOT proposed converting an equipment-hauling trailer into a mobile lab. The idea worked, and today the lab provides a convenient way for MoDOT technicians to conduct maturity testing and other research-related activities in the field. The lab includes a secondhand compressive strength machine, equipment for testing slump and air content, and a computer. MoDOT also recently modified the lab to accommodate air void analysis in the field.

"Our lab isn't as sophisticated as FHWA's mobile lab, but it's dependable and functional," Lemongelli says. "Given the minimal resources put into it, it's a great addition to our research capabilities."

and working on projects in North Carolina, Virginia, and Iowa. Using FHWA's Mobile Concrete Laboratory for technology transfers, demonstrations, and testing proved to be very successful over the years. And as technologies changed, the lab conducted additional visits to States, including a site visit to the I–26 project in Ashville, NC, in July 2002.

A mobile lab has been a key component of the MCO project as well. Sponsors from the concrete industry purchased a mobile research laboratory and donated it to Iowa State University to support the MCO study. Because part of the study includes conducting field tests to assess strength and durability, Iowa State University's Mobile Concrete Research Lab (Iowa Mobile CRL) was specifically designed for the study. The research team modeled the Iowa Mobile CRL's features and

Jim Grove, Iowa State University

This photo of the interior of Iowa's Mobile Concrete Research Lab shows the work space and some of the testing equipment.

capabilities after FHWA's Mobile Concrete Laboratory.

Not as large as FHWA's model, the 13-meter (44-foot)-long Iowa Mobile CRL was tailored to meet the specific needs of the study team and to be as small as possible for facilitating easy access to field sites. In addition, the Iowa Mobile CRL is not outfitted for mixing concrete because the team's focus is on sampling materials at construction sites.

Researchers using the Iowa Mobile CRL can perform a comprehensive suite of tests. One of the key pieces of equipment is the air void analyzer (AVA), an important technology that measures the volume, size, and distribution of air voids in concrete in the field.

According to Smith, several pavements built in Iowa in the late 1980s and early 1990s started to deteriorate prematurely, within 5 years. "We would not have expected that kind of deterioration for 20 or 30 years," he says. "After much analysis and significant research, we found that the common flaw in all of those pavements was that the air system in the concrete was not of good quality. We found that even if the pavements included enough air content, the distribution, sizing, and spacing of air bubbles was inadequate for a concrete mix that would resist freeze/thaw cycles."

The AVA is a sensitive machine that researchers historically considered accurate only when installed in buildings, thus limiting its use in field situations. Because vibrations, such as those caused by wind, can dramatically skew the results, the trailer containing the Iowa Mobile CRL was designed with a portal in the floor to accommodate the AVA equipment. When the Mobile CRL is parked, the base of the AVA rests on the ground through the hole and is surrounded by a weather shield so it is protected but not touching the trailer.

"The AVA enables us to look at the concrete in its plastic state, while we're building the pavement," Smith says. "We can determine whether there is good sizing and spacing of air bubbles in the mix. Although it isn't going to help with the concrete we put down 3 hours ago, the AVA test, which takes about an hour, enables the contractor to respond with changes in the mix so he doesn't build a whole mile of pavement with a poor air void system. It's almost a real-time analysis of the concrete mixture."

In addition to the AVA, the Iowa Mobile CRL includes a variety of other testing equipment, including a weather station, a wireless computer with global positioning system (GPS) and data analysis software, various sieves to determine coarse and fine aggregate gradations, a microwave oven to determine water-to-cement ratios, a penetrometer to test the setting time for mortar, a core drill and concrete saw, a curing tank, and calorimeters to determine the heat signature of mortar and concrete. The Iowa Mobile CRL also features a 113,400-kilogram (250,000-pound)-capacity compression tester to measure compressive and flexural strength development.

Jim Grove, Iowa State University

These researchers are using a drill to obtain core samples on a concrete test road. The core drill is one of many pieces of testing equipment available in Iowa's Mobile CRL. The truck that tows the lab also provides water for the drilling process, as shown here.

Technology Transfer

Technology transfer has been a key component of the project from the beginning. "With so many States involved, everybody is bringing something different to the table and sharing experiences," says NCDOT's Sweitzer.

During Phase 1, the team gathered data on State research related to concrete mix properties and paving practices, and compiled a detailed inventory of technologies and procedures for mix design, materials control, concrete testing, and field control. The team also obtained details on past projects that exhibited some form of early pavement deterioration. From this data, the researchers can better understand and assess the causes of pavement distress to ensure that proposed testing will address real-world problems.

Fulfilling an additional aspect of the project, the Mobile CRL visited each of the participating States at least once. In North Carolina, for example, researchers from the Iowa Mobile CRL demonstrated the suite of tests and applied them to two projects currently underway. "We actually got to see the tests being performed," says Sweitzer, "which was an excellent technology transfer opportunity for our construction engineers and technicians who are involved in the placement of concrete on a routine basis."

According to Sweitzer, North Carolina found that the AVA, microwave water/cement ratio, maturity, and unit weight tests were the most useful procedures performed onsite. As a result of the site visit, North Carolina now implements maturity testing in its specifications and will be evaluating the AVA, unit weight, and microwave water/cement ratio tests on several projects during the 2005 construction season.

The Iowa Mobile CRL also visited Wisconsin for 2 weeks and happened to be in the right place at the right time on one project. One morning the researchers were traveling along the previous day's paving when they saw a number of vehicles parked beside the new pavement, including a sheriff's car. They were investigating tire tracks in the newly placed concrete. Apparently a vandal in an off-road vehicle had jumped the vertical edge of the new road and driven for about 213 meters (700 feet) on the fresh pavement.

Staff from the Iowa Mobile CRL extracted a number of core samples from both the damaged and undamaged areas, and testing revealed small tears and cracks directly beneath the tire tracks, indicating that removal and replacement of the pavement was warranted.

The Iowa Mobile CRL also visited Missouri to conduct a demonstration project. A heavy storm passed through the area on the first night of the visit, dropping rain at a rate of nearly 11 centimeters (4.5 inches) per hour and providing an opportunity for lab personnel to demonstrate the effectiveness of a device for recording precipitation. Gauging rainfall is important because weather conditions during the first 72 hours of a pavement's life can have a significant impact on its long-term performance. On an actual paving project, MoDOT could analyze the slab's cracking potential by keying the weather information into FHWA's HIPERPAV software, also included among the lab's equipment.

MoDOT recently launched its own scaled-down version of a mobile concrete lab, with equipment to conduct maturity tests and other research-related activities. FHWA officials are pleased to see States taking the initiative to create labs that suit their own needs. "We know that FHWA can't take care of all the work that's out there, so we're encouraged to see that others have

Jim Grove, Iowa State University

The air void analyzer, shown here in Iowa's Mobile CRL, measures the distribution, sizing, and spacing of air bubbles in concrete pavement mixtures.

A New Manual for Designing Concrete Pavements

Through the MCO project and other efforts, researchers are making significant advancements in materials selection, mix design, and construction technologies for concrete pavements. Information about these advancements, however, may not always reach practitioners in a timely manner, so implementation in the field often lags behind.

To fill the need for an updated reference guide, the Center for Portland Cement Concrete Pavement Technology at Iowa State University, under a cooperative agreement with FHWA, is developing a new resource: *Integrating Materials and Construction Practices for Durable Concrete Pavements: A State-of-the-Practice Manual.*

Currently under development, the manual will introduce State and local DOTs, contractors, and consultants, including engineers, quality-control personnel, suppliers, and technicians, to new technologies, tests, and practices for identifying materials, concrete properties, and construction practices that can lead to premature pavement distress. In addition, the reference manual will impart the knowledge and skills necessary to implement new technologies, tests, and practices in the field and help practitioners troubleshoot and prevent problems.

"Experts from across the Nation contributed to writing this manual," says NCDOT's Sweitzer, who reviewed an early draft. "I see the manual as being a very beneficial tool, not just for States in the study, but nationally. It's user friendly, and it will be an excellent tool."

A number of features differentiate the forthcoming manual from existing references. First, it describes concrete pavement construction as an integrated system in which materials selection, mix design, and construction practices all affect one another in multiple ways. The manual provides straightforward, easy-to-understand information about materials' effects on mixture design, construction, and service life, and describes critical mix properties that help predict the overall quality of the final product. Further, the manual compiles information about new technologies, tests, and practices, as well as how and why to implement them.

The manual identifies and solves mixture problems at the design phase and at time of production, identifies when and how to adjust the mixture according to weather and other factors, and uses testing and performance prediction technologies and procedures to address problems with concrete pavements.

Information gathered through the MCO project represents the core content of the manual, including current standards and best practices from participating States and laboratory evaluations of materials- and construction-related tests.

The team developing the manual expects to complete a preliminary draft in time for the 8th International Conference on Concrete Pavements in August 2005 at Colorado Springs, CO. At the conclusion of the pooled fund study, the team will update the manual to include final results from the project, and the document will be incorporated into a new, state-of-the-practice publication covering all aspects of concrete pavement design and construction.

been inspired to take it to the next level," says FHWA's Vanikar.

The research team also is formalizing technology transfer through, among other activities, creating a state-of-the-practice manual.

The Future of Concrete

NCDOT's Sweitzer and the others expect that the findings from the MCO study are likely to change the way States mix and construct concrete pavements. "I envision [NCDOT] taking the results of this study and actually implementing them in our specifications for concrete pavement," he says. "So instead of just performing tests to evaluate strength and thickness, there may be additional tests we'll need to conduct to evaluate durability. I think it's really going to enable us to evaluate our pavements in a smarter fashion so that we end up with a higher quality product."

The MCO team plans to visit more States in the coming years, and some States are already well on their way toward incorporating new tests into their pavement designs. Oklahoma, for example, has purchased new equipment to improve the durability of concrete overlays on its bridges. "Through this study we've learned about a couple of new tests, including the bond or pull-off method and the air void analyzer," says ODOT's Freyne. "With the bond test, we can assess the quality of the existing concrete bridge deck prior to an overlay, and [then later evaluate] the bond between the new and old concrete after the overlay."

In the end, the study team expects the MCO project to result in more durable concrete pavements across the country.

Jim Grove, P.E., is a paving engineer at the PCC Center at Iowa State University and leads the pooled fund study for the MCO project. His experience includes serving as the PCC paving field engineer in the Iowa DOT Office of Construction and the PCC engineer in the Iowa DOT Office of Materials. Grove is a member and past chairman of the Transportation Research Board Committee on Portland Cement Concrete Pavement Construction. He has an M.S. in transportation engineering and a B.S. in civil engineering, both from Iowa State University.

Mark Anderson-Wilk is an editor for the PCC Center at Iowa State University. He leads development of the PCC Center's research and technology transfer publications. Anderson-Wilk has a master's degree in English from the University of Minnesota.

Marcia L. Brink is the communications manager for Iowa State University's Center for Transportation Research and Education, administrative home of the PCC Center and the U.S. Department of Transportation's University Transportation Centers Program serving Iowa, Kansas, Missouri, and Nebraska. Brink has a master's degree in English from Iowa State University.

For more information about the MCO project, visit www.pcccenter.iastate.edu/mco/index.htm or contact Jim Grove at 515-294-5988, jimgrove@iastate.edu. For information about Iowa's Mobile Concrete Research Lab, contact PCC Research Engineer Bob Steffes at Iowa State University at 515-294-7323, steffesr@iastate.edu.

Looking to Load and Resistance Factor Rating

by Becky Jaramilla and Sharon Huo

The LRFR process aims to improve the reliability of bridges and increase public safety.

On December 15, 1967, the Silver Bridge, carrying U.S. 35 between Point Pleasant, WV, and Gallipolis, OH, collapsed, killing 46 people and injuring 9 when 31 of the 37 vehicles on the bridge either fell into the Ohio River or onto its shoreline. Investigations later revealed that a cracked eyebar created undue stress on the other bridge members, leading to the collapse.

The incident prompted national concern about bridge conditions and led to the establishment of the National Bridge Inspection Standards (NBIS) in the early 1970s. Since then, the Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO), and others have worked to improve standards for maintaining and inspecting existing bridges. The latest major effort in this area is the development of the load and resistance factor rating (LRFR) method. In 2001 AASHTO adopted a new *Guide Manual for Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges*. The guide manual reflects the most current technologies and builds on the structural reliability approach inherent in specifications for load and resistance factor design (LRFD).

(Above) These inspectors are using a truck-mounted boom to collect data needed to determine the bridge's load carrying capacity. *Photo: Tennessee Department of Transportation (TDOT).*

All States are working to implement LRFD fully by October 2007, as decided by AASHTO and agreed upon by FHWA. As States adopt LRFD across the country, bridge professionals are recognizing the need for a methodology for rating the load carrying capacity of existing bridges that is consistent with the load and resistance factor philosophy. Although the LRFD specifications focus on the design of bridges, LRFR takes a parallel track aimed at determining the load ratings for inservice bridges.

LRFD and LRFR introduce the United States to an innovative philosophy that is consistent with major bridge design codes in Asia, Canada, and Europe. Based on factors calibrated from structural load and resistance statistics, the LRFD specifications ensure a more uniform level of public safety and reliability in newly designed bridges. Ultimately, bridge engineers expect that the LRFD/LRFR approach will help reduce maintenance and repair, avoid costly overconservative designs and ratings, and result in a more uniform level of public safety on bridges in the United States.

Overview of Load Rating

Bridge design and load rating are similar in overall approach; however, they differ in one crucial aspect. In design, engineers contend with greater uncertainty in the amount of loading the structure will experience over its service life. With load rating for an existing structure, on the other hand, bridge engineers face uncertainty in the amount of structural resistance.

In general, load rating involves determining the safe carrying capacity. Bridge owners perform three types of load rating: design, legal, and permit. Design and legal load rating involve the analysis of routine loads that are within the legal limits. Permit load rating is the analysis of specific vehicles that carry loads that are heavier than the legal limit.

Bridge owners perform load ratings for three main reasons:

1. Modern bridges generally are constructed to last at least 50 years, and some even longer. Even with proper maintenance, however, the condition of a bridge inevitably will deteriorate to some extent over its lifetime. This deterioration could lead to a reduction in the strength or load carrying capacity of the bridge. To ensure that all public bridges remain safe under current traffic loads, load-rating analyses must be performed when bridge conditions deteriorate. According to the NBIS, owners need to collect condition data for all public bridges on a 24-month cycle.

2. Bridges in the current inventory were designed using a variety of configurations for live truckloads, depending on the design specifications at the time the bridge was built. As design and rating specifications evolve, new knowledge of actual loading, behavior, and resistance are incorporated. Therefore, regardless of the design methods used, all bridges should be load rated using current traffic conditions and the latest standards, whenever practicable, to ensure the safety of the motoring public.

3. Lastly, a permit load rating is necessary for vehicles carrying loads over the legal limit. Due to increasing demands on the trucking industry, the volume of requests for permit load ratings continues to rise, according to the Bureau of Transportation Statistics. Heavy or frequent permit loads can reduce a bridge's life or cause permanent structural damage if not assessed properly.

Permit load rating calculations resulted in the safe transport of this truck, which exceeded the State's legal load and size limit.

TDOT

TDOT

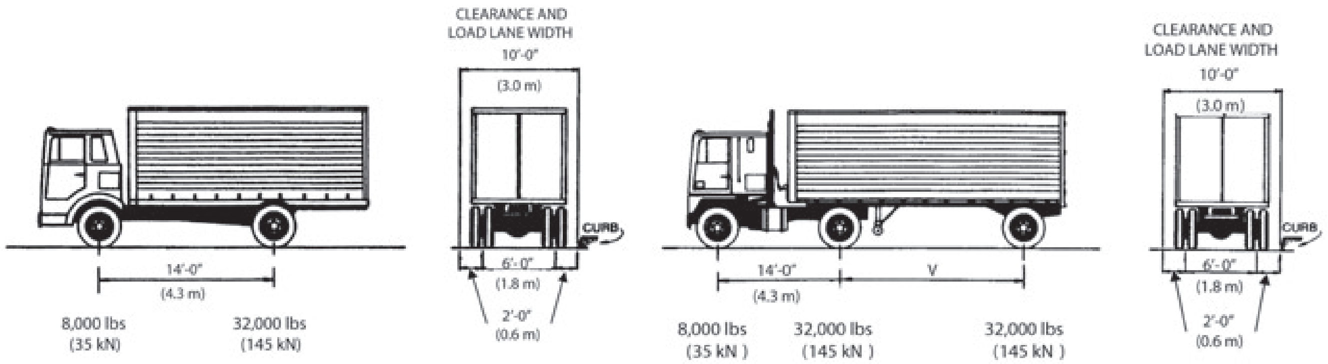
An inspector evaluates the underside of a posted bridge in a rural area. Bridge posting is based on load rating calculations for the structure.

For load rating, results are generally expressed in terms of a rating factor for a particular live load model. Rating factors greater than one indicate that the bridge is safe for the loads tested. Currently there are three methods available for load rating bridges: allowable stress rating, load factor rating, and LRFR.

Historical Background Of Load Rating

In the 1950s and 1960s, construction of the U.S. interstate system and State highway systems was progressing at an extraordinary rate. According to the *Bridge Inspector's Reference Manual* (FHWA-NHI-03-001), approximately 115,000 public bridges in the United States were designed and built between 1961 and 1970. During this time, highway officials placed little emphasis on safety inspections and maintenance of inservice bridges.

After the collapse of the Silver Bridge in West Virginia in 1967, the U.S. Congress responded to the public outcry by directing the secretary of transportation to establish national standards for bridge inspection. In 1971, when the NBIS was created, they only applied to bridges on the Federal-Aid Highway System (generally bridges on any interstate, U.S route, or State route system). Later, in 1980, FHWA extended the standards to cover all public bridges more than 6 meters (20 feet) in length. The NBIS established a national policy on inspection procedures, frequency, personnel qualifications,



These sketches illustrate the AASHTO-approved live loading specifications for standard H20 and HS20 trucks.
Source: AASHTO Standard Specifications for Highway Bridges.

reports, and maintenance of the National Bridge Inventory (NBI).

Three detailed manuals soon were developed to support the NBIS:

- The FHWA *Bridge Inspector's Training Manual,* released in 1970 (now the *Bridge Inspector's Reference Manual)*
- The AASHTO *Manual for Maintenance Inspection of Bridges,* released in 1970
- The FHWA *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges*, released in 1972

The NBIS established directives not only for inspecting bridges but also for evaluating and analyzing the observed condition of bridges. Determination of load capacity or load rating is a key component in the evaluation of condition data gathered during inspections.

Detailed procedures for load rating first appeared in the AASHTO *Manual for Maintenance Inspection of Bridges.* The specifications provided a nationwide, unified approach to load rating. In the late 1980s, however, the bridge community identified a number of shortcomings in the specifications. For example, inspectors arrived at a wide range of results for load ratings on similar bridges. AASHTO officials determined that the disparities were mainly due to variation in interpretation of the load rating specifications.

To improve the procedures, in 1989 AASHTO released the *Guide Specifications for Strength Evaluation of Existing Steel and Concrete Bridges*, providing the first version of the LRFR procedures. By using the safety reliability approach outlined in the guide, engineers found that the load calculation results were more convergent. The guide specification also provided the option of using site-specific traffic information and the structural behavior history of the bridge to arrive at more accurate results. At that time, however, State departments of transportation (DOTs) were still using load factor design or allowable stress design, so adopting LRFR was not an attractive option for many States.

In 1994, AASHTO published the *Manual for Condition Evaluation of Bridges* to replace the *Manual for Maintenance Inspection of Bridges.* Although the new manual contained some guidance for allowable stress rating, it clearly emphasized load factor rating. Because most designers were then using load factor design, the load factor rating method was the logical and preferred system for rating bridges. In addition, FHWA released a 1993 policy memorandum requiring all States to report annual load rating data using the load factor rating method by 1994 for new or repaired bridges and by 1995 for all existing bridges. Therefore, since the early 1990s, load factor rating has been the primary load rating method used across the United States.

The AASHTO Bridge Subcommittee voted to adopt the LRFD specifications for bridge design in 1993. Then in 1998, AASHTO identified LRFD as the primary design specification for highway bridges.

Since that time, many States have fully or partially adopted LRFD as their primary method for designing bridges. With the advancing deadline for implementation of LRFD, AASHTO recognized the growing need to further develop LRFR specifications and update much of the *Manual for Condition Evaluation of Bridges*. In response, AASHTO released the 2003 *Manual for Condition Evaluation and Load Resistance and Factor Rating of Highway Bridges*.

The guide manual represents a major overhaul of the earlier *Manual for Condition Evaluation of Bridges.* All but two of the sections were entirely rewritten. Although the manual emphasizes the LRFR method, it provides rating procedures for both load factor rating and LRFR to allow States the option of rating their existing inventory with either method. The manual includes numerous examples to demonstrate the use of the LRFR method. In addition, customized load factors for overload permit review and new sections on fatigue evaluation and nondestructive testing are among some of the other enhancements. As with the earlier guide specifications, the new manual applies state-of-the-art technology and allows the use of site-specific traffic and structural behavior conditions.

As noted in NCHRP Web Document 28 (Project C12-46): Contractor's Final Report: *Manual for Condition Evaluation and Load Rating of Highway Bridges Using Load and Resistance Factor Philosophy*, the LRFR methods presented in the 2003 manual "contain the necessary ingredients to provide a more rational, a more flexible, and more powerful evaluation strategy for existing bridges."

Load Factor Rating

The load factor rating method rates bridges at two levels: inventory and operating. The *inventory* rating level corresponds to customary design-type loads while reflecting the existing condition of the structure. The *operating* rating level corresponds to the maximum permissible live load the structure can withstand safely. Further, the inventory load rating accommodates live loads that a bridge can carry for an indefinite period, while the operating load rating refers to live loads that could potentially shorten the bridge life if applied on a routine basis.

As stated in the AASHTO *Manual for Condition Evaluation of Bridges*, the general expression used in load factor rating calculations is as follows:

$$RF = \frac{C - A_1 D}{A_2 L(1+I)}$$

In the equation, RF is the rating factor for live-load carrying capacity, C is the capacity of the structural member, D is the dead-load effect on the member, L is the live-load effect on the member, I is the impact factor, A_1 is the factor for dead loads, and A_2 is the factor for live loads. The dead-load factor (A_1) equals 1.3 for all rating levels, and the live-load factor (A_2) equals 2.17 for inventory level and 1.3 for operating level.

Capacity (C) is calculated as outlined in the AASHTO *Standard Specifications for Highway Bridges*. The structural layout and materials determine the capacity. For load rating, capacity depends on the present condition of the structural components. Therefore, engineers need to account for observations such as cracked or deteriorated sections when performing capacity calculations.

In load factor rating calculations, dead loads (D) are permanent loads that do not change as a function of time. Generally, for bridges, dead loads include self weight and any permanent external loads. Live loads are temporary loads that act on a structure. As defined in the AASHTO *Standard Specifications for Highway Bridges*, the design live load is defined as H20/HS20 truck loading or lane loading using the load that produces the largest moment or shear. AASHTO established the H20 and HS20 trucks as standard live-load models to facilitate a simpler analysis based on an approximation of the actual live load; they are not meant to represent actual vehicles. Similarly, standard lane loading provides a simple method for calculating a bridge's response to a series of trucks. Bridge owners also can calculate the distribution of live load to a single structural member as outlined in the AASHTO specifications.

The load factor rating design loads do not adequately represent current loads on the highways and do not provide a uniform safety level for various bridge types and span lengths. Therefore, legal load calculations are commonly used to ensure the structural integrity of public bridges. Three AASHTO legal loads produce controlling moment and shear reactions for the short, medium, and long spans respectively. In addition to AASHTO legal loads, many State DOTs have State-specific legal loads that are used in load rating calculations.

Bridge owners also can check permit loads using load factor rating when they receive requests for overload permits. In permit load rating, the weight and dimensions of the actual truck should be used in place of the AASHTO load models.

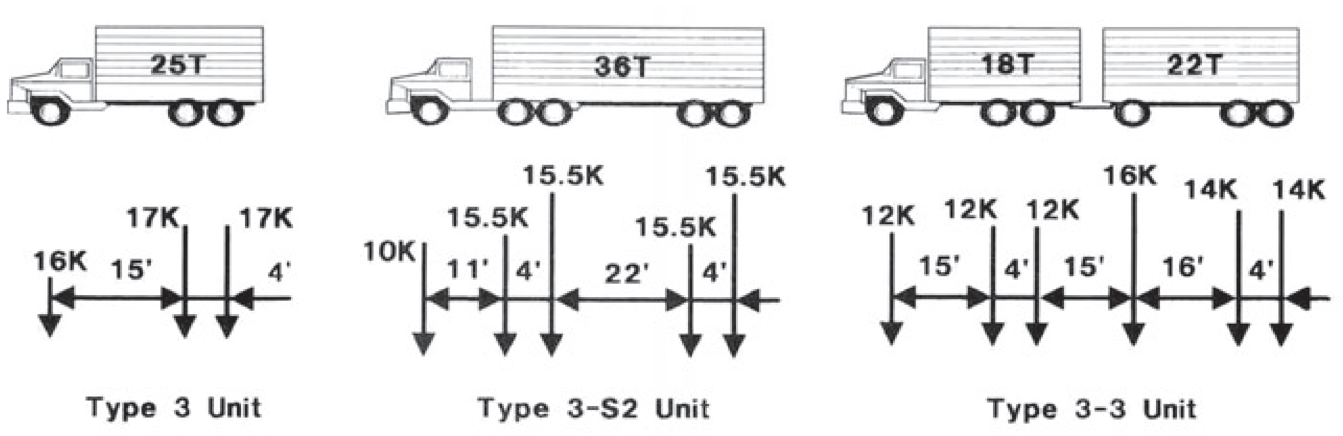
The load factor rating impact factor (I) is added to all live loads to account for the speed, vibration, and momentum of vehicular traffic. The AASHTO specifications for bridge design define the impact factor as follows:

$$I = \frac{50}{L+125} \leq 0.3$$

After determining the rating factor for a structural member, the bridge owner then multiplies the rating factor by the weight of the live load truck to yield the bridge member rating for that member. The overall rating of the bridge is controlled by the structural member with the lowest rating.

Load and Resistance Factor Rating

As with load factor rating, bridge owners can calculate load ratings on both operating and inventory levels using the LRFR method. In addition,



These illustrations show AASHTO legal loads, which control weight limits for short- (Type 3 Unit), medium- (Type 3-S2 Unit), and long- (Type 3-3 Unit) span bridges, respectively. The "T" refers to weight in tons, and "K" refers to weight in kips (1,000 pounds or 907 metric tons).

LRFR uses limit states for strength, service, and fatigue to ensure safety and serviceability in the load rating. These limit states were introduced in the AASHTO LRFD specifications. The *strength* limit state accounts for the strength capacity of the structure under permanent and live loading. The *service* limit state accounts for stress, deformation, and crack width. The *fatigue* limit state accounts for cyclical stress ranges to avoid fatigue cracking. Strength is the principal limit state and, therefore, is the main determinant for bridge posting, closing, and repair. Both service and fatigue limit states can be applied selectively to bridges.

As stated in the AASHTO *Manual for Condition Evaluation of Bridges*, the basic LRFR equations are as follows:

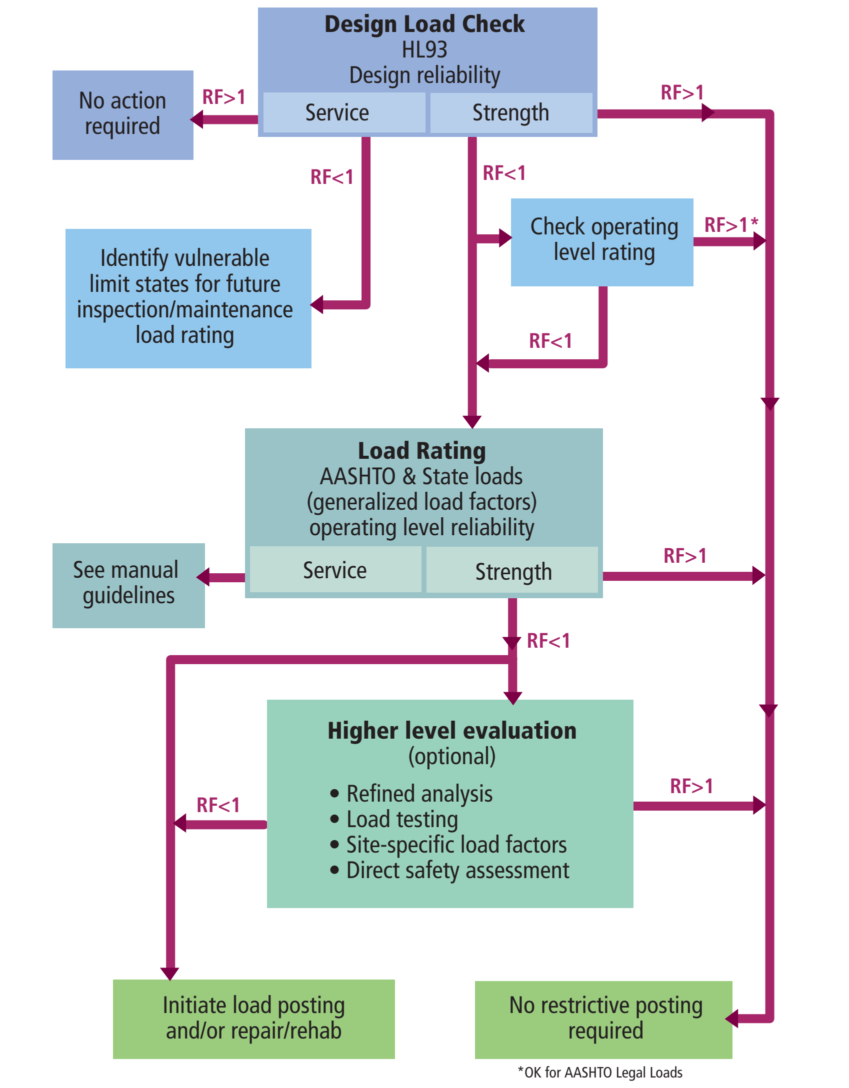
$$RF = \frac{C - \gamma_{DC}DC - \gamma_{DW}DW \pm \gamma_{P}P}{\gamma_{L}LL(1+IM)}$$

$$C = \phi\,\phi_c\,\phi_s\,R_n$$

$$\phi_c\phi_s \geq 0.85$$

In the equations, RF is the rating factor, C is the structural capacity, R_n is the nominal member resistance (as inspected), DC is the dead-load effect of structural components and attachments, DW is the dead-load effect of wearing surfaces and utilities, P is the permanent loading other than dead loads, LL is the live-load effect, IM is the dynamic load allowance, γ_{DC} is the LRFD load factor for structural components and attachments, γ_{DW} is the LRFD load factor for wearing surfaces and utilities, γ_P is the LRFD load factor for permanent loads other than dead loads, γ_L is the evaluation live-load factor, ϕ_c is the condition factor, ϕ_s is the system factor, and ϕ is the LRFD resistance factor.

Nominal resistance (R_n) is the ability of the bridge to withstand applied loads. Resistance must be calculated to determine the capacity of the bridge. For load rating, resistance depends on the structural layout, bridge material, and the *present condition* of the structural components. After determining the nominal resistance, a bridge owner can calculate the capacity by applying the product of the three safety factors: ϕ, ϕ_c, and ϕ_s. The resistance factor (ϕ) is the same factor used in LRFD bridge design and accounts for the general uncertainties of a bridge member in satisfactory condition. The condition factor (ϕ_c) is used to account for increasing uncertainties in a bridge member once its condition deteriorates. The condition factor is equal to 0.85 for members in poor condition, 0.95 for members in fair condition, and 1.0 for members in good condition. The system factor (ϕ_s) accounts for the level of redundancy in the structure. Bridges that are less redundant or nonredundant will be assigned a lower system factor and therefore will have reduced calculated capacities.



The flowchart demonstrates the decisionmaking process involved in the LRFR approach. *Source: AASHTO* Guide Manual for Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges.

In LRFR calculations, permanent loads are separated into the three variables DC, DW, and P, because each is assigned an independent load factor (γ) for each load rating limit state. All permanent loads are calculated in accordance with the bridge conditions at the time of the analysis. Load factors for permanent loads and live loads are specified in the AASHTO *Guide Manual for Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges*.

As with load factor rating, LRFR live loads are temporary loads that act on a structure. Vehicular loads are the primary live loads that affect

TDOT

Inspectors deemed this bridge closure necessary based on a load rating calculation.

bridges. For nonpermit load rating, the LRFR system is a tiered approach. The bridge owner performs an initial check based on the HL-93 design load at the applicable design limit states. As with H20/HS20 loading, AASHTO established HL-93 as a standard model for live loads, so it does not represent an actual vehicle. The HL-93 load model under the LRFD methodology is equivalent to the H20/HS20 model truck in combination with the HS20 uniform lane loading. The load rating equation has been calibrated such that if a check of the design load yields a satisfactory load rating, then the bridge owner can assume that the bridge will yield satisfactory load ratings for all AASHTO legal loads. Therefore, an inventory design load rating resulting RF >1 requires no further legal load analysis.

Bridge owners generally perform legal load rating only as a second-level evaluation when HL-93 loads exceed the bridge capacity. Legal load rating provides the load capacity of any of the AASHTO or State models for legal load. (Note: If States develop their own legal loads, owners need to perform an analysis to ensure that the State-specific loads are enveloped within the HL-93 design load.)

Finally, owners perform permit load rating only for vehicles carrying loads that exceed the legal limit. Permit procedures apply only to bridges that have adequate capacity to carry design or legal loads. In permit load rating, the weight and dimensions of the actual truck should be used in place of the AASHTO load models.

Calibrating LRFR

When calibrating any design or evaluation code, engineers develop a procedure to account for structural reliability or, conversely, the probability of failure. The LRFR, like the LRFD code, bases this reliability on the safety index (β) system, where, as described in the National Cooperative Highway Research Program's *NCHRP Report No. 454: Calibration of Load Factors for LRFR Bridge Evaluation*, β is defined as follows:

$$\text{Safety Index, } \beta = \frac{\text{mean value of } g}{\text{Standard deviation of } g}$$

$$g = \text{Resistance} - \text{Dead Load} - \text{Live Load} + \text{Impact}$$

As the equations indicate, large positive values for g (a positive value indicates a safe element) and/or small values for the variation of g will yield a higher safety index. Higher safety indices mean higher reliability. Safety indices provide a measure of the structural reliability or, conversely, the risk that a design component has inadequate capacity in a given limit state.

Selecting a target β is based on economics. Increasing the safety index can lead to costly overconservative design and evaluation, while decreasing the safety index can lead to expensive maintenance or replacement of failed components. For LRFD, the target safety index chosen was β equals 3.5. Assuming a normal distribution, this safety index ensures that during the design life of the structure, only 2 out of 10,000 components will experience loading that exceeds the component's resistance, as FHWA's Myint Lwin noted in the article "Why the AASHTO Load and Resistance Factor Design Specifications?" published in 1999 in *Transportation Research Record* #1688.

The LRFR target safety index is β equals 2.5 at operating level and β equals 3.5 for inventory level. The operating safety index of β equals 2.5 ensures that only 6 out of 1,000 components will experience loading that exceeds the component's resistance. The operating reliability can be justified on many grounds, including the fact that the exposure period for evaluation is much shorter (2 to 5 years between inspections) compared to the 75-year exposure period for design. In addition, the relative cost for increasing the safety index during the evaluation phase is much higher when compared to the cost of increasing the index during the design phase.

The load and resistance factors ϕ, ϕ_c, ϕ_s, γ_{DC}, γ_{DW}, and γ_L are calibrated using the selected safety index targets to achieve uniform safety for all material types, spans, and load effects.

Because the LRFR live-load factors depend on average daily truck traffic (ADTT), researchers used traffic data for calibration. They used weigh-in-motion data from sites with ADTT values of at least 5,000 to determine the probability of side-by-side heavy vehicle events. The researchers used the field data in a traffic-flow model to interpolate probability values for other ADTT values.

Understanding the Advantages

To enable a smooth transition from load factor rating, the LRFR research team set a goal to make the manual practical and easy to use. "Although some bridge owners may think that it will be more difficult to use, LRFR is actually as easy, if not easier, to use than LFR," says Firas Ibrahim, senior bridge codes and specifications engineer at FHWA.

The load and resistance factors are calibrated to account for the safety reliability, so this aspect remains invisible to the evaluator. In addition, loading procedures were designed to appear to be an extension of the current load factor rating method.

As with LRFD, LRFR promises a more uniform level of safety and a lower risk of over- or underdesigned members. The LRFR approach can lead to a decrease in costly traffic restrictions and bridge strengthening or repairs as well.

Although the general equations are similar for the current LFR and new LRFR methodologies, and the procedures are straightforward, the implementation of a new load rating method can be time-consuming and costly for State DOTs. Nevertheless, the following is a list of credible reasons to justify adopting the new LRFR procedures.

1. LRFR provides a simplified approach through the use of the HL-93 live loading as a screening check for all other legal loading. Previously, with LFR, the HS20 truck did not represent current highway conditions and did not provide uniform reliability over varying span lengths. To achieve reliability, States applied load factor rating to three separate AASHTO legal load models, with each one controlling short, medium, or long spans respectively. Only the combined use of the three AASHTO legal loads resulted in uniform reliability. With LRFR, the HL-93 can achieve this uniform reliability for all span lengths with only one load combination.
2. LRFR enables bridge owners to apply traffic volume and other site-specific data when determining live-load factors for a bridge. If more information is available, such as truck loads through weigh stations, evaluators may take a more refined approach by estimating site-specific load factors that are characteristic to the bridge site. This procedure could be especially advantageous to bridges carrying light truck traffic.
3. LRFR facilitates using the past performance of a bridge to help determine its serviceability rating. If inspectors find no problems with past performance, restrictive load posting based on calculated serviceability performance measures may not be justifiable. In cases like this, evaluators can use past performance as a proof test for serviceability.
4. LRFR provides procedures for load rating vehicles with loads that exceed the legal limit (or permit vehicles). These procedures include live-load factors specific to permit loading.
5. LRFR provides procedures for evaluating fatigue on existing steel bridges, combining specifications from AASHTO's guide *Specifications for Fatigue Evaluation of Existing Steel Bridges* and AASHTO's *LRFD Bridge Design Specifications*.
6. LRFR describes procedures for nondestructive load testing, which involves field observations and measurements of inservice bridges. Because bridge ratings tend to be fairly conservative, field load testing often can reveal additional capacity, as noted by Michael Barker in "Quantifying Field-Test Behavior for Rating Steel Girder Bridges," published in the July/August 2001 issue of the *Journal of Bridge Engineering*.
7. Lastly, the NCHRP Project C12-46 reported that in trial load ratings "DOT rating engineers were able to perform the LRFR evaluations without undue difficulty and with relatively few errors." This finding demonstrates that bridge evaluators do understand the procedures and that implementation is feasible.

"Bridge owners need a rating methodology that produces results that are closer to reality, not closer to prior rating methodologies," says Ibrahim. "The LRFR methodology provides a reality check and produces meaningful, reliable results that are superior to those of prior rating methodologies."

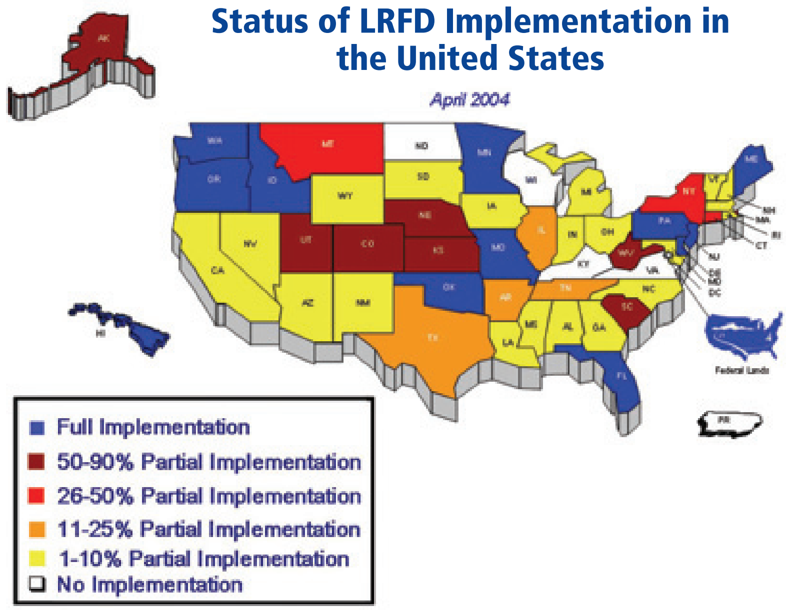
Field Trials and Comparisons

While developing the new LRFR manual, NCHRP researchers compared LRFR and load factor ratings on several actual bridges representing various types and physical conditions. Evaluators performed ratings at both inventory and operating levels under design and legal loads and presented their results for three groups of bridges: steel multigirder, reinforced concrete T-beam, and prestressed concrete I-beam bridges.

For steel multigirder bridges, LRFR design inventory ratings were slightly lower than load factor rating bridges. Lower ratings indicate a more conservative result and lower allowable loading. LRFR design operating ratings were lower than load factor rating. The LRFR legal load ratings were higher than inventory ratings and almost equivalent for operating ratings using the load factor rating method. The researchers

NCHRP Comparison of LRFR and LFR Rating Factors

Bridge Type	Average LRFR/LFR Ratios			
	Design Loads		Legal Loads	
	Inventory	Operating	Inventory	Operating
Steel Multigirder	0.9	0.71	1.74	1.04
Reinforced Concrete T-beam	0.87	0.68	1.33	0.8
Prestressed Concrete I-beam	0.79	0.65	1.08	0.65



The map shows the status of LRFD implementation across the United States as of April 2004 (the latest date for which information was available at the time of publication). *Source: FHWA.*

also performed trial ratings on nonredundant steel bridges but determined that the number of bridges studied was too small to permit drawing any conclusions.

For reinforced concrete T-beam bridges, LRFR design load ratings were lower than those achieved using load factor rating for both inventory and operating levels. Legal load ratings for LRFR were higher than those for load factor rating for inventory but lower for operating.

The results for prestressed concrete were more widely scattered than those for steel or reinforced concrete. The majority of load ratings achieved using the LRFR approach for the prestressed concrete bridges were governed by shear rather than flexure stresses, which is a substantial difference from the load factor rating method where flexural ratings typically govern for all bridge types. The researchers attribute the reversal due to a number of issues. For the design limit state, the LRFR HL-93 loading causes higher shear stress than the HS20 loading. In addition, the shear distribution factors are higher using the LRFR method. Most importantly, the evaluators used the modified compression field theory to calculate shear resistance instead of the previous semiempirical formula.

For prestressed concrete, the results generated through the modified compression field theory can be very different than those for load factor rating. However, in accordance with the AASHTO *Guide Manual for Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges*, inservice concrete bridges that show no signs of shear distress do not need to be checked for shear when rating for design or legal load. (Evaluators still need to check shear for the permit load rating.)

Moving Toward Implementation

To date, several States have either fully or partially adopted LFRD as their primary design method for bridges. Few States, however, have adopted LRFR as their primary method for load rating. A recent survey of 32 States showed that 15 have used LRFR in only sample load rating. Because the methodology of LRFR is synonymous with LRFD, advancing the implementation of the latter will help with the eventual adoption of the former. Additional sample ratings, training, and research can help the bridge engineering community gain the confidence it needs to fully implement the new LRFR method across the United States. "Although States and other bridge owners may be cautious about embracing this new approach," says Ed Wasserman, director of the structures division at Tennessee Department of Transportation (TDOT), "we understand that LRFR offers an apparent improvement in reliability and uniformity when rating bridges. We expect that any issues will be overcome with time."

The recently released LRFR software that works with the popular computer-based tool Bridge Rating and Analysis of Structural Systems or BRASS™ should help ease the concern among States about the time and effort that will be invested in switching to LRFR. As State DOTs move through the process of implementing LRFD and LRFR, FHWA staff members are available for technical assistance and consultation.

Becky Jaramilla, P.E., presently serves as the assistant bridge engineer in the FHWA Tennessee Division Office. Her role covers all aspects of bridges, including design, construction, and inservice inspection. Jaramilla holds a professional engineering license in Tennessee. She has a B.S. in engineering from the University of Illinois at Chicago and is currently working towards an M.S. in civil engineering at Tennessee Technological University.

Sharon Huo is an associate professor in the Department of Civil and Environmental Engineering at Tennessee Technological University. She holds a Ph.D. from the University of Nebraska and has 13 years of experience in structural analysis and design. Her research specialties include the behavior of prestressed concrete members, live load distribution in bridge design, and bridge analysis and rating. She is a registered professional engineer in Nebraska.

The load and resistance factor design and rating of structures is one of the FHWA priority, market-ready technologies, which are innovations that have proven benefits and are ready for deployment (see www.fhwa.dot.gov/rnt4u/pti.htm). References for this article are available online at www.tfhrc.gov.

The CP Road Map represents a long-term plan for research and technology development for PCC pavements.

Achieving Concrete's Full Potential

by Theodore R. (Ted) Ferragut, Dale Harrington, and Marcia Brink

For most of the 20th century, engineers used the same tried-and-true materials in designing concrete pavements—portland cement, high-quality aggregate, and water—with only minor refinements. "Designers used a fairly forgiving formula that allowed minor variations in subgrade quality, construction practices, and other variables, without sacrificing pavement performance," says Director Tommy Beatty of the Office of Pavement Technology at the Federal Highway Administration (FHWA).

During much of that time, the industry enjoyed the luxury of keeping traffic off the new pavements for several days, even weeks, while the concrete developed its internal strength. Over the last 15 years, however, the industry has experienced more changes than in the previous 80 years, turning the process of building concrete pavements on end, Beatty says.

Today's concrete mix designs, for example, need to integrate a multitude of new materials—including fly ashes and chemical admixtures like water reducers, retarders, and accelerators—which can cause challenges in compatibility and reduce the tolerance for variations in aggregate moisture content, materials temperatures, weather conditions, and other variables.

In addition, motorists are more demanding, tolerating only minimal closures and delays due to roadwork and increasing the need for new paving methods that enable crews to get in, get out, and stay out. And motorists want smoother and quieter pavements, which is pushing the paving industry to exercise greater control on the characteristics of the road surface.

Increasingly, highway agencies are shifting their focus from building new pavements to rehabilitating and

In this illustration of the lab of the future, researchers are using advanced computers, software, and other technology to develop innovative mix designs.

All illustrations courtesy of Iowa State University.

maintaining existing ones, which requires different designs, systems, materials, and equipment. Environmental pressures, as well, affect mix designs and construction practices, as crews work to reduce traffic congestion and manage drainage and runoff.

Further, highway budgets are being squeezed at every level, and the pavement community simply must do more with less. "In this environment, the old system for constructing concrete pavements simply does not work anymore," says Beatty. "To achieve concrete pavement's full potential in this changing world, the industry cannot continue business as usual."

To help the industry grow and meet the challenges of the 21st century, FHWA, Iowa State University, and many other partners collaborated to create the Long-Term Plan for Concrete Pavement Research and Technology. Dubbed the CP Road Map, the plan represents a comprehensive and strategic approach to research that will guide investment over the next several years and spawn a new generation of concrete pavements.

What Is the CP Road Map?

"The CP Road Map gives the concrete pavement community an opportunity to proactively reinvent itself through research," says Peter A. Kopac, research highway engineer at FHWA.

By combining more than 250 research problem statements into 12 fully integrated, sequential, and cohesive tracks of research, the project team expects that the CP Road Map will lead to specific products that will dramatically affect the way that concrete pavements are designed and constructed. The innovative track structure and cross-track integration will at once help the research teams focus on their designated tasks and effectively share information where tasks overlap.

A project team led by Iowa State University prepared the CP Road Map on behalf of FHWA, with backing and participation from stakeholders in the concrete pavement industry, State departments of transportation (DOTs), and academia.

"In a very real sense, the authors of the CP Road Map include hundreds of stakeholders from State DOTs, materials supply companies, construction contractors, research and technology transfer universities, and other organizations," Kopac says. "For the men and women who face the daily realities and challenges of constructing and maintaining concrete pavements, this is their CP Road Map."

The project stakeholders will pool their resources to jointly conduct and coordinate the research, and an innovative implementation strategy will help move useful new products and systems into the field quickly.

Drawing a New Map

The Iowa State University-led project team facilitated development of the CP Road Map through a deliberate and inclusive process. First, the team created a "living" database of existing research, cataloging recently completed and inprogress projects and their products. Regularly updated and maintained, the database will serve as a valuable resource for many years.

Next the team gathered face-to-face input from the highway community, identifying research gaps that would become the basis for problem statements. The Iowa team hosted five brainstorming and feedback sessions at major industry events: the October 2003 meeting of the Midwest Concrete Consortium in Ames, IA; a special November 2003 regional workshop for eastern and southern stakeholders in Syracuse, NY; the May 2004 meeting of the American Concrete Pavement Association in Kansas City, MO; a special January 2004 regional teleconference for western stakeholders; and, in October 2004, a final meeting of national stakeholders hosted by FHWA at the Turner-Fairbank Highway Research Center in McLean, VA.

Through these events, plus presentations at more than 20 professional conferences and workshops across the country, more than 400 engineers and managers provided direct input into the CP Road Map. In addition to the organizations noted earlier, other participants included representatives from FHWA, State and

As shown in this illustration, researchers working on CP Road Map projects will develop tools and models to help designers manipulate multiple variables in paving projects—such as materials, weather, structural requirements, pavement characteristics, subgrade, and drainage—and understand the implications of various design scenarios.

local DOTs, the Portland Cement Association, the American Association of State Highway and Transportation Officials, the National Ready Mixed Concrete Association, Transportation Research Board and National Cooperative Highway Research Program committees, the American Public Works Association, the National Association of County Engineers, contractors, materials suppliers, universities with departments conducting applied research, and private concrete-testing laboratories.

The project team asked the participants to provide their insights in four broad categories: mixtures and materials, design, construction, and pavement management and business systems. Again and again, the stakeholders reported that they need improved analysis tools for measuring performance at every stage of the pavement system. They need to understand how and why pavements fail or succeed. Because variables in each stage affect the others, the methods and tools need to be integrated across stages, from mix and materials to design and construction, and with pavement management and business systems.

Based on these concepts of pavement performance and systems integration, the team proposed the following overall goal for the CP Road Map: By 2015, the highway community will have a comprehensive, integrated, and fully functional system of concrete pavement technologies that provides innovative solutions for customer-driven performance requirements.

This illustration depicts a construction supervisor using a hand-held device to monitor pavement data during construction and make real-time adjustments. Technologies such as satellites, global positioning systems, pavement sensors, and advanced paving and construction equipment will help engineers make timely decisions during construction projects in response to weather and other variables.

Research Tracks

With abundant input from industry stakeholders and a strategic goal in hand, the project team identified dozens of specific research objectives and filtered them through the database of existing research to identify where gaps exist. The gaps became the basis for the 250 problem statements, which were added to the research database as work to be accomplished.

Team members organized the problem statements into 12 product-focused research tracks, which together form the long-term research plan. This structure captures the integrated, cross-category nature of the research and encourages stakeholder groups to step forward as champions for specific tracks. Research in one track often affects or is affected by research in another track, so team leaders for each track are responsible for ensuring that research is coordinated and integrated appropriately.

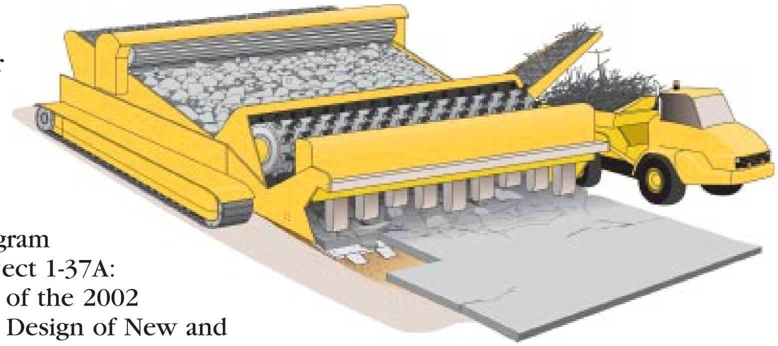
In addition to the defined tracks, the team leaders can sort information in the research database to isolate problem statements on a variety of subjects. Several problem statements, for example, are cross-referenced in multiple tracks, including those related to foundations and drainage systems, maintenance and rehabilitation, and advancements in environmental strategies.

Each of the 12 tracks is a complete research program in itself, with its own budget, two to seven subtracks, and as many as 20 problem statements. Tracks 1 through 9 consist of timed sequences of research leading to particular products that are essential to reaching overall research goals. Tracks 10, 11, and 12 are not phased because timing is not as critical.

One subtrack in every phased track is devoted to training tools and methods of technology transfer to ensure that innovative research products move into practice quickly and efficiently. The team defined the primary research tracks as follows:

1. Performance-Based Mix Design System. The final product of this track will be a practical yet innovative procedure for concrete mix design with new equipment, consensus target values, common laboratory procedures, and full integration with both structural design and field quality control—a lab of the future. This track also lays the groundwork for the concrete paving industry to assume greater responsibility for mix designs as State highway agencies move from method specifications to more advanced acceptance tools. For this move to be successful, the concrete paving industry and owner-agencies need a single document for the state of the art in mix design.

2. Performance-Based Design Guide for New and Rehabilitated Concrete Pavements. Under this track, the research community will expand the mechanistic approach to restoration and preservation strategies for concrete pavements, which involves using a structural response model to calculate pavement responses due to applied traffic and environmental loads. The track builds on and continues to develop



This illustration depicts a futuristic, one-step pavement lifter, crusher, and sorter. Developing advanced and automated equipment like this will help the concrete paving industry complete highway projects quickly and effectively with minimal disruption to traffic.

the models created under the comprehensive National Cooperative Highway Research Program (NCHRP) Project 1-37A: Development of the 2002 Guide for the Design of New and Rehabilitated Pavement Structures. The work in this track will be closely integrated with track 1.

3. High-Speed Nondestructive Testing and Intelligent Construction Systems. This track will develop high-speed, nondestructive quality-control systems to monitor pavement properties continuously during construction. As a result, workers will be able to make on-the-fly adjustments to ensure the highest quality finished product that meets given performance specifications. Many problem statements in this track relate to both tracks 1 and 2.

4. Optimized Surface Characteristics for Safe, Quiet, and Smooth Concrete Pavements. This track will result in improved understanding of the surface characteristics of concrete pavements. The research will provide tools to help engineers meet or exceed predetermined requirements for friction, safety, tire noise on pavements, smoothness, splash and spray, wheel path wear (hydroplaning), light reflection, rolling resistance, and durability (longevity). Each of these functional elements is critical. The challenge is to improve one characteristic without compromising another, while continuing to protect the safety of the public.

5. Equipment Automation and Advancements. This track will result in process improvements and the development of high-speed, high-quality concrete paving equipment to meet the concrete paving industry's projected needs and the traveling public's expectations for highway performance in the future. Examples include the next generation of concrete batching and placement equipment; behind-the-paver equipment to improve curing, surface treatment, and jointing; mechanized ways to place and control subdrains and other foundation elements; equipment to remove and replace the slab in one-pass construction; improved repair processes that decrease the time of operations and provide the workforce and traveling public with less exposure; and methods for evaluating new equipment on actual construction projects.

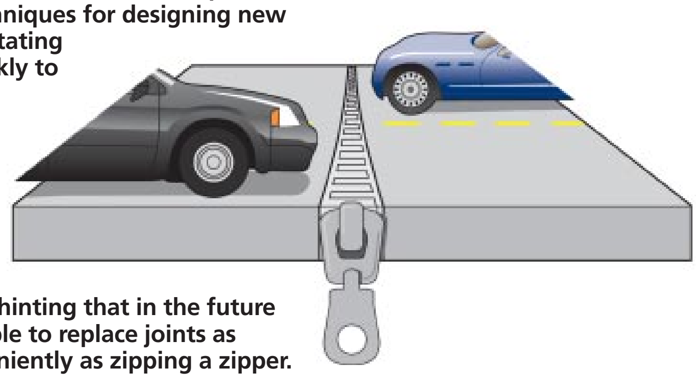
6. Innovative Joint Design, Materials, and Construction. Potential products for this track include a new joint design, high-speed computer analysis techniques for joint performance, a more accurate installation scheme, and faster rehabilitation strategies. The problem statements address the basics—joint design, materials, construction, and maintenance activities. The track also specifies research that will help develop breakthrough technologies and techniques for extremely high-speed joint repair. The team designed track 6 as a crosscutting track to ensure that all topics related to innovative joints are addressed. Much of the proposed research will develop important incremental improvements.

7. High-Speed Rehabilitation and Construction. To help develop faster techniques and higher quality for tomorrow's pavements, this track addresses a number of activities: the planning and simulation of high-speed construction and rehabilitation, precast and modular options, and fast-track construction and rehabilitation techniques for concrete pavement. The track also covers the evaluation and technology transfer of products and processes for high-speed construction and rehabilitation developed through research. Tracks 1 and 3 will likely involve the investigation of high-speed construction issues, so the CP Road Map project team will closely coordinate those efforts with track 7.

8. Long-Life Concrete Pavements. The need for longer lasting pavements that maximize the time between maintenance, restoration, or rehabilitation activities underlies all of the tracks in the CP Road Map. Track 8, however, draws attention to specific research that may lead to pavement life that approaches 60 years or more.

9. Accelerated and Long-Term Data Collection. This track provides the infrastructure—including data collection and reporting tools and testing methods—for a future national program that will plan accelerated loading and long-term data needs, construct test sections, and collect and share data. The problem statements in this track will identify the most useful data and determine the amount of time needed to collect that data.

10. Performance of Concrete Pavements. This track addresses key



The CP Road Map calls for the development of breakthrough techniques for designing new joints and rehabilitating existing ones quickly to ensure long-term performance. The illustration depicts two cars approaching a joint in a slab of concrete. The joint is drawn to look like a zipper, hinting that in the future workers will be able to replace joints as quickly and conveniently as zipping a zipper.

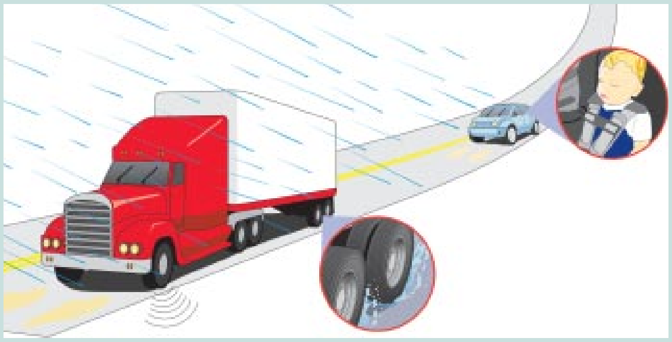
Research Tracks, Subtracks, and Estimated Budgets*

1. **Performance-Based Mix Design System** ($29.8M–$67.8M)
   Subtracks:
   - PCC Mix Design System Development and Integration
   - PCC Mix Design Laboratory Testing and Equipment
   - PCC Mix Design Modeling
   - PCC Mix Design Evaluation and Implementation
2. **Performance-Based Design Guide for New and Rehabilitated Concrete Pavements** ($40.5M–$59.6M)
   Subtracks:
   - Design Guide Structural Models
   - Design Guide Inputs, Performance Models, and Reliability
   - Special Design and Rehabilitation Issues
   - Improved Mechanistic Design Procedures
   - Design Guide Implementation
3. **High-Speed Nondestructive Testing and Intelligent Construction Systems** ($19.6M–$41.1M)
   Subtracks:
   - Field Control
   - Nondestructive Testing Methods
   - Nondestructive Testing and Intelligent Control System Evaluation and Implementation
4. **Optimized Surface Characteristics for Safe, Quiet, and Smooth Concrete Pavements** ($25.4M–$54.25M)
   Subtracks:
   - Concrete Pavement Texture and Friction
   - Concrete Pavement Smoothness
   - Tire-Pavement Noise
   - Integration of Concrete Pavement Surface Characteristics
   - Evaluation of Products for Concrete Pavement Surface Characteristics
   - Implementation of Concrete Pavement Surface Characteristics
   - Other Concrete Pavement Surface Characteristics
5. **Equipment Automation and Advancements** ($25.65M–$56.15M)
   Subtracks:
   - Concrete Batching and Mixing Equipment
   - Concrete Placement Equipment
   - Concrete Pavement Curing, Texturing, and Jointing Equipment
   - Concrete Pavement Foundation Equipment
   - Concrete Pavement Reconstruction Equipment
   - Concrete Pavement Restoration Equipment
   - Advanced Equipment Evaluation and Implementation
6. **Innovative Joint Design, Materials, and Construction** ($10M–$15.3M)
   Subtracks:
   - Joint Design Innovations
   - Joint Materials, Construction, Evaluation, and Rehabilitation Innovations
   - Innovative Joints Implementation
7. **High-Speed Rehabilitation and Construction** ($10.3M–$20.3M)
   Subtracks:
   - Rehabilitation and Construction Planning and Simulation
   - Precast and Modular Concrete Pavements
   - Fast-Track Concrete Pavements
   - Rehabilitation and Construction Evaluation and Implementation
8. **Long-Life Concrete Pavements** ($10.5M–$16.6M)
   Subtracks:
   - Pavement Strategy for Long-Life Concrete Pavements
   - Construction and Materials for Long-Life Concrete Pavements and Overlays
   - Long-Life Concrete Pavement Implementation
9. **Accelerated and Long-Term Data Collection** ($9.75M–$15.5M)
   Subtracks:
   - Planning and Designing Accelerated Loading and Long-Term Data Collection
   - Preparation of Data Collection/Testing Procedures and Construction of Test Road
   - Implementation of Accelerated Loading and Long-Term Data Collection
10. **Performance of Concrete Pavements** ($2.7M–$4.15M)
    Subtracks:
    - Technologies for Determining Concrete Pavement Performance
    - Guidelines and Protocols for Concrete Pavement Performance
11. **Business Systems and Economics** ($21.15M–$31.2M)
    Subtracks:
    - Concrete Pavement Research and Technology Management and Implementation
    - Concrete Pavement Economics and Life Cycle Costs
    - Contracting and Incentives for Concrete Pavement Work
    - Technology Transfer and Publications for Concrete Pavement Best Practices
    - Concrete Pavement Decisions with Environmental Impact
12. **Advanced Concrete Pavement Materials** ($11.45M–$23.25M)
    Subtracks:
    - Performance-Enhancing Concrete Pavement Materials
    - Construction-Enhancing Concrete Pavement Materials
    - Environment-Enhancing Concrete Pavement Materials

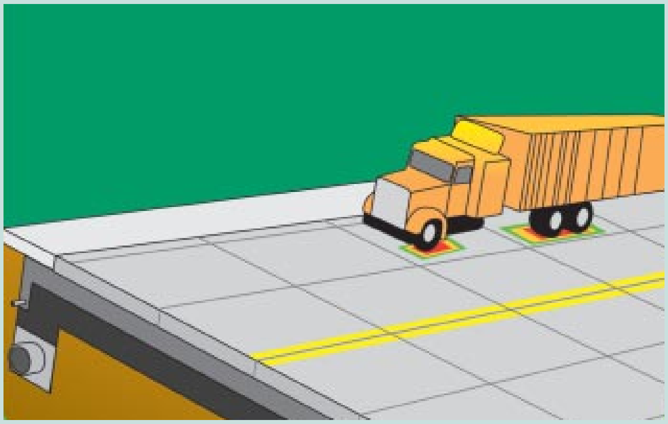
$216.8M–$405.2M total (estimated)

*All numbers are rounded.

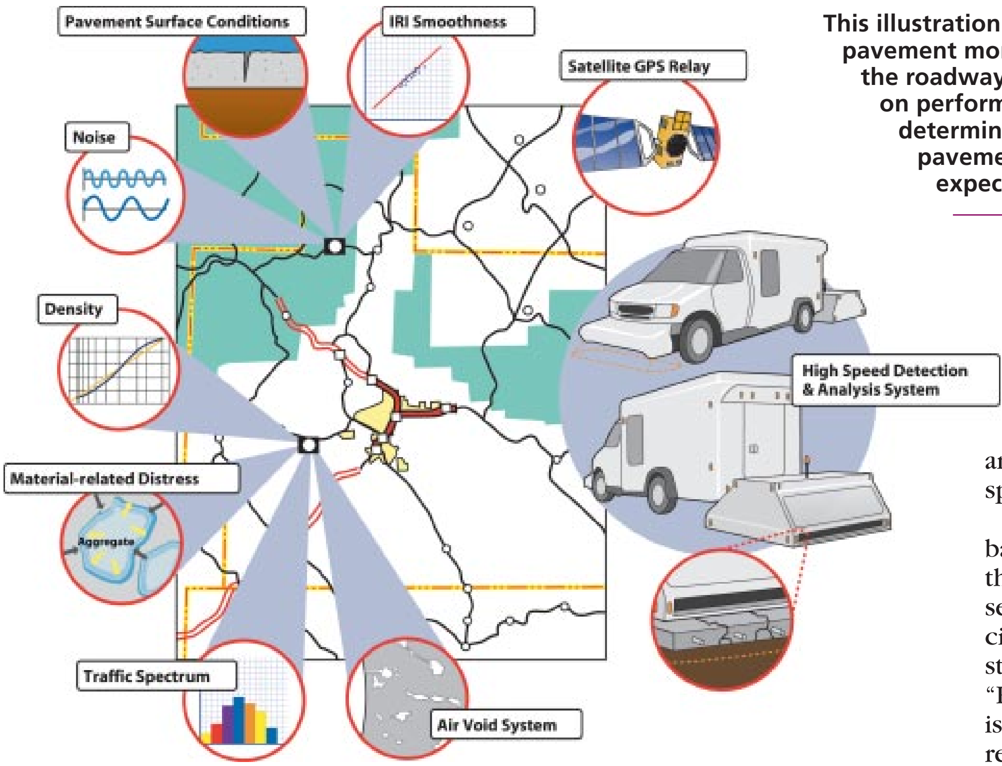
Source: Long-Term Plan for Concrete Pavement Research and Technology: The CP Road Map, An Executive Summary (draft), www.pcccenter.iastate.edu/publications/task15/pc_road_map_execsumm.pdf.



The CP Road Map will fund research aimed at improving pavement surfaces to provide a safe, quiet, and smooth ride. The illustration depicts a semitractor-trailer and passenger car driving on a road during the rain. An inset closeup of the truck's tires emphasizes the goal of reducing splash and spray on the wet pavement surface. The inset of a sleeping child in the car emphasizes the need for pavement surfaces that reduce pavement-tire noise and provide adequate traction for safety.



This illustration shows a grid of concrete slabs and a large truck on top of them, depicting the pavement deflection caused by a heavy truck. A future national program for research will involve constructing test sections and collecting data on long-term performance from accelerated load tests.



This illustration depicts data being collected by pavement monitoring devices placed throughout the roadway system. Collecting detailed data on performance will help State DOTs determine how well their concrete pavements live up to agency and user expectations.

elements of pavement and asset management systems to determine whether pavements meet the performance characteristics that highway agencies and users desire. Research will determine and address the functional aspects of performance, particularly factors such as tire noise on pavements, friction, and smoothness. Research also will examine ways to schedule improvements to surface characteristics and conditions. Developing feedback loops in highway agencies' pavement management systems will be crucial to monitor performance quickly and effectively.

11. Business Systems and Economics. Roles and responsibilities are changing within the highway industry, affecting the way paving projects are designed, bid, built, and maintained. Increasingly State DOTs are asking contractors to assume greater control of the operation and quality-control inspections. By including warranty provisions in project contracts, owner agencies are asking for additional assurance that contractors are building pavements that will perform as expected. Many European countries like Spain and Great Britain have made dramatic changes in project funding methods and in the roles of contractors and suppliers. Track 11 captures important research that the industry needs to consider as this process of transformation continues in the United States. Problem statements cover contracting options, new technology transfer systems, public-private partnerships, and economic models.

12. Advanced Concrete Pavement Materials. The problem statements in this track address the development of new materials and refine or reintroduce existing advanced materials to enhance performance, improve construction, and reduce waste. Many of the existing materials studied in this track have been used only on a small scale or in laboratory evaluations. Many of them have not been used in the United States but show promise based on work completed in other countries. Track 12 will experiment with such materials on a larger scale and develop standards and recommendations for their use. The research will foster innovation in the development of additional new and innovative materials for constructing concrete pavements.

Reaching the Destination

Finally, the CP Road Map project team developed a management plan that outlines a progressive, cooperative approach to managing and conducting the research in the long-term plan. Under the management plan, participating organizations identify common interests, partner with one another to leverage funds and human resources, and execute specific contracts.

The research management plan is based on several assumptions. First, the CP Road Map is a national research plan for FHWA, State agencies, and industry, and it is not restricted to any single funding source. "Publicly financed highway research is decentralized and will probably remain so," says Director Dennis Judycki of the Office of Research, Development, and Technology at FHWA. "In a decentralized arena like research, it is critical for stakeholder groups to come together voluntarily. Federal, State, and industry research staff and engineers around the country are looking for more opportunities to pool their funds and other resources in win-win situations."

Under the management plan, communication, technology transfer, and outreach activities will avoid the all-too-common disconnect between research results and implementation. "Technology implementation must be elevated to the same level of importance as research itself," Judycki adds.

Finally, managing the CP Road Map effectively and judiciously will require full-time, dedicated personnel with adequate resources. The CP Road Map project team, therefore, developed a governing structure in the research management plan that outlines a four-tiered system of participation and responsibility.

A three-party executive advisory committee, representing FHWA, State DOTs, and industry organizations, will provide broad oversight. The executive advisory committee will serve as a decision- and policy-making entity and will have the following responsibilities:

- Assembling team leaders for each research track

Depicting pages in a calendar, this illustration shows various stages in the life of a concrete pavement system, including scenes showing rainy and sunny weather, surveyors, excavation equipment, paving equipment, and traffic on the finished roadway. Researchers aim to design concrete pavements that perform well year after year, achieving a lifespan of 60 years or more.

- Promoting partnering arrangements
- Ensuring adequate integration of research across tracks
- Developing and implementing a strategy to ensure that software products developed through various research tracks will be compatible with each other
- Identifying new program areas for research
- Overseeing updates to and maintenance of the research database
- Developing a comprehensive program for technology transfer and training for products created through the CP Road Map
- Developing a communications effort to keep the CP Road Map and its products in front of stakeholders and the public
- Conducting self-evaluation studies
- Keeping the momentum focused on outcomes, not just output

An administrative support group will provide professional management services for the executive advisory committee. The administrative group will coordinate and support activities like maintaining the research database.

Team leaders for the research tracks will coordinate and oversee all activities within specific research tracks, such as validating and updating the track, developing broad problem statements into specific research projects, identifying organizations to conduct or partner in the research, and ensuring proper integration of work within the track and across track lines.

Finally, sustaining organizations, which include highway agencies, consultants, universities, professional associations, and other organizations that have specialized interests and skills and are interested in pooling dedicated funds, will assume responsibility for conducting research through cooperation, partnerships, and funding agreements. Sustaining organizations may retain full fiscal and technical control of the work under their jurisdictions.

Future Steps

FHWA intends to implement the roadmap in cooperation with all partners and stakeholders. The CP Road Map project team likens a long-term research program to turning an oceanliner around. The process involves a long, slow sweep. In this case, the team has turned the rudder—the CP Road Map—in the right direction. The next step is to fire the engines, full speed ahead.

"We see the CP Road Map as a living document that will help all of us—FHWA, the States, the concrete paving industry, and other stakeholders—work together to make the most of our investments in concrete pavement research," says Cheryl Allen Richter, technical director of pavement research and development in the FHWA Office of Infrastructure Research and Development. "We look forward to working with stakeholders throughout the concrete paving industry to maintain the Road Map and—more importantly—fire up those engines to get the research underway."

The project team invites stakeholders in the concrete pavement industry to get on board. To become involved, please contact Cheryl Richter at 202–493–3070 or Peter Kopac at 202–493–3151.

Theodore R. (Ted) Ferragut coordinated the effort to develop the Long-Term Plan for Concrete Pavement Research and Technology. He is owner and president of TDC Partners, Ltd., a sole proprietorship in Alexandria, VA, that works with government agencies and private companies to move innovative technology into practice in the areas of highway pavement design, construction, maintenance, and performance. Ferragut is a registered professional engineer in Virginia and has a B.S. in civil engineering from the University of Massachusetts.

Dale Harrington administered the long-term research planning effort. He is the former director of the Center for Portland Cement Concrete Pavement Technology at Iowa State University. Harrington has 30 years of experience in the public and private sectors in pavement design, performance evaluation, construction, and rehabilitation. He is a registered professional engineer in Iowa and has a degree in civil engineering technology from Iowa State University.

Marcia Brink is the communications manager for Iowa State University's Center for Transportation Research and Education, which is the administrative home of the Center for Portland Cement Concrete Pavement Technology and the U.S. Department of Transportation's University Transportation Centers Program serving Iowa, Kansas, Missouri, and Nebraska. Brink has a master's degree in English from Iowa State University.

To receive a printed copy of the CP Road Map, contact Peter Kopac with FHWA at 202–493–3151, peter.kopac@fhwa.dot.gov. A draft electronic version of the CP Road Map is available at www.pcccenter.iastate.edu.

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.

Policy and Legislation

FMCSA Evaluates Rulemaking on Hours Of Service for Truck Drivers

USDOT's Federal Motor Carrier Safety Administration (FMCSA) recently announced that it will reexamine the 2003 hours of service (HOS) rule that regulates the amount of time commercial truck drivers can operate their vehicles. During the winter of 2004, FMCSA encouraged truck drivers and operators, law enforcement officials, safety advocates, and others to respond to a notice of proposed rulemaking published in the *Federal Register*. FMCSA asked respondents how the current HOS regulations have affected driver quality of life, whether naps improve driver alertness, and whether working 11-hour shifts—instead of 10—is detrimental.

FMCSA will use the information to enhance a comprehensive scientific review of the HOS rule and its physical effect on drivers operating commercial vehicles. The 2003 HOS rule increased the daily driving limit from 10 to 11 hours, continued drivers' use of sleeper berths, and allowed a 34-hour restart period—the period of consecutive offduty hours that a driver may take before initiating a 60- or 70-hour onduty period.

FMCSA initiated the evaluation in response to a July 2004 decision by the U.S. Court of Appeals for the District of Columbia Circuit that directed the agency to specifically consider the 2003 rule's impact on the health of drivers. Since the HOS rules issued in April 2003 will remain in effect only until September 2005, FMCSA is working under a compressed schedule to upgrade the rulemaking.

To view the notice of proposed rulemaking, visit http://dmses.dot.gov/docimages/p80/312470.pdf.

Public Information and Information Exchange

WSDOT Evaluates New Winter Weather Approach

The Washington State Department of Transportation (WSDOT) is collecting feedback on an improved road weather information system (RWIS) and highway advisory radio (HAR) deployed recently on a remote section of U.S. Route 395 north of Spokane, WA. The evaluation began with a baseline survey involving data collection during the winter of 2000–2001, at which time Internet weather information covered only the immediate Spokane area, and broadcast radio reports were limited to general information on traffic conditions. Closed-circuit television camera coverage and onsite highway advisory radio systems also were not yet available.

In 2002 WSDOT integrated two environmental sensing stations, along with an RWIS and transportation management center. The agency disseminated the information collected by the environmental sensor stations and closed-circuit television cameras to travelers via the WSDOT traveler information Web site, www.wsdot.wa.gov/traffic. In addition, two mobile HAR systems provided travelers with updated information in the areas of Loon Lake and Laurier on U.S. Route 395, and at Sherman Pass on State Route 20. Since then, the agency has been conducting an evaluation of the project using customer satisfaction surveys to evaluate the impacts of the new technologies on the behavior, safety, and efficiency of commercial vehicle operators with regard to trip timing, trip routing, and level of preparedness. The evaluation team identified approximately 40 carriers in the project corridor who were willing to participate in before and after telephone interviews.

Following the deployment of the new systems, 39 operators were surveyed and asked, "Has the availability of HARs, camera images of key roadway segments, and enhanced Internet information affected driving safety for you in this region compared with last year?" Eleven of the respondents said they did not know whether their drivers used the information sources, or they themselves did not use them. Of the remaining 28 operators, 16 (57 percent) said the availability of the new information made them "somewhat" or "a lot" safer. The remaining 12 (43 percent) said the safety benefit to them was "about the same as before." No one reported a reduction in safety.

To view related information on the benefits and costs of these systems, visit www.benefitcost.its.dot.gov/ITS/benecost.nsf.

Winners of Work Zone Safety Awards Recognized

The American Road & Transportation Builders Association (ARTBA) and National Safety Council (NSC) recently recognized several public and private transportation groups for their commitment to work zone safety. The 2005 Roadway Work Zone Safety Awareness Awards, given in the categories of private outreach, government outreach, public-private collaborations, and safety training, recognize efforts to help reduce crashes, injuries, and fatalities at roadway work zones.

In the private outreach category, ARTBA and NSC recognized the New York State Chapter, Inc., of the Associated General Contractors of America for its involvement in promoting State legislation on work zone safety in 2004. The organization developed a radio advertisement campaign and held news conferences to coincide with the introduction of the act in the New York State Legislature. The proposed legislation would impose a 30-day license suspension for drivers who exceed work zone speed limits and would establish a fund for programs promoting education and advocacy for work zone safety.

In the safety training category, High Temp Repair and Inspection, Inc. (HRI) was recognized for its collaboration with the Pennsylvania Department of Transportation and law enforcement officials to address safety issues relating to lane closures during a major repair project in eastern Pennsylvania. HRI coordinated daily preshift meetings with contractors and State troopers to review traffic patterns, traffic control plans, and potential hazards that could stem from the replacement of 42 bridge decks on I-81 in Lackawanna and Luzerne Counties. HRI also developed a unified warning system for workers and troopers in the event of a crash. The system paid off when a properly positioned trooper spotted an intoxicated driver entering a closed work zone lane and immediately radioed another trooper stationed near the workers.

For more information on the Roadway Work Zone Safety Awareness Awards, visit www.artba.org/foundation/2005_Roadway_Workzone/index.htm, or contact Rhonda Britton at 202-289-4434 or rbritton@artba.org.

American Road & Transportation Builders Association

FHWA Issues New Compilation of Freight Statistics

Freight transportation has expanded dramatically with the growth of population and economic activity in the United States and with the increasing interdependence of economies across the globe. The U.S. population increased by 27 percent between 1980 and 2002, while the economy, measured by gross domestic product, nearly doubled in real terms during the same time period. Other indicators of growth, such as employment and household income, also have risen by 37 percent and 16 percent, respectively. Foreign trade has grown faster than the Nation's overall economy, more than doubling between 1980 and 2002, reflecting unprecedented global interconnectivity.

To illustrate how these trends have affected freight transportation in the United States, the FHWA Office of Freight Management and Operations recently released *Freight Facts and Figures 2004* (FHWA-OP-05-009)—a snapshot of the volume and value of U.S. freight flows, the physical network through which freight moves, the economic conditions that generate freight movements, the industry that carries freight, and the safety, energy, and environmental consequences of freight transportation. The statistics help planners, decisionmakers, and the public understand the magnitude and importance of freight transportation in the U.S. and global economies.

The report offers several key predictions for the industry, such as growth in demand for freight transportation outside the Nation's northeastern manufacturing belt. Population, employment, and income figures also show greater variance in the geographic concentration of economic activity throughout the country. Over the next 10 years, the U.S. economy is projected to grow by 38 percent, while the U.S. population will increase by 9 percent. At the same time, transportation and warehousing employment is expected to increase by 22 percent over this period, faster than employment as a whole at 15 percent.

To view the report, visit www.ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/04factsfigures/pdf/fff2004.pdf.

Personnel

Lettiere Becomes AASHTO President, Linnenkohl Named Vice President

The American Association of State Highway and Transportation Officials (AASHTO) recently named new officers, including Commissioner John F. "Jack" Lettiere, Jr., of the New Jersey Department of Transportation (NJDOT), as president and Georgia Department of Transportation (GDOT) Commissioner Harold Linnenkohl as vice president. Lettiere, who recently stepped in to fill out the remainder of J. Bryan Nicol's 2004-2005 presidential term, becomes the first president of AASHTO from New Jersey. After serving NJDOT for 30 years, Lettiere received a Governor's appointment to the role of commissioner in December 2002. As commissioner, he oversees 16,000 employees and an annual budget of more than $3 billion.

Following his own appointment, Lettiere named GDOT Commissioner Harold Linnenkohl as vice president of the association. Linnenkohl has served GDOT for 36 years, acting as both assistant State bituminous construction engineer and State aid administrator. As commissioner, Linnenkohl directs a department of 5,800 employees and manages a budget of more than $2 billion.

For more information, please contact Sunny Mays Schust at 202-624-5800.

AASHTO

Reporting Changes of Address

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

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NHI Fosters Collaboration Between Safety and ITS Communities

The U.S. rate of highway fatalities per 100 million vehicle miles traveled—1.48 in 2003—compares favorably with that of European countries. However, the relatively high rate of highway deaths per 100,000 people—14.66 in the same year—reveals the Nation's high level of mobility and the consequent need for continued safety improvements. To identify highway safety challenges and recommend improvements, the Federal Highway Administration's (FHWA) Office of Safety, in partnership with the Office of Professional and Corporate Development, conducted a survey on highway safety in March 2002. The survey results led to recommendations that included offering courses on safety. To address this need, the National Highway Institute (NHI), the training branch of FHWA, now provides training focused on fostering sustainable collaboration between intelligent transportation systems (ITS) and highway safety communities.

In one of its newest classes, Improving Highway Safety with ITS (#137044), NHI provides an interactive training environment where practitioners learn to use ITS technologies in safety planning, project execution, and other areas to improve highway safety at both the project and strategic planning levels. In addition, the 2-day course will increase awareness of how transportation agencies can use ITS applications to make highway safety improvements for stand-alone projects, mainstream projects, and even entire highway systems. By increasing awareness of these links, the course will enhance collaboration between ITS and safety personnel while providing participants with basic tools and resources needed to choose appropriate ITS solutions for various highway safety issues. In fact, the Office of Safety, the ITS Joint Program Office, and the Operations Technical Service Team from the FHWA Resource Center—all of whom helped develop or fund the course—have begun an important effort to increase interaction between transportation engineers who focus primarily on solving safety issues and those focused on implementing ITS.

These activities indicate increasing recognition that transportation professionals involved with roadway safety, operations, and even infrastructure, encounter ITS technologies daily. Although training traditionally has catered to transportation professionals who deal with ITS routinely, agencies such as NHI are providing more opportunities for professionals who want to learn more about the functions of ITS and how they relate to their respective sectors. This particular course will draw roadway planners, operators, designers, and maintenance personnel from State departments of transportation, metropolitan planning organizations, and other city and county agencies. Course organizers hope to achieve an equal representation of participants from the safety and ITS sectors in each class.

The course will include some lectures using Microsoft® PowerPoint® slides but will rely more heavily on workshops, teamed problem-solving activities, and sessions to develop action plans. After participating in the lectures and sessions and exchanging experiences, each participant will have learned about:

- Other participants' highway safety challenges and successes in the context of ways that ITS can help
- Highway safety priorities specific to their States or local transportation agencies
- Ways in which ITS can contribute to improved highway safety and traffic operations in work zones
- ITS-supported countermeasures that address highway safety priorities identified in the participants' jurisdictions
- Organization-level activities appropriate and necessary for potential ITS and safety collaboration on planning
- Actions needed to enable the development and implementation of a collaborative safety-ITS program

The course, piloted in February 2005 and available more widely in November 2005, can be accessed via NHI instructor-led training at regular prices. FHWA also has developed a 1-hour executive summary for senior officials. Course materials will be available for review, especially to potential instructors and training institutions. Course planners suggest that participants have some experience in either ITS or highway safety and have some familiarity with strategic planning activities and goals or ITS strategic activities and initiatives in their States.

The FHWA Resource Center and Office of Safety, starting in 2002, offered the original version of the training as a workshop, Improving Highway Safety with ITS, in several States while it was being refined as an NHI course. The workshop not only attracted more than 240 participants at presentations in Florida, Michigan, Minnesota, Pennsylvania, and Wisconsin, but also achieved the highest attendance of all workshops at the Intelligent Transportation Society of America's 2004 Annual Meeting & Exposition in San Antonio, TX. The transportation community's enthusiasm revealed a growing demand for safety courses that reflect the increasingly explicit, primary, and data-driven nature of safety and the use of ITS technologies to solve specific safety problems.

"This course brings safety and ITS professionals together to collaborate on the common goal of how to save lives on our highway system," says retired FHWA Associate Administrator for Safety A. George Ostensen. "FHWA has increased its national emphasis on safety training in order to accelerate the rate of improvement in saving lives on our Nation's highway system."

For more information, contact Ann Gretter, NHI, at 703-235-1260 or ann.gretter@fhwa.dot.gov. For technical information on the course, contact Morris Oliver (Safety) at 202-366-2251, morris.oliver@fhwa.dot.gov, or Ron Giguere (ITS) at 202-366-2203, ron.giguere@fhwa.dot.gov. To schedule a course, contact Danielle Mathis-Lee at 703-235-0527 or e-mail danielle.mathis-lee@fhwa.dot.gov. To obtain information about NHI courses, access the course catalog at www.nhi.fhwa.dot.gov or contact NHI at 4600 N. Fairfax Drive, Suite 800, Arlington, VA, 22203; 703-235-0500 (phone); or 703-235-0593 (fax).

By Keri A. Funderburg

New Web Site Helps Make Streets Friendly For Traffic and Feet

In recent decades, suburbanization with single-use, low-density land developments has created environments where walking to and from destinations may not be safe or feasible. Walking is an environmentally friendly mode of transportation, which has grown in popularity as the health benefits have become better known. However, pedestrian facilities such as multiuse paths and sidewalks to commercial areas need to "catch up" with development.

To create more walkable communities, planners and transportation professionals need to integrate land use and transportation planning, create more infill development, and encourage changes in zoning laws and other restrictions to allow for more pedestrian connections, such as sidewalks, easy-to-access crosswalks, and shared-use paths.

Several years ago, the Federal Highway Administration (FHWA) started encouraging transportation planners to help develop more pedestrian-friendly communities. In 2002 FHWA published a handbook, *Pedestrian Facilities User Guide—Providing Safety and Mobility* (FHWA-RD-01-102), that provides descriptions of engineering countermeasures and treatments that planners and engineers can implement to improve pedestrian safety and mobility. FHWA recently modified the handbook to create an online resource known as "PEDSAFE," which includes a pedestrian safety guide and a countermeasure selection system. Located at www.walkinginfo.org/pedsafe, the new Web site features information from the 2002 user guide, along with a wealth of other resources and tools. Although FHWA designed the site primarily for engineers, planners, safety professionals, and decisionmakers, the public also may find it useful for identifying problems and recommending solutions in their own communities.

One Location, Many Resources

At the "PEDSAFE" Web site, users can access various resources and information on walkable communities. The background section, for example, contains information on the public demand for walkable communities, the link between walking and transit, the ways that streets and traffic affect pedestrians, and the relationship between the Americans with Disabilities Act and walkable communities.

In the crash statistics section, users can access data on pedestrian-related crashes and learn about the factors involved in pedestrian incidents. Darkness and alcohol use, for example, are common factors in fatal pedestrian crashes, which typically peak between 5 p.m. and 11 p.m.

A section on implementation provides users with information and resources on pedestrian-friendly measures. Here, users can download information, for example, on walkable audits—reviews of walking conditions conducted by community members along specified streets.

Finally, in the downloads section, users will find links to additional information on pedestrian-friendly environments, including links to dozens of other Web sites, handbooks, and guidelines for constructing sidewalks, walkways, and crosswalks.

Useful for Planners

FHWA designed the online tools to provide users with a comprehensive inventory of potential engineering, education, or enforcement treatments to improve pedestrian safety and mobility.

The selection tool enables users to input information on project objectives, location, and operational character-

FHWA's new "PEDSAFE" Web site features a pedestrian safety guide and countermeasure selection system.

istics, and then provides a list of countermeasures that can make project sites more pedestrian friendly. The Web site also features interactive matrices that can help users choose the most effective countermeasures, according to varying crash types and performance objectives. By using the performance objective matrix, for example, users will view methods to improve pedestrian access and mobility by installing raised medians or barriers in the center of the street, which can serve as places of refuge for pedestrians.

This countermeasure, along with 48 others, is featured under the "PEDSAFE" countermeasures tool. Divided into seven categories such as traffic calming, roadway design, and signals and signs, the treatments and programs selected for inclusion in this part of the site have been in place for some time or were proven effective by the time FHWA produced the new Web site.

Case-by-Case Basis

In addition to the background information, resources, and tools available on the "PEDSAFE" Web site, users can review real-world examples of implemented treatments for creating walkable communities. Categorized by location and countermeasure group, each case study includes a description of the problem, relevant background information, a description of the implemented solution, any quantitative or qualitative results from evaluation studies or assessments, and a point of contact for further information.

The city of Bellevue, WA, for example, identified several problems that contributed to a reduction in safety for children walking to and from school, including a lack of sidewalks, excessive vehicle speeds in school zones, and vehicles parked too close to crosswalks. To remedy the problems at one location, the city installed a raised crosswalk to reduce vehicle speeds and improve pedestrian visibility. At 76 millimeters (3 inches) high and 6.7 meters (22 feet) in length, the raised crosswalk performs effectively as an asphalt speed hump. The city also installed crosswalk signs at the raised crosswalk and pavement markings on both sides to notify drivers about the raised roadway. In addition, planners added curb extensions to shorten the pedestrian crossing distance and improve sight distance for pedestrians, especially children. In addition, the planners developed an educational campaign for students at the nearby elementary school.

Since completion of the Bellevue project, the city has conducted studies to compare preproject and postproject vehicle speeds. During the hours before and after school, the 85th percentile speed dropped from 47 to 42 kilometers per hour (29 to 26 miles per hour). Field observations confirm that the project successfully eliminated parking near the crosswalk.

This example is just one of the successes featured on the "PEDSAFE" Web site. By providing detailed information and useful tools and resources, the new site will help ensure that streets in the future also consider pedestrians in the design.

Keri A. Funderburg 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 (TFHRC) Web site at www.tfhrc.gov, FHWA's Web site at www.fhwa.dot.gov, the National Transportation Library's Web site at http://ntl.bts.gov, or the OneDOT information network at http://dotlibrary.dot.gov.

Characteristics of Emerging Road and Trail Users and Their Safety
Publication No. FHWA-HRT-04-104

FHWA undertook this study to clarify the operational characteristics of an increasingly diverse group of trail and other nonmotorized transportation users. Three "Ride for Science" data collection events were conducted to obtain the physical trail dimensions, turning capabilities, lateral operating space, acceleration, speed, and stopping sight distance that trail users encounter. The results confirmed the diversity in the operating characteristics of road and trail user types. Below are highlights from the report's findings:

Sweep width for inline skaters. The sweep width of inline skaters falling in the 85th percentile of all sweep width measurements was 1.5 meters (4.9 feet), which actually is wider than the AASHTO recommended width for bike lanes.

Design speed. Out of all types of trail users, recumbent bicyclists had the highest observed 85th-percentile speed, clocking in at 29 kilometers per hour (18 miles per hour)—less than the American Association of State Highway and Transportation Officials' (AASHTO) minimum design speed.

Horizontal alignment. Most users did not reduce their speeds for turning radii greater than 16 meters (52.5 feet).

Stopping sight distance. A recumbent cyclist falling in the 85th percentile of measured stopping sight distances required a distance of only 32.7 meters (107.3 feet) on wet pavement—less than the AASHTO design speed.

Vertical alignment and crest vertical curves. Recumbent bicyclists required a crest vertical curve 46.7 meters (153 feet) in length—less than the AASHTO value.

Signal clearance intervals. Five-second clearance intervals did not provide sufficient time to clear a five-lane, 18.3-meter (60-foot) wide intersection for users with clearance times falling at the 85th percentile or higher.

Characteristics of Segway® users. Many characteristics of Segway human transporter users were comparable with those of other emerging trail users.

These findings suggest that design guidelines may need to be revised to incorporate the needs of emerging trail users. The results of this study can be used to help design professionals adequately design roadway and shared-use path facilities to meet the operational and safety needs of this growing group of users.

To view the report, visit www.tfhrc.gov/safety/pubs/04104/roadstechbrief.pdf.

Long-Term Pavement Performance (LTPP) Year in Review 2004
Publication No. FHWA-HRT-04-125

In 2004 the Long-Term Pavement Performance (LTPP) program continued working toward optimizing the public's investment in the highway system by providing the information, data, and products that highway engineers and managers need to design, build, maintain, and manage more cost-effective and better performing roads. This report outlines LTPP's 2004 program area accomplishments and how the extension of the Transportation Equity Act for the 21st Century impacted the LTPP program.

To view the report, visit www.tfhrc.gov/pavement/ltpp/reports/04125/04125.pdf.

Guide for Curing of Portland Cement Concrete Pavements
Publication No. FHWA-RD-02-099

This document provides guidance on the details of concrete curing practices as they pertain to the construction of portland cement concrete pavements. The guide is organized around the major steps involved in curing pavements—curing immediately after placement (initial curing), curing during the period after final finishing (final curing), terminating the curing process, and evaluating the effectiveness of the curing process. The publication also offers specific information on selecting curing materials and procedures, analyzing concrete properties and jobsite conditions, and adjusting the curing practice to account for specific project conditions.

Conferences/Special Events Calendar

Date	Conference	Sponsor	Location	Contact
Sept 7–11, 2005	National Transportation Public Affairs Workshop	American Association of State Highway And Transportation Officials (AASHTO) and Delaware Department of Transportation	Rehoboth Beach, DE	Terry L. Petrucci 302-760-2077 petrucci@state.de.us www.aashto.org
Sept 13–16, 2005	ITSC '05 8th International IEEE Conference	Intelligent Transportation Systems Society And Institute of Electrical and Electronics Engineers (IEEE)	Vienna, Austria	Lydia Novoszel +43-1-595 48 96 39 office@itsc2005.at www.itsc2005.at
Sept 15–20, 2005	AASHTO 2005 Annual Meeting	AASHTO	Nashville, TN	Hannah Whitney 202-624-5800 hwhitney@aashto.org www.aashto.org
Sept 21, 2005	Freight Capacity Challenges	FHWA Office of Freight Management and Operations and Office of Planning	Webcast	Carol Keenan 202-366-6993 carol.keenan@fhwa.dot.gov talkingfreight.webex.com
Sept 22–23, 2005	6th International Conference on Walking in the 21st Century	Walk21 2005 Organisation	Zurich, Switzerland	Ingrid Schmid (++41) 1-252-40-70 info@walk21.ch www.walk21.ch
Sept 27–29, 2005	Intertraffic North America	American Road & Transportation Builders Association (ARTBA)	Baltimore, MD	Beth Tilahun 202-289-4434 btilahun@artba.org www.northamerica .intertraffic.com
Oct 6–7, 2005	The 17th Annual Conference on Public-Private Ventures in Transportation and Federal Highway Administration Workshop on Project Finance	ARTBA	Washington, DC	Ed Tarrant 888-821-9653, ext.119 etarrant@artba.org www.artba.org/meetings _events/2005 /PPV _Conference/index.htm
Oct 16–19, 2005	National Bridge Conference	Precast/Prestressed Concrete Institute	Palm Springs, CA	John Dick 312-360-3205 jdick@pci.org www.pci.org
Oct 19, 2005	Freight Security: Effects on Industry	FHWA Office of Freight Management and Operations and Office of Planning	Webcast	Carol Keenan 202-366-6993 carol.keenan@fhwa.dot.gov talkingfreight.webex.com
Oct 24–28, 2005	14th Argentine Congress of Road and Traffic	Institute of Transportation Engineers (ITE), Asociación Argentina de Carreteras	Buenos Aires, Argentina	Analia Wazlo (+54-11) 4372-3519 (+54-11) 4371-0083 expovial@aacarreteras.org.ar www.ite.org/meetcon /argentina_congress.pdf
Nov 3–5, 2005	Society of Women Engineers National Conference 2005	Society of Women Engineers	Anaheim, CA	Jeanne Elipani 800-892-2858 jeanne.elipani@swe.org www.swe.org/2005

Date	Conference	Sponsor	Location	Contact
Nov 3–6, 2005	Fifth International Conference on Plain Language	The Plain Language Association International	Washington, DC	Sarah Cooper 800-833-1354, ext. 103 sarah@nataliepshear.com www.centerforplainlanguage.org
Nov 6–10, 2005	12th World Congress on Intelligent Transport Systems	Intelligent Transportation Society Of America (ITSA)	San Francisco, CA	Sandra Fitzgerald-Collier 202-721-4214 scollier@itsa.org www.itsworldcongress.org
Nov 7–10, 2005	6th National Conference on Transportation Asset Management	Transportation Research Board (TRB)	Kansas City, MO	Tom Palmerlee 202-334-2907 tpalmerlee@nas.edu Brian Canepa 202-334-2966 bcanepa@nas.edu www.trb.org/conferences/asset
Nov 16, 2005	Freight Models: State of the Practice and Needs for Improvement	FHWA Office of Freight Management And Operations and Office of Planning	Webcast	Carol Keenan 202-366-6993 carol.keenan@fhwa.dot.gov talkingfreight.webex.com
Dec 14, 2005	Considerations of Freight in Disaster Planning	FHWA Office of Freight Management And Operations and Office of Planning	Webcast	Carol Keenan 202-366-6993 carol.keenan@fhwa.dot.gov talkingfreight.webex.com
Jan 22–26, 2006	TRB 85th Annual Meeting	TRB	Washington, DC	Linda Karson 202-334-2362 lkarson@nas.edu www.trb.org

On the Road to Stewardship

International Conference on Ecology and Transportation

August 29–September 2, 2005
San Diego, CA

Sampling of Technical Sessions

- Aquatic and Marine Ecosystems
- Bioacoustics: Terrestrial Noise Impacts and Barotrauma on Aquatic Organisms
- Context Sensitive Solutions
- Regulatory Streamlining, Stewardship, and Sustainable Solutions
- Transportation Corridor Vegetation Management
- Wildlife Impacts and Conservation Solutions

Who Should Attend?

Transportation planners, engineers, ecologists, environmental consultants for transportation projects, university researchers, students, and nonprofit/industry representatives

Join Us!

For more information, visit www.icoet.net
or contact:

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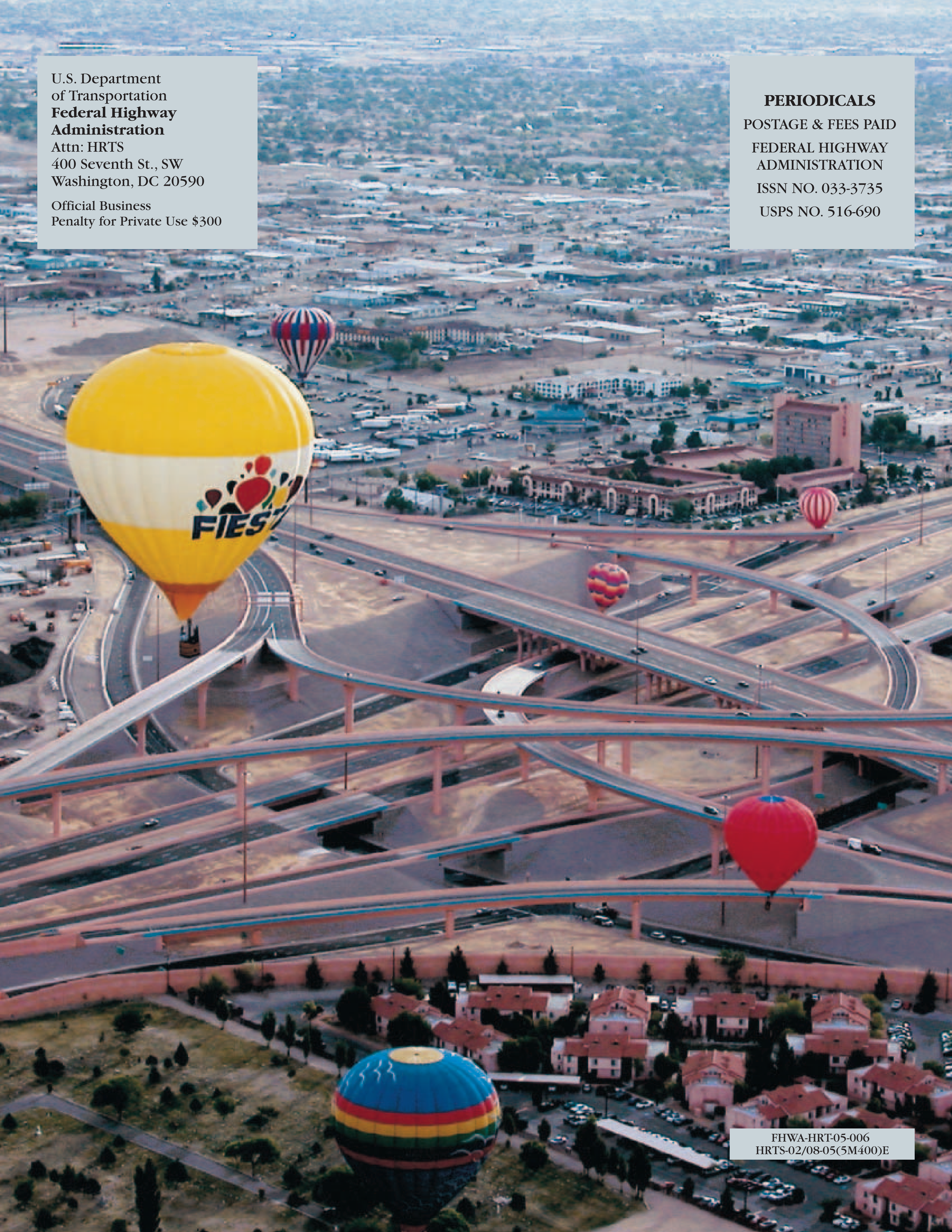

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