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COVER: Truck-only lane emerges from tunnel on Southbound I-5 near Santa Clarita, California—a solution for handling increases in freight volumes, and one of many innovative strategies encountered on 2007 state field visits by TRB staff. (Photo by Duncan McIntosh, Caltrans.)

TR NEWS

features articles on innovative and timely research and development activities in all modes of transportation. Brief news items of interest to the transportation community are also included, along with profiles of transportation professionals, meeting announcements, summaries of new publications, and news of Transportation Research Board activities.

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ALSO IN THIS ISSUE:

COMING NEXT ISSUE

An overview of the first group of safety projects sponsored through the Strategic Highway Research Program 2, the contributions of an early public roads administrator to the development of rural free delivery, and the most important question in engineering are among the topics of articles in the March–April issue of *TR News*—which also includes photographic highlights from the 2008 TRB Annual Meeting.

(*Above:*) A delegation of transportation officials from Iraq, led by Construction and Housing Minister Bayan Dezei (*seventh from right*), attended TRB's 87th Annual Meeting in January and were greeted by former U.S. Secretary of Transportation (DOT) Norman Mineta (*fourth from left*) and TRB Executive Committee Vice Chair Debra Miller (*fifth from right*). Poster presentations (*left*) and podium sessions engaged the participation of more than 10,500 registrants. A highlight was the Dialogue on Reforming Federal Transportation Policies and Programs, featuring a panel of U.S. DOT leaders, including (*below, left to right:*) Krista Edwards, Paul Brubaker, John Hill, and Tyler Duvall.

A Roadway Photolog Goes High-Definition

Connecticut Expands User Network, Realizes Cost Savings

BRADLEY J. OVERTURF

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On October 26, 2006, a Connecticut Department of Transportation (DOT) photolog van drove eastbound along Route 920, the newest route in the Connecticut state highway network. With all systems running, the vehicle rolled slowly by the just-completed Connecticut Convention Center in Hartford, a destination worthy of the new access road.

At the end of the route, all systems were stopped with the push of the F4 computer key, and the data—including the high-definition (HD) images at a resolution of 1920 × 1080 pixels—were saved to several computer system hard drives in the back of the van.

The filming of Route 920 marked the end to Connecticut DOT's most successful season of collecting photolog data. From late May to the end of October 2006, as part of its annual automated inventory, Connecticut DOT's Data Services Section collected HD images for every 10-meter section of state-maintained roadway in Connecticut—more than 1.2 million images. For the first time, the images were distributed incrementally for desktop viewing to approximately 400 agency users via the department's local area network.

Connecticut became the first state—and possibly the first governmental agency in the world—to complete a ground-based, automated HD image inventory for its entire roadway network. Connecticut DOT has developed a unique system of quality control, image editing, and distribution known as the DigitalHIWAY System, which makes the images available to a growing number of users, usually within one to two days of filming.

Image Quality

The success of Connecticut DOT's photolog program is a result of a continuous effort to improve photolog value and to increase the base of users. The latest research project started in February 2003 with support from the Federal Highway Administration (FHWA). The goal was to improve the photolog imaging technology and the delivery of images to clients. The project, New Technologies for Photolog Image and Data Acquisition, responded to requests from photolog clients for enhanced image retrieval that could provide better image resolution, allowing the capability of reading such details as small roadway signs, bridge numbers, and utility pole numbers.

High-definition (HD) photolog image from Route 920, Hartford, Connecticut.

Zoom image (*left*) from low-resolution (640 x 480 pixels) 2003 photolog. Fine details are unclear.

In 2003 the photolog camera produced images at a low resolution of 640 x 480 pixels, which precluded clear and detailed viewing. At the same time, researchers at FHWA and the University of Connecticut were attempting to employ pattern recognition to extract automatically the attributes of lanes, pavement markings, signs, and curbs from photolog images. The researchers had met with limited success because of the low resolution of the images.

Although many aspects of photologging had undergone upgrade and improvement, Connecticut DOT had not addressed image quality since 1997. The Division of Research and the Data Services Section were aware that new technologies—such as high-resolution digital cameras and high-definition cameras—could improve the viewing applications for photolog clients immediately and could allow for many new applications.

Choosing the Camera

The first task was to identify a camera. An extensive three-month search ended at the 2003 convention of the National Association of Broadcasters in Las Vegas, Nevada. A photolog and imaging expert from Connecticut DOT's project partner, the Connecticut Transportation Institute (CTI) at the University of Connecticut, traveled to the convention to identify a camera that would optimize the imaging.

Thomson Grass Valley Worldcam, chosen for Connecticut DOT's high-definition image gathering.

Connecticut DOT and CTI selected the Thomson Grass Valley Worldcam LDK 6000 MK II for evaluation. The camera captures progressive-scan high-definition images with three 9.2-million pixel, high-definition, charge-coupled devices in multiple formats. A demonstration by Thomson at the Connecticut DOT photolog facility in July 2003 confirmed the camera's functionality and the extraordinary quality of the images.

In-Vehicle Installation

The Roadware Group, Inc., of Paris, Ontario, Canada, was charged with incorporating the HD technology into the vehicle. Connecticut DOT has owned and operated two of Roadware's Automatic Roadway Analyzer (ARAN) vans since 1994.

The vehicles consist of a standard cutaway van chassis affixed to a large rear cube with ample space for the vehicle system modules, an operator console, a power generator, and a backup generator. The onboard systems include a Global Positioning System (GPS); a gyroscope that accurately measures roadway curvature and grade; laser-based modules for collecting data on roughness and on the vertical underclearance of structures; ultrasonic rut-depth measurement; automated pavement crack detection; and a new HD image capture system.

The modular design of the vehicles allowed replacement of the old imaging system with HD, and addressed the first of three major challenges:

1. The image quality had to improve dramatically over that of the previous camera;
2. The large-format HD images had to be converted on the fly to a JPEG file format; and
3. Onboard storage had to be increased to accommodate the larger files.

Solutions to these challenges had to be implemented without adversely affecting clients who depended on access to the photolog roadway images and data.

Connecticut DOT photolog vans were reconfigured for HD equipment and image storage.

Dual camera views from the old camera system (*above*), compared with single HD image of the same roadway segment (*below*).

Answering the Challenges

The Thomson camera answered the first challenge. The image quality was better, and it allowed Connecticut DOT to eliminate a dual camera system that doubled the imaging hardware in the van and accumulated twice as many images as a single camera system. The old system's images were difficult for field and office personnel to manage and move across Connecticut DOT's computer network.

The single HD camera, mounted just above the dashboard, replaced two seven-year-old Sony DXC-9000 digital video cameras, one facing forward and one facing out the passenger side of the rear cube. These had generated forward view and side view photolog images.

A Canon HJ11EX4.7 High Definition lens was chosen for the new camera. The lens captures images at the high-definition standard 16 × 9 aspect ratio, with a 4.7 mm to 52 mm zoom. The focal length of the lens is fixed at 4.7 mm to maximize the field of view. At this setting, the camera captures in a single image a field of view similar to that of the old dual camera system, eliminating the need for a second camera.

The HD camera was acquired in early 2004, and Roadware Group's imaging systems engineers proceeded to install it. A critical task was identifying an HD capture card that was compatible with the camera and adaptable to the ARAN system. Trial and error identified the Xena HD PCI card from AJA Video Systems, Inc.; Roadware tested and installed the card in a new computer at its facility for software development in January 2005.

Harvesting the Images

Roadware had developed the computer software, Harvest, two years earlier for lower-resolution digital cameras and adapted it for the AJA card in late winter and spring 2005. The user can configure the software to collect images at intervals of 5 to 20 meters at various standard JPEG compression rates. The software initiates when the ARAN system starts up and runs seamlessly with all other subsystems.

For Connecticut DOT, Harvest is set up to capture a JPEG-formatted image at 10-meter intervals. Each

Portion of an HD image of Route 920, Hartford, which was distributed to the DigitalHIWAY client network on the same day.

image is saved to an 80-gigabyte removable hard drive, and a backup copy is saved simultaneously to a mirrored 1-terabyte external hard drive.

After the file format and storage approach were chosen, the first of Connecticut DOT's ARANs was delivered in May 2005. After a short period of calibration and testing, the unit was deemed ready to operate. It collected HD images for approximately 40 percent of the 2005 network. The second vehicle was retrofitted in winter 2006, preparing Connecticut DOT for an all-HD collection beginning that spring.

Effective Image Distribution

After filming Route 920, the field crew returned to the Office of Research and Materials Testing Laboratory in nearby Rocky Hill. They parked the vehicle in the designated garage, plugged into shore power, switched on the appropriate systems computers, connected a network cable into a gigabit Ethernet switch, and downloaded into an image and data editing computer.

Because the route was close by and short in length, the image and data editing was completed and the final product was distributed that same day to approximately 500 photolog clients throughout the DOT, the State Police, and the FHWA state headquarters in Glastonbury.

While Roadware upgraded the ARAN, Connecticut DOT worked with a systems developer to update and improve the client-server application—that is, the DigitalHIWAY System.

Before the HD project, Connecticut DOT had been photologging for nearly 30 years. The Data Services Section and the photolog program have been successful not by archiving millions of images but by focusing on distributing the images to as many clients as can benefit.

In the 1970s, the photolog was viewed on three filmstrip displays in the basement of the department's headquarters building. In the 1980s, the user base grew to 16 customized laserdisc-based stations controlled by the then-new personal computer (PC) and an exorbitantly priced graphics generator. Advances in PC technology in the 1990s significantly lowered the cost of laserdisc stations, and the department set up 30 photolog stations. Finally, in the early part of this decade, Connecticut DOT converted to distribution via DVD and an agencywide client-server.

System Modules

The DigitalHIWAY System includes three modules: the Incremental Index and Editor, the ImageServer, and Client. The Incremental Index and Editor postprocesses the raw streams of collected data into a form suitable for delivery via the ImageServer to the software Client on the end-user's desktop.

Postprocessing

During postprocessing, image and nonimage data streams are associated and checked for completeness. Multiple photolog film sessions can be edited into a seamless ImageServer data set, so that long routes can be photologged in separate segments. The department's traditional linear referencing of locations is applied to correlate the images with the images from the previous year.

The final step in the postprocessing of images from a route or direction is the creation of a concatenated JPEG library (CJL) file and an upgrade file that contains a new route index for the end user. The CJL file serves as a single container for all images of a route or direction.

Incremental Index and Editor's linear-referencing screen shows the 2005 image (*right*) with the 2006 image proposed for a checkpoint.

CJL files are an efficient file format, easily managed by both the administrator of the DigitalHIWAY system and the end user. A system administrator can manage image data more easily when a single file replaces hundreds of individual image files in a complicated directory structure. Ease of copying increases because no single picture can get lost. For the DigitalHIWAY end user, the indexed CJL files speed up retrieval.

Each individual JPEG image file from the ARAN is copied directly into the receiving CJL file, along with a small index for rapid access to any image. The ImageServer accesses CJL files from a co-located disk array and transmits them via the network to DigitalHIWAY clients. The CJLs also are mastered on a DVD for distribution to clients not on the network.

The Incremental Index and Editor can operate in a single-route mode, providing users with daily access to images and data, or in batch mode, which allows the operator to create indices and georeferencing for multiple routes. The single-route mode provides quick postprocessing after a day's photologging, as well as rapid delivery of the images to the end user's PC.

System Server

The ImageServer sends CJL route images to users via the DigitalHIWAY System protocol layered on top of the standard transmission control and Internet protocols. The software runs on any Microsoft server-based PC and can be administered locally or remotely with the DigitalHIWAY ImageServer Controller.[1]

The ImageServer distributes the index file updates created by the Incremental Index and Editor to client workstations. Client software upgrades and repairs also are made this way, maintaining uniformity and compatibility for all end users. In addition, the ImageServer distributes a "Data Services News" feature that lets the Data Services Section communicate with users about DigitalHIWAY and photolog operations (see photo, this page).

Client Interface

The Client module resides on individual PC workstations throughout Connecticut DOT and other state agencies.[2] Installation requires copying a single file to an empty subdirectory on the user's computer, and then running it once for setup.

After installation and start-up, the general user interface displays a list of all state-maintained highways by route and direction; the client is prompted to select a route. The software then loads the first CJL image, representing the start of that route and direction, along with a control window for forward and reverse motion, an HD image window, and an interactive link to traditional linear referencing locations along each roadway.

The Data Services Section distributes an electronic news bulletin with practical tips and updates for DigitalHIWAY users.

Users and Uses

Connecticut DOT offices using DigitalHIWAY daily include Permits, Planning, Geographic Information Systems, Maintenance, Pavement Management, Traffic Signals, Traffic Engineering, Design, Rights-of-Way, Central Surveys, Research, Materials Testing, Landscape Design, Bridge Design, Bridge Safety, Incident Management, the four district offices, the State Traffic Commission, the Chief Engineer's Office, and the Commissioner's Office.

Uses can be broken down into five categories: familiarization, review, confirmation, documentation, and presentation.

Familiarization

Photolog provides a safe and efficient way to gain familiarity with a roadway before a planned field trip. Rights-of-way property agents can review property being acquired or sold. Traffic engineers can study busy intersections without putting themselves or state property at risk during the work day. Staff in the commissioner's office or the chief engineer can view a location in a matter of seconds and address a variety of administrative issues.

Review and Documentation

Most clients describe the photolog as "a great review tool." With the photolog, any Connecticut DOT employee can perform a virtual field trip without leaving his or her desk. Employees can quickly review current or historic field conditions using the images and then determine if a field trip is warranted or if an operational decision can be made.

The review can lead to implementation of an operational improvement, such as a photolog-based feature inventory. Recent inventories performed with the photolog include guide rails, by Pavement Management; drainage features, by Central Surveys; and sign locations, by Maintenance. This valuable information previously went unrecorded or was recorded by laborious manual methods.

[1] The software runs as a service, so that if the server hardware shuts down for any reason, the DigitalHIWAY software will start automatically when the PC is rebooted.

[2] Connecticut DOT, the State Police, and the University of Connecticut own site licenses for DigitalHIWAY. At Connecticut DOT, DigitalHIWAY is preinstalled on every new PC.

DigitalHIWAY Client desktop view, showing HD image window, image control and options window, and virtual link to linear reference locations.

Confirmation and Documentation

Connecticut DOT photologs all state roads every year. DigitalHIWAY can access data going back to 1985 via online storage. For all state agencies as well as private-sector users, photolog is often the only accurate documentation for a given state roadway and its surroundings. The photolog technology augments and enhances utility audits, accident reconstruction and investigation, and safety studies. The Connecticut State Police have installed DigitalHIWAY on several computers in the accident investigation unit.

Presentations

HD images are a powerful presentation tool. The State Traffic Commission uses DigitalHIWAY at public meetings to present more clearly the changes proposed for roads and the impacts on communities, enhancing the public's understanding. The image export feature allows a client to save a picture for use in any word processing, spreadsheet, or presentation software.

At the University of Connecticut, professors and graduate students use the client-server application daily for classroom study and research on topics ranging from highway safety to geographic information systems and GPS.

Tracking Usage and Benefits

Incremental distribution of photolog data began with the HD implementation in 2006. The response to the improvements has been positive. Feedback, usage tracking, and cost savings analysis have confirmed Connecticut DOT's premise that agencies can derive millions of dollars in cost savings with photolog technology.

Viewing recently recorded roadway pictures on an office PC, for example, often can substitute for a field trip. The higher the quality of the collected data, the greater the user's confidence, so that more field trips—requiring fleet vehicles and person-hours—can be eliminated. This translates into dollars saved.

With improvements in PCs, local area networks, GPS, and storage technologies, DigitalHIWAY usage tracking is an easy-to-implement, comprehensive, and automated reporting tool. Usage tracking helps to justify the expense of the photolog operations and improves client support and outreach.

DigitalHIWAY distribution and retrieval software manages the flow of information to users, and it records how the data are being used. With this information, photolog staff can understand user needs and can derive critical cost savings.

During a session, the photolog usage tracking software measures a straight-line distance from the GPS coordinate of the Client location, determined by the computer's network name in the server's userlog file, to the coordinate of the route or direction and mile-point that the client has chosen to view. Data Services Sec-

Zoom image (*below*) from high-definition (1920 x 1080 pixels) 2006 photolog (*below, right*), clearly showing small text on signs.

tion staff can estimate the round-trip travel costs for each occasion of use with a formula that applies the GPS distance, the salary of the personnel, and the charges for the fleet vehicle.

Total savings, number of clients, logins, workstations, routes viewed, and percentage of all state routes viewed are reported to FHWA quarterly. User logs for the standalone DVDs are not gathered and reported, but the usage is estimated with data from the server.

The improvements made during the advanced imaging data acquisition technologies research project have led to a 58 percent increase in photolog usage of routes viewed—and to a 51 percent increase in savings since full implementation in 2006 (see comparison charts, below).

Sound Economic Sense

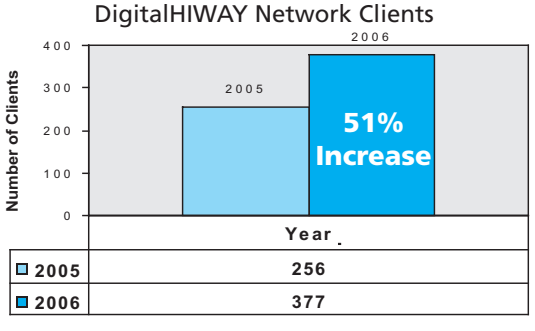
HD images, bridge underclearance, and incremental indexing and image distribution are the latest in a series of improvements to Connecticut DOT's photolog program. Savings from these technologies are impressive, even for a small state; savings in states with larger areas should be equally or more substantial.

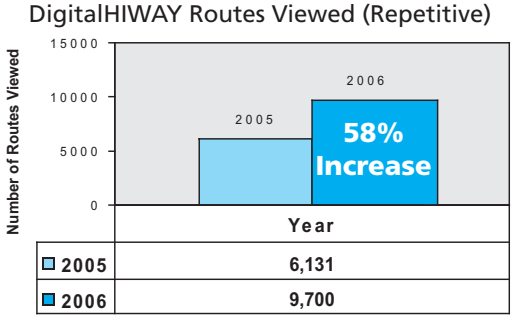
The Connecticut DOT experience indicates that it makes sound economic sense for state transportation agencies to allocate resources to improve and upgrade ground-based image and data acquisition systems as a high priority. Key to the investment is providing access to HD photolog images and data via local area networks and other media.

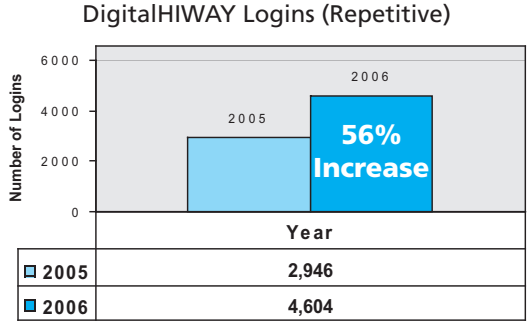
Ralph Carpenter, immediate past Connecticut Transportation Commissioner, described the photolog—shown on a notebook computer in his office—as a "valuable resource that saves time, increases employee safety and productivity, and augments field work performed by Connecticut DOT."

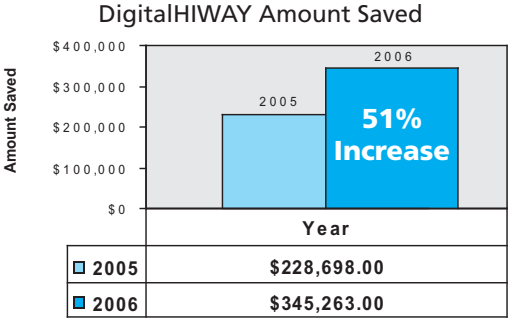
With the projections for standalone usage included, Connecticut DOT's 500 DigitalHIWAY users save the state an estimated $2 million per year in the costs of field trips. This delivers an impressive 3:1 benefit–cost ratio, based on the annual operating budget for this function.

Photolog has become a mainstream tool used daily by all Connecticut DOT bureaus, with a framework firmly in place to maintain use and allow for growth as the department changes. Connecticut DOT's experience extends the adage, "a picture is worth a thousand words," to include a thousand practical applications and millions of dollars saved.









TRB's 2007 FIELD VISIT PROGRAM

Partnerships for Progress in Transportation

Specialists in the Transportation Research Board's (TRB's) Technical Activities Division identify current issues, collect and generate information on the issues, and disseminate the information throughout the transportation community. The TRB Annual Meeting, TRB-sponsored conferences and workshops, standing committee meetings and communications, publications, and contact with thousands of organizations and individuals provide TRB staff with information from the public and private sectors on all modes of transportation.

A major source of this information is the TRB annual field visit program. Senior program officers in TRB's Technical Activities Division meet on site with representatives of state departments of transportation (DOTs) and also with representatives of universities, transit and other modal agencies, and industry. In addition, TRB staff members are involved with planning and delivering many conferences, workshops, and meetings. This report presents a summary of what the TRB staffers learned from visits and activities in the past year.

"Partnerships for Progress in Transportation" was the spotlight theme of the TRB 2008 Annual Meeting, January 13–17, in Washington, D.C. Progress in addressing the critical issues in transportation will require joint efforts and collaboration, and partnerships were a high-priority topic at the state DOTs and other agencies visited by TRB staff in 2007. The following report presents many examples of the ways that transportation agencies are forging partnerships to address and resolve such issues as aging infrastructure, congestion, safety, funding, energy, environment, security, and infrastructure protection and preservation.

Institutional Issues

Policy, Management, and Leadership

A surge of initiatives that could increase the role of the private sector in financing and operating transportation facilities marked 2007. Following the lead of Chicago in leasing the Chicago Skyway and of Indiana in leasing the Indiana Toll Road, many states pursued agreements or conducted studies of leasing or concession arrangements between public-sector transportation agencies and the private sector. The monetization of public-sector transportation facilities has prompted debates and studies of the financing, roles, and responsibilities of the public and private sectors in transportation.

The aging population and a changing workforce are affecting state DOTs throughout the country. Anticipating an increase in employee retirements, New Jersey DOT is preparing productive younger employees for management and leadership. In 2002, the agency established an Office of Succession Planning, which administers a voluntary program, limited to 60 participants, to match mentors with mentees. A "lunch and learn" series offers younger professionals the opportunity to meet with experienced senior staff in an informal setting to exchange information. The transfer of knowledge, the sharing of experiences and expertise, and the retention of institutional memory are the objectives of the program.

Virginia DOT also has established a Core Development Program to shape young rising-star employees into future leaders. In addition, Virginia DOT has started a knowledge management program to capture and preserve the institutional and professional knowledge of experienced employees.

PHOTO: VIRGINIA DOT

The Virginia Department of Transportation's 24-month Core Development Program prepares new hires and young employees for assuming critical roles within the department.

Planning

In an environment of constrained financial resources, rapidly changing construction costs, heavily congested facilities, and concerns about disaster response, the

planning community is adopting tools from other fields. One tool that has gained attention for improving the transportation planning process is risk assessment.

Risk assessment is a systematic examination of a task, job, or process to identify the hazards or problems that could arise, assess the likelihood of their arising, estimate the consequences, and identify measures to reduce the risk to an acceptable level. Many professions apply risk assessments, and transportation planners are finding many uses for the technique.

The planning risks associated with a project include problems with the project itself and problems with the cost estimates. Assessing project risks—such as exposure to unexpected hazardous materials—has long been part of the construction process but is now being included, in more approximate terms, during the planning process. The project risks become an input into the risk analysis for the project costs. At each step, the risk assessment and the measures identified to mitigate the risk are refined.

Legal Issues

Transportation attorneys at public agencies are responding to diverse issues:

- Highway and bridge design—Facing environmental concerns, challenges involving cultural and historical sites, and budget shortfalls, transportation professionals are looking to develop new tools for innovative design that also minimize the potential for tort liability.
- Highway construction claims disputes—The highway construction contract law community is fostering discussion of state-of-the-art, alternative dispute resolution practices and is applying these in many states to address and resolve multimillion-dollar construction claims. Strategies include the establishment of dispute resolution boards and the use of project realignment, an aggressive partnering practice.
- Eminent domain—In the 2005 decision on *Kelo v. New London*, the U.S. Supreme Court held that local governments can condemn property solely for economic reasons. The decision has no direct effect on state transportation agencies but has influenced nearly every state legislature to explore the extent of the state's eminent domain powers, including use in public–private partnerships.

Transportation lawyers also must keep informed about the ever-changing environmental laws and related developments. With the U.S. Supreme Court's 2007 decision in *Massachusetts v. Environmental Protection Agency*, climate change and air emissions from transportation have become major environmental issues. The Supreme Court accepted that carbon dioxide is a pollutant that should be regulated under the Clean Air Act. The decision also accepts the relationship between carbon emissions and climate change. The U.S. Environmental Protection Agency (EPA) now must determine how to regulate carbon dioxide emissions—a task that could take years. Moreover, the decision has spawned claims and lower court decisions that states preparing documents for roads in accordance with the National Environmental Protection Act now must address the contribution of automobile emissions to global warming.

Energy and Environment

Increasing public pressure and more rigorous environmental documentation requirements are shaping transportation agencies' approaches to environmental stewardship. Storm water management, wetlands mitigation, and air quality—including climate change—are among the key environmental challenges.

The measurement of storm water quality and the methods of mitigation for a network of highways are testing the resources of many state agencies. In highly populated states that have minimal amounts of land to spare, finding suitable wetland mitigation sites is delaying construction-related activities, sometimes indefinitely. In states with more rural or semirural communities, the effects of changes in the transportation system are gaining scrutiny, particularly in relation to cultural impacts on communities that no longer benefit from direct highway, rail, or aviation access.

Public pressure on the topic of local and global emissions levels is continuing to spur research into alternative fuel sources and ways to reduce fuel consumption, including increased use of public transportation. Biodiesels, hydrogen fuel cells, ethanol, and solar and electric fuel options for private and public vehicles are being looked at to reduce emissions that affect local air quality and human health and to reduce emissions that affect the global climate.

In 2005, New Jersey Gov. Jon Corzine mandated that the state's agencies must reduce energy consumption by 20 percent by 2020. New Jersey DOT commissioned the Voorhees Institute at Rutgers Uni-

CT Transit, which provides public transit for Hartford, New Haven, and Stamford, Connecticut, has tested a hybrid passenger bus that uses a zero-emission hydrogen fuel cell.

TRB's 2007
FIELD
VISIT
PROGRAM

PHOTO: NYSERDA

PHOTO: NYSERDA

New York State is promoting a Clean Air School Bus Program: (*right*) compressed natural gas powers school buses in the Long Beach Public School system, Long Island; (*below:*) a diesel closed-crankcase filter retrofit on a school bus engine in the Cobleskill Central Schools system, Schoharie County, near Albany.

versity to undertake an innovative study to estimate the effect of transportation control measures on energy consumption.

The study concluded that the governor's 2020 target was attainable with a mixture of 10 percent ethanol added to the gas supply; adoption of California's vehicle emissions standards by 2009, including a mandated percentage of zero-emission vehicles; continued investment in public transit; and implementation of a "feebate" program. Under the proposed feebate, the state would set a miles-per-gallon average; motorists whose vehicles performed better than the average would receive a rebate on their registration rates.

New York State DOT supports and funds the state's Energy Research and Development Authority, with approximately 200 projects under way, including the management of the state's Clean Air School Bus Program, which has converted 3,000 buses to alternative fuels. The program has funded the purchase of 10 clean-fuel buses for the New York Metropolitan Transit Authority and has deployed 1,500 additional clean-fuel buses nationwide.

Infrastructure Preservation

Infrastructure preservation is a comprehensive management approach to maintain the functional condition of the transportation infrastructure through cost-effective treatments that safeguard structural integrity and extend performance life for the safety, mobility, and benefit of users. In contrast to the "worst-first" approach, preservation programs optimize projects according to the engineering benefit–cost.

Transportation agencies have developed infrastructure management systems along traditional engineering lines, but managers are finding the need to merge these approaches into an enterprisewide system that focuses the limited funds on areas of higher benefit–cost. By integrating management systems through coordination and cooperation among agency divisions, agencies can improve the effectiveness of limited funding.

Agencies can assess the effectiveness of their program by determining the portion of the total network involved in major rehabilitation and reconstruction projects in any year. If 2 percent of the network is involved in these activities, the preservation program must extend the performance life between rehabilitation and reconstruction projects to an average of 50 years; if 3 percent, then 33 years; and if 4 percent, then 25 years.

If the performance life between major rehabilitation and reconstruction projects averages less than the durations cited, the network is deteriorating faster than it is being maintained. A holistic approach applies a combination of actions over many years by

- Implementing high benefit–cost engineering projects within a comprehensive preservation program to extend the performance life of 96 percent to 98 percent of the network;
- Incorporating infrastructure preservation actions into design-life considerations for major rehabilitation and reconstruction projects applied to the remaining 2 percent to 4 percent of the network; and
- Applying ordinary maintenance actions.

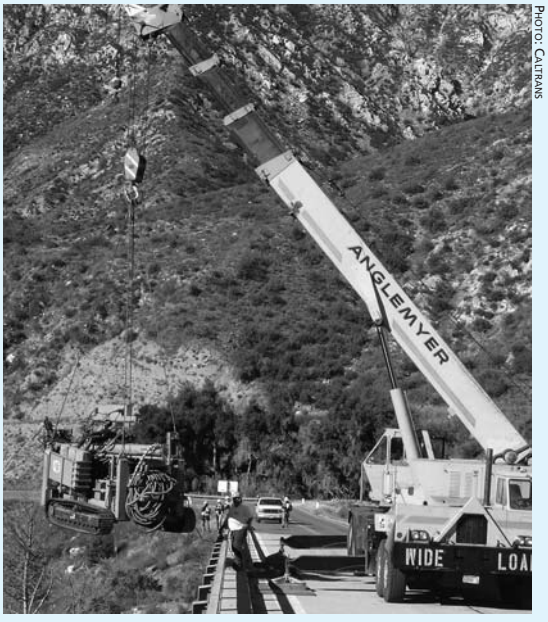


PHOTO: CALTRANS

A California Department of Transportation bridge rehabilitation project on Route 39.

Data and Information Technologies

Resource constraints continue to affect investment in data and information technology programs and tools. The complexity of the issues and a reduced workforce, however, are leading to the realization that improving the availability, access, and use of data to evaluate programs and inform policy development is important.

Many DOTs are aligning data resources with departmental priorities—evaluating the resources and developing investment strategies to assure relevant data quality. A key to cost-effective data programs is the development of cooperative programs to share data. In Pennsylvania, state and regional agencies share responsibility for much of the traffic data development. Carefully defined responsibilities, guidelines, and tools to facilitate data sharing contribute to data quality assurance.

Improved understanding of freight flows is a recognized need, as freight-related traffic is projected to grow at a faster rate than passenger traffic. States seek a better understanding of freight issues at the regional, state, and metropolitan levels, and timely data are a major challenge. States and consultants are looking for new ways to combine national data sets with proprietary data and targeted local data collection, to support projects and to gain a better understanding of the role of freight-related traffic. The current Freight Analysis Framework provides valuable information and tools to support regional work.

Aviation

Funding for the national aviation system and the future of the aviation industry are continuing concerns for state aviation officials. Officials are searching for innovative solutions to support the aviation network—especially general aviation airports.

Fuel costs and the related instability of the airline market, the loss of U.S. DOT subsidies, and the fate of the Essential Air Service program contribute to the uncertainty at most airports throughout the country. The new very light jet market is slowly taking off, but its potential to change the national airspace system and its airports remains a subject for speculation.

PHOTO: JOHN MICHAEL ENTERPRISES, LLC

The Federal Aviation Administration certified the first very light jet—or entry-level business jet—in September 2006 for single-pilot operation, day–night operations, visual and instrument flight rules, and operations in reduced visual separation minimum airspace.

The federal government is reviewing funding for such major needs as air traffic control and airport infrastructure throughout the aviation system. Fuel taxes, user fees, and other charges now in place may not be sufficient to cover these needs, and their equitability among users of the system has become a topic of debate.

Freight Systems

Freight has become a critical issue for most states, with growth in freight volumes evident in congested highways, ports, intermodal facilities, and rail lines. Adequate freight capacity in all modes is needed to sustain business and to foster new economic development, adding urgency to the involvement of public agencies with private industry.

To facilitate the dialog between public and private interests in freight and to educate elected officials, Maryland DOT conducted the Maryland Freight Summit, highlighting the importance of freight to the state's economy and putting the state's freight-related challenges and opportunities into a national and international perspective. Iowa DOT held a combined economic development and transportation conference, bringing rail and truck carriers and users together to explore interactions that support the econ-

PHOTO: DUNCAN MCINTOSH, CALTRANS

Dedicated truck lanes merge onto I-5 near the SR-14 Interchange, north of Los Angeles, California.

omy. Such efforts can bridge the gulf between the public and the private sectors, shifting the focus to shared concerns and interests.

As large metropolitan areas experience the effects of increased truck flows, officials are exploring alternatives to improve mobility. The Atlanta Regional Commission, for example, has undertaken a comprehensive mobility study, working closely with public and private stakeholders. In a related effort, Georgia DOT is studying the possibility of truck-only lanes in sections of the Interstate and limited-access highways in Atlanta and in other major freight corridors across the state.

Freight transportation has been described as "the economy in motion," and the public sector's roles and responsibilities are evolving with greater understanding of the implications for the economy, the environment, and quality of life.

Highways

Design

In pavement design, TRB's National Cooperative Highway Research Program (NCHRP) developed the *Mechanistic–Empirical Pavement Design Guide* for the American Association of State Highway and Transportation Officials (AASHTO). The guide represents a longstanding collaborative effort by the states, AASHTO, the Federal Highway Administration (FHWA), NCHRP, and countless researchers in the United States and abroad.

The AASHTO Standing Committee on Highways adopted the guide in 2007 as an interim specification, and states are now conducting field and laboratory calibrations to develop computer input data and to run computer trials to test the sophisticated design tool. The guidelines should enable engineers to design more durable, longer-lasting pavements that will reduce the need for pavement repairs, including the time spent by maintenance and construction crews in resurfacing and rehabilitating the nation's highways.

The promotion and implementation of accelerated bridge construction with prefabricated bridge elements and self-propelled modular transporters is another significant result of collaboration among the states, AASHTO, FHWA, and NCHRP. Projects in Florida and Utah have demonstrated the feasibility of these design and fabrication methods and construction technologies to construct bridges rapidly with minimal disruption to the motoring public or to freight transport. With load and resistance factor design (LRFD) standards applied to bridge superstructures, substructures, and high-performance materials, bridges are being designed for greater durability and service life.

In addition, context-sensitive design and solutions for pavements and bridges allow for projects that are more closely related to community values and aesthetic preferences. The design approaches require much more community outreach and public involvement than in the past but are being adopted quickly and successfully by many states.

Highway Construction and Materials

The deteriorating and congested infrastructure remains a construction challenge for state DOTs faced with materials shortages, increasing construction costs, reduced competition, widening gaps in funding, and a depleted workforce. States are looking for cost savings and innovative ways to deliver construction projects.

One state is controlling project costs through practical design, value engineering, competitive alternate bidding, and employee incentives for mitigating contract growth. Another state has established a recruitment program with community colleges to address the shortage of construction labor.

With most work now performed under heavier traffic conditions than in the past, state DOTs must apply methods that minimize disruptions and produce long-lived facilities. States are anticipating the results from studies under the Strategic Highway Research Program 2 dealing with rapid renewal.

States are striving for good environmental stewardship with construction materials. Most allow hot-mix asphalt with a content of 10 to 25 percent recycled asphalt pavement (RAP). This may increase to 50 percent, helping to reduce the accumulating stockpiles of RAP. States also are evaluating the viability of warm-mix asphalt, which produces fewer emissions. Some states allow fly ash, a byproduct of coal combustion, in concrete, but others are awaiting the results of an NCHRP project on recommended specifications and test protocols.

PHOTO: MISSOURI DOT

Construction on the I-64–I-70 interchange outside St. Louis employed Missouri DOT's practical design approach.

Geotechnical Engineering

All state DOTs were required to convert to the LRFD method for the design of structural foundations as of October 1, 2007. The mandated conversion should produce consistent levels of reliability, as well as cost savings. States are at different stages in implementing LRFD.

Several state DOTs have developed or updated their soil investigation and geotechnical design manuals, and others are in the process. Interest in nondestructive testing—such as seismic, electromagnetic, and electric methods—has increased.

Cross-hole sonic logging (CHSL), a test of the integrity of drilled shafts, is becoming a common practice among state DOTs. Some test all the shafts, others test a required minimum percentage of the shafts, and others test only if problems develop. Most DOTs hire consultants who are certified to perform the tests. California DOT (Caltrans) routinely conducts its own gamma-gamma logging to test the integrity of drilled shafts; but when anomalies are detected, CHSL is used to determine the details.

For quality assurance and quality control of earthworks, states have tried many devices but most still rely on the nuclear gauge to determine the density of compacted material. The search for nonnuclear devices has not revealed any with the required accuracy, repeatability, or ability to correlate the measured property with the density.

Rock fall–related issues are a concern for most states. A new TRB report, *Rock Fall Characterization and Control*, prepared by a task force chaired by A. Keith Turner, is expected to serve as a single source of information on many aspects of rock falls. Publication of the report is expected later this year.

PHOTO: CALTRANS

Technician with Caltrans Foundation Testing Branch inserts a gamma-gamma logging probe over rebar cage for a drilled shaft.

PHOTO: U.K. HIGHWAYS AGENCY

As part of an active traffic management strategy, a hard shoulder is opened on the M42 highway near Birmingham, England. U.S. agencies are adopting the approach of applying a toolbox of countermeasures to manage roadway congestion.

Highway Operations

According to surveys, highway users are frustrated by the lack of reliability in their journey time. Traffic operations professionals are focusing on new strategies to improve travel time reliability.

Active traffic management (ATM) is a toolbox of countermeasures that can be used in various combinations to manage congestion dynamically in response to prevailing traffic conditions, by maximizing the use of road space. As traffic congestion increases, various countermeasures are applied—not necessarily all at once—including improved detection, dynamic speed limits, electronic variable message and lane control signs, temporary shoulder use, ramp metering, managed lanes, and dynamic rerouting. These countermeasures are all controlled and implemented as needed from the traffic management center (TMC).

The TMC continually monitors the traffic congestion information from detectors and surveillance cameras. When the traffic data indicate that the traffic flow is about to break down, variable speed limits are introduced to smooth out the traffic flow and allow traffic to travel closer together, so that more vehicles can use the roadway. If congestion increases, ramp metering will go into effect to regulate how many vehicles can merge into the mainline traffic and to minimize the impact of traffic merging all at once. If congestion still increases, then the shoulders will be opened to traffic to provide an additional travel lane until the congestion dissipates.

A motorcycle–car collision near the township of Oshtemo, Kalamazoo, Michigan. Motorcycle fatalities increased by 9 percent in 2007 and now exceed pedestrian fatalities.

ATM has been deployed in Europe and other parts of the world and is now being tried in California and is being considered by other states.

Highway Safety

The number of traffic deaths declined to 42,642 in 2006 from 43,510 in 2005. This resulted in a fatality rate of 1.42 per 100 million vehicle miles, down from the 2005 rate of 1.46. Motorcycle fatalities rose for the ninth year in a row, up 9 percent in 2006, from 4,576 to 4,810, exceeding pedestrian fatalities (4,784) for the first time.

Although crash numbers, rates, and costs are reported annually, the magnitude of the highway safety problem becomes more apparent when the numbers are considered across several years. First, the change in the numbers is not encouraging—44,599 fatalities in 1990 to 42,642 in 2006. With 43,000 fatalities as a rough annual average, approximately 731,000 people have died on U.S. roads since 1990. The National Highway Traffic Safety Administration estimates the annual crash cost at $230 billion; that yields a cumulative cost of more than $3.9 trillion since 1990. Systematic and focused efforts to reduce the numbers of crashes, therefore, have a large potential to save lives, prevent injuries and suffering, and decrease costs.

A few states have made progress in the past three to five years. NCHRP and FHWA prepared case studies of four states—Iowa, Michigan, Minnesota, and Washington—that have reported continuing trends in reducing fatalities. The case studies highlight management processes, data reporting, and multidisciplinary techniques. Other states, such as Missouri and Colorado, are developing similar trends.

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) mandated that each state develop a strategic highway safety plan (SHSP) to focus multiagency and multidisciplinary efforts to reduce crash rates. All states have completed the SHSPs. A few states—such as Missouri and Oregon—are updating their plans. Most states report that translating the plans into specific actions with the necessary resources has been a challenge.

Ports and Waterways

The nation's rivers and intracoastal waters are receiving consideration throughout the country for the relief of congestion and as an alternative to highways. Marine highway developments include barge service between Port Elizabeth, New Jersey, and Bridgeport, Connecticut; a service linking the ports of Hampton Roads, Virginia, with smaller ports; barge service between the Ports of Oakland and Sacramento, California; and a service connecting ports in Texas and Mexico.

The California Air Resources Board has approved measures to reduce pollution from commercial harbor craft, such as dinner cruise and tour boats, tugs, and towboats in California waters. The Ports of Los Angeles and Long Beach jointly launched the San Pedro Bay Clean Air Action Plan to cut emissions of diesel particulate matter in half by 2011 and to reduce nitrogen oxides, sulfur oxides, and other pollutants.

APL, the global container shipping line, has teamed with regional, state, and federal agencies to test new marine technologies to reduce exhaust pollution. Several ports are testing or are operating technology to cut exhaust emissions from docked cargo ships. Through a pilot program at Hampton Roads, the Virginia Port Authority is supporting EPA's SmartWay Transport Partnership, which enables truckers to obtain low-cost loans to purchase trucks with cleaner-burning engines.

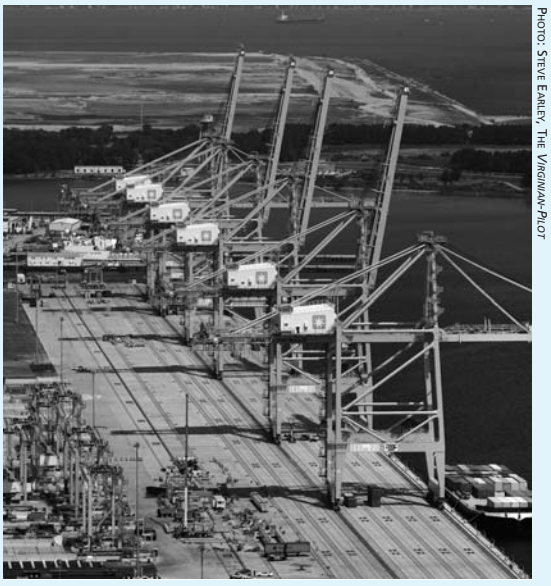


Photo: Steve Earley, The Virginian-Pilot

New APM Terminals container facility in Hampton Roads, Virginia, was built on a greenfield site.

The Alabama State Port Authority has implemented a biodiesel program to reduce greenhouse gas emissions at public seaport terminals. In Washington State, Foss Maritime plans to introduce a new hybrid harbor-assist tug, the Eco-Tug, capable of operating on batteries in standby mode, reducing main engine idling, fuel consumption, and air emissions in port.

Major new port terminals have opened or are in development. Collaborative efforts among local, state, and federal agencies, the Virginia Port Authority, and the International Longshoremen's Association contributed to the development and opening of a new APM Terminals facility in Hampton Roads. Located on a greenfield site, it is the most highly automated container terminal in the United States.

The Port of Houston, Texas, opened the first phase of the Bayport Container Terminal, which is likely to attract more Asian cargo to the region. Recognizing that this will expand the port farther inland, the Texas legislature approved a bill to create a freight rail district.

The Port of Tacoma, Washington, plans to build a 168-acre container terminal on the Blair Waterway, to be leased to Yusen Terminal, Inc., a subsidiary of NYK Line, a major international ocean carrier. The port also will develop a redesigned terminal with expansion capabilities for Totem Ocean Trailer Express, a major domestic shipping line.

SSA Marine and the Native American Puyallup Tribe have partnered to build a 180-acre container terminal at the Port of Tacoma on jointly owned land. A major new container facility is under construction at the Port of Mobile, Alabama, and will connect to the inland waterway system.

Rail

Most states have an active interest in rail transportation as a solution to passenger and freight transportation demands. Many areas seek commuter rail services to relieve traffic congestion, and states are developing funding mechanisms and relationships with freight railroads to initiate new services.

Successful partnerships can benefit the freight railroads by alleviating rail congestion and improving freight capacity. For example, Florida DOT is using the state's transportation trust fund to finance a comprehensive project that includes purchasing a 61-mile line in the Orlando area from a freight railroad for commuter service, enhancing other lines owned by the freight railroad, and relocating intermodal freight facilities to a new integrated logistics center.

Many states are supporting rail freight services in various ways. For example, Georgia is the buyer of last resort for rail lines in the state and owns 540 miles, most of which are leased to operating railroads. Georgia DOT serves as a conduit for state funds for improvements to rail lines and facilities, which are viewed as tools for economic development.

PHOTO: DALLAS AREA RAPID TRANSIT

Construction on a Dallas Area Rapid Transit light-rail station at Fair Park, September 2007.

Intercity rail passenger ridership is increasing, but plans for improved and higher-speed services in several corridors are stymied by a lack of funding.

To make productive investments in freight rail projects and to establish constructive partnerships to improve the transportation system, states are seeking to understand which benefits accrue to the public and which to the private sectors.

Public Transportation

Public transportation was not immune to several trends much in the news this past year, such as rapid urban population growth and congestion, aging infrastructure and equipment, global warming, increasing operating costs, and petroleum prices reaching almost $100 a barrel.

As transit ridership nationwide increases, deteriorating infrastructure and equipment are a concern in major rail cities, such as New York City, Chicago, Washington, D.C., Boston, and Philadelphia. Service disruptions, accidents, and delays can occur. Some jurisdictions—for example, New York City, Chicago, and Washington, D.C.—have implemented or are considering fare increases, and others are proposing tax increases.

Several major transportation tax and bond measures passed on the November 6 ballot in such jurisdictions as Charlotte and Mecklenburg County, North Carolina; Fairfax County, Virginia; Toledo, Ohio; San Francisco; Kalamazoo and Saginaw, Michigan; and Weber and Box Elder counties, Utah. Four counties in Washington State—Kitsap, King, Snohomish, and Pierce—defeated a major transportation funding measure. Pennsylvania earlier approved a public transportation trust fund of $1.08 billion.

Both the public and private sectors have developed

new transit services. Light rail systems are adding lines in Portland, Los Angeles, Salt Lake City, Dallas, and St. Louis; and commuter rail is expanding in San Diego North County, Seattle, Salt Lake City, and South Florida. Bus rapid transit was added in Eugene, Oregon, and in Seattle, Denver, and Boston. Private-sector carsharing has expanded in Washington, D.C., Boston, and San Francisco.

Transit-oriented development is occurring in Denver, Portland, Baltimore, Seattle, and Charlotte. The easy access to transit has attracted office, retail, and residential developments.

Transit services have made a positive impact on the physical and human environment also. Transit fleets are "greening" by adding energy-efficient, low-polluting vehicles. In addition, transit vehicles were used to evacuate hundreds during the horrific mountain brush fires in the Southern California and San Diego areas in October.

Partnership Potential

Progress in addressing the critical issues in transportation will not be possible without joint efforts and collaboration. Resolving issues such as the aging infrastructure, congestion, safety, funding, energy, environment, intellectual capital, security, and infrastructure protection and preservation will require partnerships among a myriad of players. The role that partnerships can play inside and outside of the transportation community and around the world was on display repeatedly for TRB staff during field visits to the states in 2007.

Did You Know?

◆ Texas DOT has created a state grant program, the Routine Airport Maintenance Program (RAMP). Individual grants do not exceed $50,000 per year per airport and require a local government to match 50 percent of the actual costs plus any costs that exceed a total of $100,000. These grants enable airports to make lower-cost airside and landside improvements, such as constructing airport entrance roads, paving airport public parking lots, installing security fencing, and replacing rotating beacons. The grant program has been a success, and the state has seen a dramatic improvement in safety at smaller airports that have taken advantage of the program. More information is available at www.txdot.gov/services/aviation.

◆ Carson City, Nevada, is west of Los Angeles.

Hybrid snowmobile competes in the Clean Snowmobile Challenge.

◆ Snowmobiles often are criticized as sources of air and noise pollution. Across the country, park managers are studying the impact of snowmobiles on the environment, and some have called for a ban on snowmobiles in some national parks. The Society of Automotive Engineers issued the Clean Snowmobile Challenge, a collegiate design competition, bringing together teams of engineering students to reengineer a stock snowmobile to reduce emissions and noise while maintaining or improving performance. Utah State University won the 2006 Challenge's new zero-emissions division with an electric sled. The competition often has led to offers of industry jobs for students on the teams.

◆ Utah DOT has partnered with Utah State University to explore the possibility of growing biodiesel-producing plants along state highways. Nearly one-half of the 6,000 miles of roads maintained by Utah DOT have adjacent ground that can be cultivated, to produce approximately 500 gallons of biodiesel per mile. Utah DOT started by planting almost 4 miles of right-of-way with canola, safflower, and perennial flax, which do not require irrigation. A full planting could enable Utah DOT to fuel its entire fleet with homegrown biodiesel, save on maintenance costs, and aesthetically improve rights-of-way.

◆ New Jersey was the first state to purchase variable message signs powered by fuel cells.

◆ New York has the most school buses of any state in the nation—50,000 vehicles.

◆ Louisiana Department of Transportation and Development and Virginia DOT each manage more than 56,000 miles of roadway and Interstate lanes—more roadway lane miles than Caltrans manages.

◆ As directed by the Code of Virginia, the state is outsourcing 1,200 miles of Interstate maintenance by July 1, 2009.

POINT OF VIEW

Driver Behavior

A Moving Target

ALISON SMILEY

The author is President, Human Factors North, Inc., Toronto, Canada. This article is adapted from her keynote address at the Human Factors Workshop, January 2007, in Washington, D.C.

The central goal of human factors research is to improve performance and reduce error, injuries, and crashes. The goal is achieved through design that takes human characteristics into account. It sounds straightforward—using information on seated eye height should contribute to a better location for a display on a console and therefore to greater ease in reading the display and less likelihood of misreading it. Using information on visual acuity and contrast sensitivity should result in highway signs that are readable at the desired distance and that allow drivers time to make lane changes comfortably and safely.

Providing information through a traffic sign or through a collision warning device that would allow a driver to anticipate a hazard appropriately should reduce the risk of a crash. Design that takes such physical, perceptual, and cognitive human characteristics into account should lead to better driver performance and consequently to lower error and crash rates.

Safety and Human Factors

The assumption is that improvements in performance will reduce the number of crashes. For example, if a driver can stop the vehicle more quickly, or if a driver can see lane markings farther at night, the number of crashes should be reduced. But we cannot be sure of this without results from crash studies. Crash studies are the gold standard for assessing whether changes in design produce the desired results.

In the past 15 years, the highway design and traffic engineering community has increased interest in how road engineering countermeasures—such as warning signs, widening of curves, and post-mounted

PHOTO: SEIH-YING CO., LTD.

Raised pavement markers, intended to improve visual guidance for drivers, instead may encourage higher, unsafe speeds.

delineators—change driver performance and the associated crash rates. Some of the results of this work have been counterintuitive, as countermeasures that were expected to improve safety did the opposite.

One underlying explanation is the phenomenon of "driver adaptation." If the task is made easier through a design that accommodates driver needs, the driver will change his or her behavior. This adaptive behavior can make it difficult to predict accurately the effect of countermeasures; reliable crash studies, therefore, are needed.

New Developments in Safety

Several changes have occurred in the field of crash analysis. Anyone who uses crash studies should be aware of these changes.

Figure 1 shows the count of crashes at an intersection during an 8-year period. No changes were made to the intersection in this period. The figure illustrates several important points. First, crashes are rare—thousands of drivers pass through this intersection daily, yet few crashes occur. Second, crashes are random. After the crash count peaks, it drops the following year—this is referred to as the "regression to the mean."

This is problematic, because many crash studies are before-and-after studies. In practice, locations with high numbers of crashes receive attention, not a representative sample of locations.

Adding countermeasures at locations when crashes peak, therefore, has a high likelihood of success, if only because of the regression-to-the-mean effect—it really does not matter what countermeasures are implemented. Newer methods consider the variability in crashes—for example, through an empirical Bayes analysis—and produce a more realistic prediction of the safety benefits by avoiding a built-in bias to find a positive effect (*1*). Many older crash studies are misleading, because regression to the mean was not considered. The results of better-designed studies are discussed here.

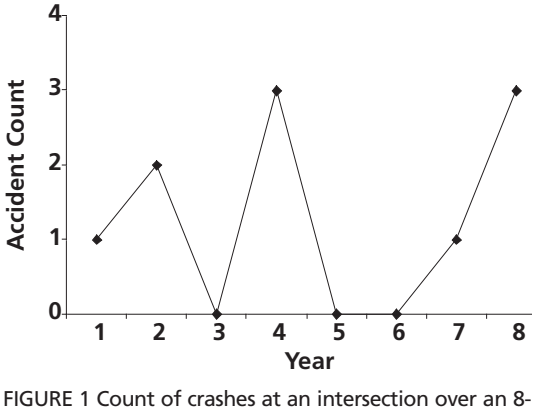


FIGURE 1 Count of crashes at an intersection over an 8-year period (adapted from Figure 4.1, in Elvik, R., and T. Vaa. *The Handbook of Road Safety Measures*, Elsevier Science, 2004; copyright Elsevier).

Path Guidance Improvements That Reduce Safety

Under the assumption that drivers are running off the road at curves because the guidance around the curve path is inadequate or lacking, traffic engineers have applied various devices to convey better information about the path ahead. These devices include post-mounted delineators and raised pavement markers. Human factors studies have determined the number of delineators and markers required to ensure that drivers can comfortably predict changes in road direction at highway speeds and have shown that these devices greatly improve drivers' preview of the road ahead (*2–4*).

Post-Mounted Delineators

What do the crash studies show? Kallberg in Finland examined post-mounted delineators on roads of various designs—those posted at 100 km/h with gentle curves and wide clear zones and those posted at 80 km/h with sharper curves and less room for error if the driver should leave the road (*5*). Twenty pairs of road sections were selected, and one of each pair was randomly assigned to have post-mounted delineators, thus avoiding a potential regression-to-the-mean effect.

Kallberg found that improved guidance with post-mounted delineators had minimal effects on nighttime speed or on crashes on 100 km/h roads. On the 80 km/h roads, the speeds increased at night, with a highly significant 40 percent to 60 percent increase in nighttime injury crashes. Because the driver preview was improved, drivers sped up, with disastrous results on roads that were not able to encompass higher speeds. This was not the intended outcome.

Nevertheless, the study did not result in a ban on post-mounted delineators on roads with sharp curves. Perhaps traffic engineers did not hear about the study; perhaps those who heard about the study found it hard to believe.

Raised Pavement Markers

A recent, extensive research project conducted under the National Cooperative Highway Research Program (NCHRP) strongly confirmed Kallberg's findings by looking at the effects of another device intended to improve guidance for drivers—raised pavement markers on undivided highways and freeways (*6*). Applying empirical Bayes statistical techniques to data from several hundred miles of roadway, the researchers reached several surprising conclusions. Raised pavement

The better the roadway and the gentler the curves, the more likely that raised pavement markers will improve safety.

markers, placed to improve the driver preview on sharp curves—that is, with greater than 3.5 degrees of curvature—on low-volume roadways with an average annual daily traffic (AADT) of less than 5,000 vehicles were associated with a 43 percent increase in crashes when compared with the number of crashes when the pavement markers were not present.

Human factors studies are needed to explain this. But Kallberg's findings that speed increased at night when post-mounted delineators were installed, as well as older research by Allen showing that higher-contrast lane markings led to higher speeds both in simulators and on real roads, indicate a likely explanation—speed increases when the road is better delineated (*7*). On roads with little room for error, even small increases in speed greatly increase the risk of a crash.

The NCHRP research on raised pavement markings is not all bad news. The better the roadway and the gentler the curves, the more likely the crash experience associated with the presence of raised pavement markers will improve. The best effect is on freeways with traffic volumes of more than 60,000 AADT. Here the number of crashes on roads equipped with raised pavement markers are 67 percent of the number of crashes on roads not so equipped.

Positive Guidance

Although pavement markers and post-mounted delineators are installed to provide positive guidance, positive guidance is more than providing more information to the driver—it "increases the driver's probability of selecting the speed and path most appropriate to the operating conditions of the highway" (*8*). Although they greatly improve preview distances and driver comfort, raised pavement markers do not increase the driver's probability of selecting an appropriate speed on sharp curves. Sharp curves are associated with higher numbers of crashes and are, ironically, the locations in which traffic engineers want to implement countermeasures such as raised pavement markers.

Human factors specialists need to acknowledge an inconvenient truth and to make traffic engineers, technicians, and manufacturers aware of it—improving visibility and guidance does not necessarily lead to lower crash rates.

Path Guidance Improvements That Improve Safety

Rumble Strips

Guidance that is not visible and does not tempt drivers to increase speed may be more effective in reducing crashes. Distracted or fatigued drivers who cross longitudinal rumble strips along the shoulder edge or the centerline are alerted by the sound that they are about to leave the roadway.

Crash studies show that shoulder-edge rumble strips reduce run-off-road crashes on rural highways by 21 percent (*9*). Centerline rumble strips are associated with a 25 percent reduction in target crashes (*10*). Perhaps the auditory warning of crossing the lane edge on sharp curves would be better than improving the driver's preview and tempting an increase in speed. A study of driver performance and safety impacts comparing rumble strips and improved path delineation on sharp curves would be useful and may show that rumble strips do not lead to increased speed at night and are more effective in improving safety.

Guidance information, such as post-mounted delineators and raised pavement markers, improves driver comfort and confidence. Yet in some circumstances, increasing driver confidence can lead to inappropriately higher speeds.

Removing Guidance

A controversial and much-reported Dutch approach to residential streets or town centers with high pedestrian and bicyclist volumes involves the removal of guidance, to make drivers less certain about their right-of-way in relation to other road users. The intent is to

PHOTO: WASHINGTON STATE DEPARTMENT OF TRANSPORTATION

Rumble strips may be effective because they do not function as visible guidance and do not tempt drivers to increase speed.

PHOTO: SHARED SPACE

PHOTO: SHARED SPACE

The Shared Space approach, adopted in Haren (*above*) and Oodehaske (*below*), in the Netherlands, removes guidance to reduce automobile speeds and to force eye contact between drivers, bicyclists, and pedestrians.

force more eye contact between all road users to establish who will have the right-of-way and to slow drivers down.[1] Positive guidance is turned on its head—less guidance equals less confidence but results in lower speeds and perhaps fewer and less severe crashes.

Whether or not this theory is correct remains to be seen. Studies are needed to show the impacts of such changes on speed, on crash rates, and on traffic volumes. If many drivers go elsewhere, the success of the intervention would be moot. Evaluations are needed for an extended period of time—drivers initially may be intimidated and slow down, but the speeds may creep up gradually as drivers become used to the situation.

Much research suggests that speeds will be lower in such situations. In a study of 51 sites posted at 50 km/h (30 mph), Bellalite found that speed was related to building density, building setback, and to the presence or absence of a sidewalk (*11*). In other words, to some degree speed is related to perception of risk. Nonetheless, the jury is still out on whether the removal of guidance in high-density pedestrian and bicyclist environments will improve safety, the ultimate goal.

[1] www.shared-space.org.

Increased Task Difficulty That Improves Safety

The expectation that improved information will improve driver behavior, and therefore safety, also applies to task difficulty. The human factors approach generally seeks to reduce task difficulty from a high to a moderate level—avoiding monotony—to improve safety. But sometimes, making the task more difficult can reduce speeds, with positive consequences for safety.

Forcing a Visual Search

A study by Summala et al. assessed countermeasures against bicycle–vehicle crashes that occurred when drivers turned right and collided with bicyclists coming from the right (*12*). Video observations showed that drivers looked left into the oncoming traffic and rarely looked to the right. Three interventions were assessed: a warning sign, an elevated crossing, and a speed hump.

Video observations indicated that the warning sign had no impact on visual search. The elevated crossing and the speed hump forced drivers to slow down—as a result, they looked right more often, making it more likely that they would detect the cyclists. The safety studies are not yet available, but an improvement is to be expected if drivers take more time to search at intersections.

Intersections and Roundabouts

A more convincing example of the occasional benefits of increased workload comes from a comparison of intersections and roundabouts. In North America, the crossing of streams of traffic is typically handled with intersections; in Europe, roundabouts are more common.

If greater driver comfort and reduced workload can be associated with fewer crashes, then intersections seem preferable—the lanes are designated, and it is clear who has the right of way at all times. A study by Lerner et al. suggests that drivers do not perceive intersections as particularly risky (*13*). The study recorded driver speeds on the same section of road for which drivers rated the risk of a crash. Driver speed was inversely correlated with perceived risk. For the most part, lower speeds were associated with sharp curves and limited sight distance but not with intersections—

a highway feature associated with a high risk for crashes.

Although the workload may be less, intersections create many conflict points between crossing and turning vehicles and other road users. Roundabouts reduce the number of conflict points. The driver workload in a roundabout requires slowing down, following a curving path, changing lanes to access the exit in a two-lane roundabout, and maintaining awareness of vehicles on both sides. A conceptual task analysis and anecdotal evidence suggest that North American drivers find roundabouts intimidating and rate the attentional requirements—the mental workload—higher than those for standard intersections.

Yet crash studies show that when modern roundabouts replace signalized urban intersections at U.S. sites where drivers are unfamiliar with roundabouts, all crashes—property damage only, injury, and fatal—are reduced to 68 percent of their previous values, and injury crashes are reduced to 32 percent (*14*). Roundabouts work through a geometry that decreases and equalizes speeds and eliminates right-angle conflicts. Although the design is likely associated with decreasing driver comfort and increasing workload, the result is a greatly improved crash outcome.

This leads to another inconvenient truth—increasing driver workload does not necessarily reduce safety.

Safety Interventions and Adaptive Behavior

Effects on Speed

Central to the failure of post-mounted delineators and raised pavement markers on sharp curves and to the success of roundabouts is the effect on speed. Lower speeds mean less distance traveled during the perception-reaction time and less energy expended in a collision. Any intervention on behavior therefore should consider the influence on driver speed, especially if the feature improves driver comfort and decreases workload. Higher speeds are associated with more negative crash outcomes. Although findings on path guidance and on roundabouts versus intersections have been highlighted, any safety intervention—for example, an antilock braking system (ABS)—that improves performance but increases speed (*15*) may result in no improvement in safety (*16*).

Changes in speed are not the only concern. Safety interventions can result in other types of adaptive behavior. Two examples are red light cameras and vision enhancement systems. When drivers become aware of red light cameras, some change their criteria for stopping and decelerate abruptly instead of at the more desirable, lower speeds. Crash studies show the good news that red light cameras are associated with fewer angle crashes; the bad news is that rear-end crashes increase significantly (*17, 18*).

PHOTO: CITY OF SPRINGFIELD, OREGON, PUBLIC WORKS

Roundabouts increase the driver's workload, or attention requirements, but reduce the number of vehicle conflict points at intersections.

Simulator studies have shown that vision enhancement systems lead to poorer detection of targets in the unenhanced portion of the field of view, compared with performance without an enhancement system (*19*). The effect on crashes is as yet unknown.

Drivers do not always change their behavior in the presence of design changes. For example, a study of taxis going to the airport found that those equipped with ABS drove with shorter headways than those not so equipped, but that drivers with air bags drove at the same speeds and headways as drivers without air bags (*20*). Perhaps the less obvious the safety intervention, the less likely an adaptation will occur. Similarly, shoulder-edge and centerline rumble strips effectively warn drivers who are about to leave the lane, but because the features do not improve the preview as do raised pavement markers or post-mounted delineators, they do not encourage higher speeds.

Producing the Optimal Behavior

The aim of human factors practitioners should be to find the design that produces the optimal behavior. For example, a study by van der Horst found that increasing the length of the caution interval at signalized intersections by 1 second would improve safety

PHOTO: DEREK JENSEN

Red light cameras are associated with fewer angle crashes, although rear-end crashes increase significantly.

(*21*). A year after this change was made, the percent of drivers caught in the dilemma zone—the area near the stop bar in which the decision to stop or go is difficult—was halved, as was the percent of drivers running the red light.

Too much warning can have a contrary effect. In a driving simulator study, a flashing green phase followed the solid green phase of a traffic light to warn of the upcoming caution phase. The result was a substantial increase in perception-reaction time and in rear-end crashes (*22*). The optimal warning interval must be sought.

Anticipating Unintended Changes

Recent crash studies have produced unexpected results, and the human factors community must respond. Reducing driver workload and improving information through driver preview of the road do not always result in fewer crashes.

When safety interventions are made, the driving task changes, and drivers adapt—driver behavior is a moving target. Drivers respond to the change through speed selection, changes in visual search and focus of attention, adjustments to headways, and so on. This adaptive behavior—especially the increases in speed—can negate the expected benefits of safety interventions.

Human factors studies must consider the unintended changes in behavior—which to some degree are predictable—to anticipate the crash outcomes associated with each safety intervention. Human factors studies should focus on providing the optimal amount of information—for example, learning from the lesson that greater preview information at sharp curves can lead to inappropriate speed choice. Finally, human factors specialists should consider the visibility of the interventions to the driver. Interventions that are less obvious to drivers may be less likely to result in adaptive behavior that negates safety improvements.

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TRB SPECIAL REPORT

Metropolitan Travel Forecasting

Current Practice and Future Direction

JON WILLIAMS

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Metropolitan planning organizations (MPOs) develop regional transportation plans and programs to accommodate mobility needs for urban America. MPOs use network-based, computerized travel forecasting models to study proposed policies, operating strategies, and capital investments for the metropolitan transportation system and to determine which of these will best serve the public's needs for future travel and economic development. MPOs also use the model outputs to determine air quality and other environmental impacts of proposed transportation plans and projects.

The Federal Highway Administration (FHWA), the Federal Transit Administration (FTA), the Office of the Secretary of Transportation, and TRB initiated a study to assess the state of the practice in metropolitan travel forecasting. The committee that conducted the study was also charged with identifying shortcomings in travel forecasting models, obstacles to better practice, and actions needed to ensure the use of improved travel forecasting methods. Chaired by Martin Wachs of the RAND Corporation, the committee included members experienced in the theory and practice of travel forecasting and who represented perspectives of MPOs, state transportation agencies, academic research, and private consultants (see box, page 27).

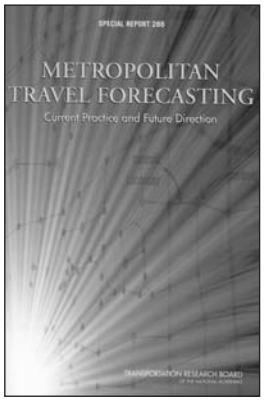
State of the Practice

The committee's report, *Metropolitan Travel Forecasting: Current Practice and Future Direction,* found that most agencies rely on a trip-based travel modeling process that has remained fundamentally unchanged in the past 40 years, despite incremental improvements. The current models may be appropriate for smaller metropolitan areas with stable growth but exhibit basic, documented deficiencies in meeting current analytic needs for larger, faster-growing metropolitan areas that have complex transportation systems. In addition, deficiencies in practice—particularly gaps in the data—must be redressed.

Advanced models that better meet the more com-

PHOTO: BILL HALL, CALTRANS

Interstate 80, San Francisco, west approach to the San Francisco–Oakland Bay Bridge—a major urban facility whose planning has benefited from urban travel demand forecasting.



TRB Special Report 288, *Metropolitan Travel Forecasting: Current Practice and Future Direction*, is available from the TRB online bookstore, www.TRB.org/bookstore; to view the book online, go to http://onlinepubs.trb.org/onlinepubs/sr/sr288.pdf. The findings of the surveys used to develop the report are also available online at http://onlinepubs.trb.org/onlinepubs/reports/VHB-2007-Final.pdf.

plex needs of MPOs have been developed and implemented satisfactorily in some metropolitan areas, such as New York; Columbus, Ohio; and the city of San Francisco. These more advanced models can provide a better representation of travel behavior and have been combined successfully with land use and traffic simulation models.

Considerable barriers to fundamental change remain, however, including resource limitations, practitioners' uncertainty that new practices will be better than those they replace, lack of coordination among stakeholders, and inadequate investment in the development and transfer of new techniques. Finally, the committee notes that no single approach or set of procedures for travel forecasting is correct for all applications or for all MPOs. Travel forecasting tools should be appropriate to the questions posed and to the types of analysis conducted.

Improving Travel Demand Forecasting

According to the committee, policy makers must be able to make informed decisions about future investments and public policies for the transportation system. The committee therefore recommends the development and implementation of new modeling approaches to demand forecasting that are better suited to providing reliable information for applications, such as multimodal investment analyses, operational analyses, environmental assessments, evaluations of a range of policy alternatives, toll-facility revenue forecasts, and freight forecasts. These new approaches are also needed to meet federal and state regulatory requirements.

The committee acknowledges that current practice is deficient in many respects and that introducing advanced models will not in itself improve practice. Therefore, steps must be taken to improve both current and future practice in metropolitan travel forecasting.

The committee believes that the government agencies with programs that would benefit from accurate, reliable travel forecasts—MPOs, states, and the federal government—are the key to change and growth in these areas. Following are the main recommendations from the report, organized by the level of government that would be responsible for the implementation.

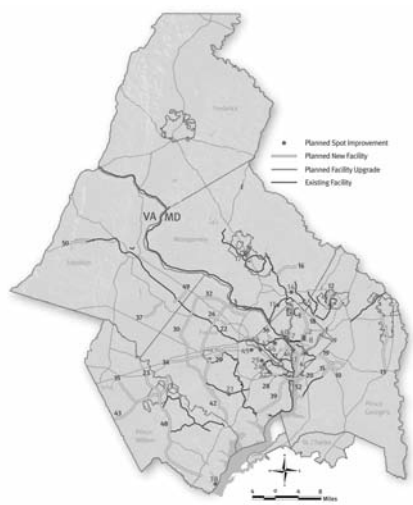
Metropolitan Planning Organizations

The committee believes that MPOs should

- Establish a national metropolitan cooperative research program, perhaps using a modest take-down from the approximately $365 million that FHWA and FTA annually provide to all MPOs;
- Conduct formal peer reviews of modeling practices;
- Develop partnerships with universities to foster research on travel modeling and on the implementation of advanced modeling practices;
- Check the reasonableness of demand and cost forecasts for major projects; and
- Document experiences associated with the introduction of advanced modeling practices.

State Transportation Agencies

States play an important role in supporting travel forecasting at smaller MPOs, and they collaborate with the larger MPOs within their borders. Accordingly, the committee recommends that states



Images: National Capital Region Transportation Planning Board

Planning maps showing (*left to right*) highway, transit, and bicycle projects in the metropolitan Washington, D.C., area.

◆ Support the creation of a national metropolitan cooperative research program and encourage other research related to MPO needs;

◆ Support model user groups for training, discussion of common issues, and purchase of modeling software for use statewide;

◆ Evaluate, in cooperation with MPOs, the socioeconomic forecasts used for MPO modeling and forecasting; and

◆ Coordinate with MPOs on statewide and metropolitan models and data needs.

Federal Government

The federal government has a historic precedent for providing strong leadership and resources for the development and implementation of travel models and for associated training. This role is underscored by the many federal requirements that guide MPO planning activities. The federal government has an interest in ensuring that federal funds are supporting the highest-priority needs for maintenance and improvement of the national transportation system.

The committee recommends, therefore, that the federal government support and provide funding both for incremental improvements to trip-based models in settings appropriate for their use and for the continued development, demonstration, and implementation of advanced modeling approaches, including activity-based models. Specifically, the committee recommends that the federal government

◆ Rely on the Travel Model Improvement Program as an appropriate mechanism for advancing the previous recommendations and ensure the funding necessary to support the program;

◆ Continue to support the implementation of activity-based modeling and other advanced practices and expand this support through deployment in several urban areas;

◆ Request Congress to authorize additional funding at an appropriate level to support the federal government's role as a partner with MPOs and state transportation agencies—$20 million annually would be comparable to the amounts invested by the federal government for developing models 30 years ago;

◆ Continue the federal MPO certification process, with a checklist to provide MPOs with useful information on the minimum expectations for their models and incorporate into the process an examination of the results of peer reviews; and

◆ Support planning guidance and planning regulations that allow MPOs substantial flexibility in their travel demand modeling practices.

Committee for Determination of the State of the Practice in Metropolitan Area Travel Forecasting

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Guy Rousseau, Atlanta Regional Commission, Georgia
Mary Lynn Tischer, Virginia Department of Transportation, Richmond
Richard E. Walker, Metro Portland, Portland, Oregon

Intergovernmental Cooperation

A large degree of intergovernmental cooperation is inherent in the metropolitan planning and travel forecasting process. As a result, the committee recommends that

◆ MPOs, state transportation agencies, and federal agencies should work cooperatively through a national steering committee to establish appropriate goals, responsibilities, and means for improving travel forecasting practice;

◆ A national travel forecasting handbook should be developed and kept current, to provide salient information for travel demand forecasting practitioners;

◆ Studies should compare the performance of conventional and advanced models; and

◆ MPOs, with the federal government and the states, should examine in detail the data requirements for validating current travel forecasting models, meeting regulatory requirements, and developing freight models and advanced travel models.

A Call to Action

The practice of metropolitan travel forecasting has resisted fundamental change. Every 10 years or so a cycle of research, innovation, and resolve begins with the goal of putting innovation into practice but eventually fails to effect a change in travel forecasting practice.

This sobering assessment underscores the need to break out of the cycle by coordinating the resources of each level of government in an alliance with academia and the private sector. This would stimulate creativity and a willingness to innovate—the hallmarks of the early days in which travel forecasting was pioneered.

TRB SPECIAL REPORT

Building the Road Safety Profession in the Public Sector

THOMAS R. MENZIES, JR.

The author is Senior Program Officer, TRB Division of Studies and Special Programs, and served as study director for this project.

More than 40,000 people die each year in motor vehicle crashes in the United States, and many more people are seriously injured. With continued growth in motor vehicle travel, more dramatic improvements in crash rates are needed to reduce this tragic toll. Government leadership and actions are vital to bringing about safety gains.

Federal, state, and local agencies plan, finance, build, operate, and maintain the nation's highway system. They regulate motor vehicle safety requirements and educate and license drivers. They set and enforce traffic laws and provide emergency response and medical services. They collect safety data and conduct and support safety-related research. Collectively, governments have a deep and far-reaching impact on the safety of the nation's roadways.

The thousands of federal, state, and local agencies that have road safety responsibilities employ hundreds of thousands of workers who influence safety performance on a regular basis. These workers have expertise in fields such as engineering, education, law enforcement, emergency response, public health, psychology, communications, statistics, and planning. Collectively, they have had a central role in bringing about a dramatic reduction in crash rates over the past 40 years, even as motor vehicle travel has grown relentlessly.

In recent years, crash rates have leveled off, and finding and taking advantage of opportunities for safety improvements are becoming increasingly difficult. The marked gains in safety performance that are needed to outpace traffic growth will require careful scientific and systems approaches to safety management. A talented and highly skilled professional workforce must be in place to lead this effort.

Study Origin and Aims

The Federal Highway Administration, the Federal Motor Carrier Safety Administration, and the Transportation Research Board (TRB) sponsored a study to examine the future supply of and demand for road safety professionals in the public sector. Through the

PHOTO: OREGON DOT AND FHWA

A team of transportation professionals confers during a road safety audit on a segment of US-97, Oregon.

National Research Council of the National Academies, TRB assembled a special committee to conduct the study under the leadership of Kam K. Movassaghi, President of C. H. Fenstermaker and Associates, Inc., and former Secretary of Transportation for Louisiana (see box, page 29). Over a one-year period, the 11-member committee studied how safety professionals are educated, trained, recruited, and hired.

In Special Report 289, *Building the Road Safety Profession in the Public Sector*, the committee describes the history and current state of the road safety profession, observing how the profession has evolved in the past 50 years to encompass experts from many disciplines. Informed by interviews with road safety professionals, educators, trainers, and agency executives, the report explains how workers have found their way into the road safety field, how they received their safety-related education and training, and the kinds of safety-related knowledge and skills they possess. The report further explains how a dedicated cadre of experts within the road safety profession has advocated the use of scientific methods and empirical evidence for understanding road safety problems and for finding and implementing mitigations.

Scarcity of Education and Training

Looking to the future, the committee expresses concern that development of the road safety profession remains a mostly ad hoc and unstructured process, as workers

obtain road safety knowledge and skills piecemeal, seldom through comprehensive education and training programs. Few universities offer a road safety curriculum, and public agencies have few places for recruiting trained safety professionals. Without such professional development capacity, the ability of government agencies to build the needed analytical and multidisciplinary safety workforce is questionable.

Much evidence suggests that the demand for road safety professionals is growing. Skilled professionals, for example, are needed to apply new safety-related tools and technologies and to meet legislative mandates for data-driven safety programs. This desirable trend reflects the recognition that safety gains are not random occurrences but the consequence of well-informed and well-implemented decisions. The challenge, therefore, is in building a pool of safety professionals who can provide this information and expertise for public agencies with road safety responsibilities.

Alliance to Champion the Safety Profession

To meet this challenge, the committee urges the American Association of State Highway and Transportation Officials and the Governors Highway Safety Association to forge a broad-based alliance of safety-related organizations to build the road safety profession. These state-oriented, national associations are in a good position to lead the endeavor, because states have a prominent role in road safety.

The states plan, design, build, operate, and maintain large portions of the highway infrastructure; pass and enforce traffic safety laws; regulate driver instruction and licensing; and administer statewide programs that encourage safe driving. Because they employ thousands of road safety professionals, state governments must play a central role in any effort to build the profession.

The alliance must extend beyond these state-oriented associations, however, and include the many other public agencies and associations that have a strong interest in road safety and that encompass many relevant disciplines—such as engineering, enforcement, education, and emergency management—as well as jurisdictional levels: federal, state, regional, and local. The alliance likewise should seek the involvement and support of private-sector organizations, universities, and professional associations that share an interest in developing the road safety workforce.

The committee envisions a broad-based alliance that champions the road safety profession by

- Promoting a multidisciplinary safety workforce that recognizes the importance of applying a science-based and systems-level approach to safety management and is capable of implementing that approach;
- Commending and publicizing agencies that are recruiting, developing, and building a professional road safety workforce within their organizations;
- Encouraging the continued development and wider use of core competency definitions to guide the education, training, and promotion of road safety professionals who are skilled in scientific methods and in pursuing safety solutions from a systems level;
- Promoting road safety management as a distinct profession and a desirable career path;
- Convincing public agencies, industry, and universities of the value of forming road safety education and training partnerships, to foster demand for road safety training and education and to expose road safety professionals to the methods and results of science-based safety research; and
- Advocating support for science-based safety research to inform road safety professionals and to attract top faculty and students from many disciplines into the field of road safety—for example, through scholarships, internships, training grants, endowed university chairs, and research centers—across the many disciplines that contribute to road safety.

The study committee is convinced that road safety organizations can and must do more than call attention to workforce needs—they must make a lasting commitment to meeting those needs.

Nearly 40 years have passed since concern about the environment prompted a dedication of resources to developing the nation's environmental expertise, spawning educational programs, certification activities, and professional societies devoted to a now well-recognized profession. The road safety profession is on the cusp of a similar opportunity for gaining similar attention and recognition.

Committee for a Study of Supply and Demand for Highway Safety Professionals in the Public Sector

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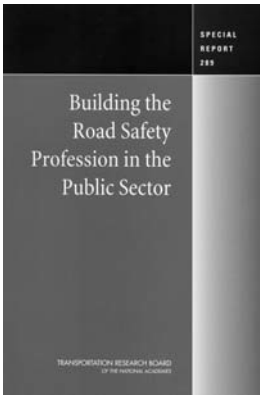
Thomas M. Welch, Iowa Department of Transportation, Ames



TRB Special Report 289, *Building the Road Safety Profession in the Public Sector*, is available from the TRB online bookstore, www.TRB.org/bookstore; to view the book online, go to http://onlinepubs.trb.org/onlinepubs/sr/sr289.pdf.

Oregon Department of Transportation

Assessing the Load Capacity of Oregon's Aging Bridges

STEVEN M. SOLTESZ

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Oregon underwent a boom in bridge construction during the 1950s and 1960s—the era of building the Interstate highways. The bridge of choice in Oregon was the cast-in-place, reinforced concrete deck girder (RCDG) bridge, following the specifications of the American Association of State Highway Officials.[1] In the early 1960s, other states started to build bridges with prestressed concrete. But because of its success with the model, Oregon continued to construct RCDG bridges in accordance with the design codes.

Problem

The design specifications for RCDG bridges 50 years ago were based on truck loads and traffic volumes that were much lower than those in traffic today. In addition, the accepted practice at that time did not conservatively account for the stresses that beams must accommodate in service. As a result, cracking is common in Oregon's Interstate-era RCDG bridges.

The situation became a priority for the state in 2001, when in-depth inspections revealed the extent of the problem. Of the 555 RCDG bridges owned by Oregon, 487 had structural cracks.

The understanding was that the stresses in some of the reinforcing steel in a cracked reinforced concrete girder could be large enough to cause failure in certain circumstances. In addition, engineers were concerned that the repeated opening and closing of cracks caused by traffic could lead to metal fatigue in the steel reinforcement. Fatigue failure was particularly worrisome, because no visible warning would precede the fracture of an embedded steel bar.

More cracks and wider cracks were considered indications of greater damage and of reduced load capacity. Consequently, the number of bridges with load restrictions increased rapidly as the extent of the problem unfolded, growing from 68 bridges in 2001 to 140 in 2003. Billions of dollars would be needed to repair and replace bridges to maintain freight mobility and highway safety.

Cracked RCDG bridges were instrumented and monitored.

Solution

In 2002, the Oregon Department of Transportation (DOT) contracted with Oregon State University to investigate the load capacity and fatigue damage of cracked RCDG bridges. The researchers installed instruments on in-service bridges to determine the stresses on the steel reinforcement in cracked girders. The measurements were made for weeks under ambient traffic conditions and with truck loads of known axle weights. The data were used in computer models and were incorporated into the laboratory portion of the research.

Replicas and Ratings

The researchers constructed full-size replicas of the vintage girders. The replica beams followed the detailing and construction practices of 50 years ago, and concrete and steel were specially ordered to approximate the lower materials strengths of that era. Internal and external sensors were incorporated to monitor the behavior of the beams during the tests.

The replica beams were precracked and loaded to the point of failure, following a protocol that characterized the beam behavior at several load levels. Some beams were subjected to 2 million load cycles—the equivalent of 50 years of heavy truck traffic—before loading to failure.

The research results conclusively indicated that the

[1] As of 1973, the American Association of State Highway and Transportation Officials. *Standard Specifications for Highway Bridges*, published since the mid-1920s, is now in its 17th edition.

steel reinforcement in cracked RCDG bridges was not undergoing fatigue damage. Furthermore, cracks did not necessarily indicate that a girder had lost load capacity; in short, the crack density and the crack size were not good indicators of damage level. Instead, the findings showed that the key to load capacity was the detailing of the steel reinforcement, especially how well the longitudinal steel bars that run the length of the beam were anchored at the ends of the beams.

Research revealed that the calculations for the load and resistance factor rating (LRFR)—the newest code for rating bridge capacity—accurately accommodate the effects of cracks. The state-of-the-art load-rating method incorporates realistic operating conditions to achieve rational, consistent, and safe load-rating results.

State-Specific Factors

The LRFR method incorporates consideration of traffic loading or live loads—particularly truck loading—with data that are representative of heavy truck traffic nationwide. The code allows jurisdictions to use their own truck weight data, however, if the local data will result in calculations that have the same reliability.

Researchers at Oregon State University developed a method to analyze Oregon's weigh-in-motion (WIM) data that met the requirements of the LRFR code. Contributing to the quality of the WIM data were state policies that allowed trucking firms easy access to obtain heavy load permits, good enforcement of weight regulations, and few alternatives for truckers to avoid scales. The researchers therefore were able to use the state's WIM data to characterize with a high degree of confidence the heavy live loads that Oregon bridges may experience.

The Federal Highway Administration has approved Oregon DOT's use of the Oregon-specific live-load factors for state highway bridges. Because Oregon DOT is able to quantify its heavy truck traffic so well, Oregon's new live-load factors are less stringent than the national factors, but the state's level of safety remains consistent with that of the rest of the nation. Some bridges that previously had a marginally insufficient load rating and were slated for repair or replacement have been load-rated again and shown to have adequate capacity.

Application

Oregon DOT has adopted the LRFR with Oregon-specific live-load factors, confident that the method provides a high degree of reliability and safety in rating the many cracked RCDG bridges in the state. No extraordinary considerations need to be imposed for metal fatigue.

The shift to LRFR has improved the load rating values for many of the cracked RCDG bridges rated as insufficient under the previous method. As a result, 120 bridges were removed from the list of those to be replaced, and 80 bridges were shifted from the list of those to be repaired or replaced to the list of those that require no work.

Laboratory tests were conducted on large-size, replica beams.

Benefits

From 2001 to 2003, the Oregon legislature allocated nearly $1.8 billion for bridge repair and replacement. After reevaluating the bridge work, Oregon DOT estimates that approximately $0.5 billion dollars can be reallocated from the initial set of bridges designated for repair or replacement to other needed bridge improvements. The research has provided Oregon DOT with a good understanding of the structural health of its aging, cracked RCDG bridges and has helped the agency develop a long-term strategy to address the challenge.

For more information contact Steven M. Soltesz, Research Coordinator, Oregon Department of Transportation, 200 Hawthorne SE, Suite B-240, Salem, OR 97301-5192, telephone 503-986-2851, fax 503-986-2844, e-mail steven.m.soltesz@odot.state.or.us.

Additional Resources

Assessment Methodology for Diagonally-Cracked Reinforced Concrete Deck Girders, October 2004. ftp://ftp.odot.state.or.us/tdb/Research/_PUBLISHED%20REPORTS_/Assessment%20Methodologies%20for%20Cracked%20RCDGs/.

Calibration of Live-Load Factors Using Weigh-in-Motion Data, June 2006. www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/LiveLoadFactors.pdf.

Remaining Life of Reinforced Concrete Beams with Diagonal Tension Cracks, April 2004. www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/SPR341.pdf.

EDITOR'S NOTE: Appreciation is expressed to David Beal, Transportation Research Board, for his efforts in developing this article.

Suggestions for "Research Pays Off" topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, Keck 488, 500 Fifth Street, NW, Washington, DC 20001 (telephone 202-334-2952, e-mail gjayaprakash@nas.edu).

Malcolm Kerley

Virginia Department of Transportation

"Careful planning, development, and implementation of transportation programs and policies is of paramount importance for ensuring the delivery of transportation engineering projects," notes Malcolm (Mal) Kerley, chief engineer at the Virginia Department of Transportation (DOT).

A member of the Virginia DOT commissioner's staff, Kerley provides direction, guidance, and management for the agency's engineering program; ensures agency compliance with federal and state laws and regulations; monitors project quality control and assurance; determines the fiscal and programmatic impacts of existing and proposed transportation legislation; and directs development and delivery of critical projects.

"Careful planning, development, and implementation of transportation programs and policies is of paramount importance for ensuring the delivery of transportation engineering projects."

Kerley began his career with Virginia DOT in 1971, as a highway engineer trainee. Assigned to the bridge section of the first Interstate 95 "mixing bowl" interchange project near the Pentagon, he worked to ensure project compliance with Virginia's road and bridge specifications and to assist with field engineering problems. Kerley later served the department as a materials technician and bridge design engineer, a transportation engineer program supervisor, and division administrator for the structures and bridges program.

As a representative of Virginia DOT, Kerley has worked closely with many agencies on both the federal and state levels to deliver projects in a timely and cost-effective manner. He has served as a department liaison to federal and local transportation officials and to representatives of the steel, concrete, and fiber-reinforced polymer industries, improving working relationships and determining research needs.

Involved in the activities of many transportation organizations, Kerley is a member of the American Association of State Highway and Transportation Officials' (AASHTO's) Standing Committee on Highways (SCOH) and chairs the Subcommittee on Bridges and Structures. He is also a member of the SCOH 20-7 Committee, which works with the National Cooperative Highway Research Program; AASHTO's Technology Implementation Group Executive Committee; the PIARC (World Road Association) Committee on Bridges and Related Structures; a past member of the AASHTO Technology Information Group Committee on Rapid Bridge Replacement; and a participant in many Federal Highway Administration-sponsored workshops and committees.

"As chief engineer for Virginia DOT, I am actively involved in many committees and working groups to enhance delivery of the department's construction program," Kerley explains. "Representing the department on external committees within the state, nationally, and internationally, as well as meeting with contractors and with state and local officials and others, is crucial in ensuring the success of Virginia DOT projects."

Having worked many years to create relationships with other professionals for the benefit of the transportation community, Kerley maintains that young transportation professionals should volunteer and take part in professional activities and organizations outside their primary workplaces, to gain exposure to research needs and to interact with other transportation professionals.

"Early in my career, I had the opportunity to work at the Virginia Transportation Research Council (VTRC), assembling technical reports for distribution," Kerley recalls. "My experience—and my continued involvement—with the council was beneficial in my later work at Virginia DOT's bridge division, where because of my previous experience, I was assigned as a liaison between the bridge division and VTRC. I also represented Virginia DOT on the Subcommittee on Bridges and Structures for 10 years, and I chaired the Technical Committee on Research for several years."

Active in Transportation Research Board project panels and committees since 2000, Kerley has served as chair of the National Cooperative Highway Research Program Panel on Extending Span Ranges of Prestressed Concrete Girders by Splicing, Posttensioning, and the Use of High-Performance Concrete, and he has served as a member of the Steel Bridges Committee. He has been a regular TRB Annual Meeting attendee for many years.

Kerley graduated with a bachelor's degree in civil engineering from the Virginia Military Institute in 1971, and he earned a master's degree in civil engineering from the University of Virginia in 1973. He served in the U.S. Army Corps of Engineers from 1973 to 1974, studying basic engineering design principles, vehicular maintenance, and field construction. He has been a registered professional engineer in Virginia since 1976.

Edward J. Christopher

Federal Highway Administration

A self-described career public-sector transportation planner and an expert in data collection, travel survey techniques, transportation system demand management, and program evaluation, Ed Christopher believes that "transportation planning is a behavioral science in which transportation professionals are continually learning about society and human behavior in the context of trying to shape the future."

As the metropolitan planning specialist at the Federal Highway Administration's (FHWA's) Resource Center in Olympia Fields, Illinois, Christopher is a leader in the development of customized census data products for the transportation community. He contributed to the creation of the 1990 and 2000 Census Transportation Planning Packages, which produced high-quality census datasets for easy access and use by the transportation research community.

"[T]he demand for highly detailed transportation data is increasing. As researchers, we must continue to develop a variety of data-synthesizing and -transferring techniques, and we must work to ensure data quality, quantity, and availability, as well as funding."

"Technicians, project managers, politicians, and the public raise questions on all transportation projects," Christopher explains. "To answer these questions responsibly, planners must have access to quality data. Data collection and technical advances to aid data collection, information dissemination products, and improved data analysis techniques are critical to overcoming project hurdles and providing answers to problems."

Christopher began his work in the planning field in 1979, during his graduate studies. He took a position as a research analyst for the Chicago Area Transportation Study (CATS). His many accomplishments at CATS include publication of more than 60 reports and papers, the design and execution of many large-scale surveys—including a travel survey of 20,000 households; a household-based, long-distance travel survey; origin and destination studies; and a contracted external travel survey. In 1998, Christopher took a leave of absence from CATS and began work with the U.S. Department of Transportation's (DOT's) Bureau of Transportation Statistics (BTS).

As a BTS transportation industry analyst, Christopher worked on data collection issues related to state and metropolitan planning and went on to win the U.S. DOT Secretary's Award for his contribution to *The Changing Face of Transportation*, a 350-page compendium detailing transportation-related accomplishments in the United States for the 25 years prior to 2001 and outlining the challenges facing the transportation system in the future.

An advocate for transportation research, Christopher maintains that research in the United States is suffering from the reduction of data programs—such as the Vehicle Inventory and Use Survey and the National Household Travel Survey—as well as from a reduction in program funding.

In his current position at FHWA, Christopher is working with the American Association of State Highway and Transportation Officials to secure approximately $6 million in funding for a comprehensive package of Census Transportation Products that will include training courses, technical assistance, research and data from the Census Bureau's American Community Survey, and publication of many technical articles and papers.

"On the national level, the demand for highly detailed transportation data is increasing," Christopher observes. "Unfortunately, this demand is being accompanied by a reduction in data program funding and a dilution of data collection methodologies. As researchers, we must continue to develop a variety of data-synthesizing and -transferring techniques, and we must work to ensure data quality, quantity, and availability, as well as funding."

Christopher is a member of many professional transportation organizations and has served on many TRB committees. He chairs the Urban Transportation Data and Information Systems Committee and is a past member of the Statewide Transportation and Information Systems Committee, the Committee on National Transportation Data Requirements and Programs, and the Data and Information Systems Section. He also served as an officer for the Association for Commuter Transportation from 1984 to 1991; as director of the association's Illinois Chapter, from 1981 to 1986; as an officer of the Association of Ridesharing Professionals, from 1980 to 1986; and was recently elected to a 2-year term on the Association of Public Data Users' board of directors.

Christopher received an associate's degree in science from Moraine Valley Community College, Palos Hills, Illinois, in 1974; a bachelor's degree in liberal arts and sciences from the University of Illinois, Chicago Circle, in 1977; and a master's degree in urban planning and policy from the University of Illinois, Chicago, in 1983.

CALENDAR

TRB Meetings 2008

April

1–4 Innovative Instrumentation for Quality Control Assessments of Ground Improvement Projects*
Taipei, Taiwan
G. P. Jayaprakash

8–9 Highway Economic Requirements Modeling and Data Integration Conference
Irvine, California
Thomas Palmerlee

10–11 Western Traffic Data Workshop: Successful Strategies in Data Collection for Corridors and Planning
Irvine, California
Thomas Palmerlee

May

TBD High-Speed Nondestructive Testing and Intelligent Construction Systems Forum (*by invitation*)
Frederick Hejl

6 Symposium on Problem Soils and Surficial Deposits
Santa Fe, New Mexico
G. P. Jayaprakash

12–14 10th Annual Harbor Safety Committee Conference
Seattle, Washington

13–14 Open Architectures to Support Data Integration Peer Exchange (*by invitation*)
Washington, D.C.
Thomas Palmerlee

15–16 Aligning Data to Support Transportation Decision Making (*by invitation*)
Washington, D.C.
Thomas Palmerlee

18–21 National Roundabout Conference
Kansas City, Missouri

19–22 International Conference on Heavy Vehicles*
Paris, France

27–31 10th International Conference on Application of Advanced Technologies in Transportation*
Athens, Greece

June

2–4 25th International Bridge Conference*
Pittsburgh, Pennsylvania

15–18 TRB Summer Conference 2008
Baltimore, Maryland

15–19 2nd Freeway and Tollway Operations Conference*
Ft. Lauderdale, Florida
Richard Cunard

16–17 4th National Conference on Surface Transportation Weather
Indianapolis, Indiana

16–18 6th RILEM International Conference on Cracking in Pavements*
Chicago, Illinois

17–19 7th International Symposium on Snow Removal and Ice Control Technology
Indianapolis, Indiana

19–20 33rd Annual Summer Ports, Waterways, Freight, and International Trade Conference
Baltimore, Maryland

22–24 Innovations in Travel Demand Forecasting 2008
Portland, Oregon

23–28 7th International Conference on Managing Pavements and Other Roadway Assets*
Calgary, Alberta, Canada

July

TBD The Fundamental Diagram: 75 Years Later (*by invitation*)
Woods Hole, Massachusetts
Richard Cunard

8 Data Analysis Working Group Forum on Pavement Performance Data Analysis
Coimbra, Portugal
A. Robert Raab

6–9 47th Annual Workshop on Transportation Law
San Diego, California
James McDaniel

13–16 8th National Conference on Access Management*
Baltimore, Maryland

13–17 4th International Conference on Bridge Maintenance, Safety, and Management*
Seoul, Korea

27–30 6th National Seismic Conference on Bridges and Highways*
Charleston, South Carolina

28–29 Young Driver Subcommittee Midyear Workshop
Woods Hole, Massachusetts
Richard Pain

Additional information on TRB meetings, including calls for abstracts, meeting registration, and hotel reservations, is available at www.TRB.org/calendar). To reach the TRB staff contacts, telephone 202-334-2934, fax 202-334-2003, or e-mail lkarson@nas.edu. Meetings listed without a TRB staff contact have direct links from the TRB calendar web page.

*TRB is cosponsor of the meeting.

NEWS BRIEFS

WWW.UPSTATENYROADS.COM

New York State Implements Roundabouts

The New York State Department of Transportation (DOT) is implementing a program to replace vehicular traffic intersections with roundabouts to aid traffic flow and increase motorists' safety. Since 2000, the construction of approximately 33 roundabouts has been completed, with 16 more to follow.

A study by the Insurance Institute for Highway Safety (IIHS) tracked traffic data at intersections from 2001 to the present and showed that converted intersections now have 39 percent fewer accidents, a result attributed to reduced vehicle speeds and elimination of the right-angle crash. Traffic delays where the roundabouts replaced traffic signals dropped an average of 13 to 23 percent, according to IIHS studies in Kansas, Maryland, and Nevada.

Although construction costs range from approximately $500,000 to $1.2 million per roundabout, approximately the same as for a traditional intersection, roundabouts require only 40 percent of the space of a traditional, signaled intersection.

For more information, visit www.eng.umd.edu.

Annual Traffic Report Seeks Multifaceted Solutions

According to the Texas Transportation Institute's (TTI) *2007 Urban Mobility Report*, traffic congestion in all 437 U.S. urban areas is increasing and costing the national economy approximately $78 billion in lost hours and consumed fuel.

The report, analyzing 2005 figures, details congestion problems in 85 specific urban areas, as well as problems created by weather, crashes, stalled vehicles, work zones, and special events that can contribute to increased travel times. Also identified in the report are potential solutions that, when paired together, can be effective countermeasures to congestion:

- Maximizing use of the infrastructure,
- Adding road and transit system capacity in critical corridors,
- Relieving choke points,
- Changing usage patterns,
- Providing choices, and
- Diversifying development patterns.

Researchers note that there is no one technological solution to congestion and that multiple strategies involving traffic operations and public transit should be implemented to reduce problems.

To view a copy of the 2007 Urban Mobility Report, visit mobility.tamu.edu/ums.

Study Identifies Threats To U.S. Railroad System

A new Pennsylvania State University study highlights potential threats to the U.S. railroad system and presents strategies for shaping public policy and implementing changes in passenger and freight rail operations to ensure railway security.

Study findings suggest that traditional approaches to rail security, which focus on policing and cordoning of rail assets, are inadequate countermeasures to post-September 11 terrorist threats. Findings also show that responsibilities for rail security are divided among many federal agencies, between federal and state agencies, between the government and the private sector, and between shippers, users, and providers; that intermodal rail shipments, especially those involving cargo transported from and through port facilities, represent an area of major risk; and that terrorist acts directed against freight railroads threaten rail infrastructure and the U.S. economy.

For more information, visit www.hbg.psu.edu.

Past TRB Committee Chair Endows Research Grant

A past chair of the TRB Parking and Terminals Committee, active in TRB since 1962, Paul Box, Paul C. Box and Associates, Scottsdale, Arizona, recently endowed Auburn University, Alabama, with a grant to create a transportation research trust at the Samuel Ginn College of Engineering. The trust will be managed by a leadership and oversight committee and will support research in traffic generation and parking facilities, as well as in accident field studies. The funds also will provide undergraduate and graduate fellowships for students in transportation-related fields.

For more information, visit www.ocm.auburn.edu/news/releases.html.

International Forum for Pavement Performance Data Analysis

The Transportation Research Board's Data Analysis Working Group (DAWG) will conduct a forum on pavement performance data analysis in Coimbra, Portugal, on July 8, 2008. In conjunction with the 3rd European Conference on Pavement and Asset Management, the DAWG forum will foster international discussion of methods of analysis for pavement performance data.

Forum presentations will address technical aspects of highway research and engineering design, maintenance, and rehabilitation and will cover investigations of new techniques for extracting and analyzing data, as well as preliminary results from recent applications of the techniques. Other topic areas of interest include model building, sensitivity analysis, and cause-and-effect relationships that link structural response to pavement distress.

For more information, contact A. Robert Raab, TRB, rraab@nas.edu.

Larson Endowment Fund Inaugurated

Penn State University has honored the late Thomas D. Larson by establishing an endowment—the Thomas D. Larson Fund for Excellence—and by renaming the Penn State Transportation Institute in his honor. Larson, a member of the National Academy of Engineering, also served on and chaired the TRB Executive Committee, was President of the American Association of State Highway and Transportation Officials, and received the Frank Turner Medal for Lifetime Achievement in Transportation, among other major awards. He was active in TRB throughout his career.

Larson completed his undergraduate studies in civil engineering at Penn State in 1948 and later served as a Penn State professor, as Secretary of the Pennsylvania Department of Transportation, and as Administrator of the U.S. Federal Highway Administration. Larson also cofounded and served as director of Penn State's Transportation Institute—which has been renamed the Thomas D. Larson Pennsylvania Transportation Institute—from 1968 to 1979.

FHWA Administrator J. Richard Capka was one of 12 speakers who shared personal and professional recollections of Larson at a tribute, December 5. Key themes of the tributes focused on how Larson transformed organizations, shaped careers, and motivated students and leaders of government and industry to high achievement.

The Larson fund will serve to engage undergraduate and graduate students in interdisciplinary programs, develop academic and research programs that demonstrate the importance of integrating public- and private-sector transportation issues, establish undergraduate scholarship and graduate fellowships, and assist students and faculty with developing and disseminating research to the public.

"Tom Larson gave the Pennsylvania Department of Transportation a proud new direction," said Pennsylvania DOT Secretary and current TRB Executive Committee member Allen Biehler. "With a combination of vision and determination, he retooled the organization to meet Pennsylvania's ever-growing transportation expectations. The department is still building on the firm foundation Tom established nearly a quarter century ago."

For more information, visit www.engr.psu.edu/Larson.

RESEARCH CHAMPION—Immediate past director of TRB's Cooperative Research Programs, Robert J. Reilly (*center*) accepts the Texas Transportation Institute's (TTI's) 2007 Research Champion Award for providing significant contributions to advancing transportation research, technology transfer, implementation, and professional development. Presenting the award are Katherine Turnbull, Associate Agency Director, TTI (*left*), and Dennis L. Christiansen, Director, TTI (*right*).

ASTM Standards on Erosion and Sediment Technology

American Society for Testing and Materials, 2007; 600 pp.; $219; 978-0-8031-6224-2.

Revised and updated, the 2nd edition provides 72 of the latest standards for erosion and sediment control and 28 new American Society for Testing and Materials standards that did not appear in the previous edition.

Standards cover turf reinforcement mats, erosion control blankets, articulated concrete blocks, soil loss, gabions, hydraulic applied products, geotextiles, geosynthetics, and more. Complete with charts, figures, and illustrations, this edition is a useful reference for soil scientists, engineers, botanists, biologists, developers, landscape architects, excavating contractors, landscapers, and resource managers.

Competitive Tendering of Rail Service

OECD–ECMT, 2007; 230 pp.; $78; 978-92-821-0143-8.

Competitive tendering introduces competition to freight and passenger railways and helps preserve integrated networks of service. Worldwide experiences in competitive rail service tendering are examined, as well as lessons learned for the effective design of railway concessions and regulation.

Experts in passenger rail concessions from the United Kingdom, Australia, Germany, Sweden, and the Netherlands analyze ways in which governments promote railway competition to reduce costs and improve levels of service; the use of concessions to bring private capital to the rail industry; and the need for a transparent and durable regulatory framework to protect public and concession-holder interests. Examples of freight rail concessions in Latin America are also presented and analyzed.

The Parking Garage: Design and Evolution of a Modern Urban Form

Shannon Sanders McDonald. Urban Land Institute, 2007; 250 pp.; $87.97; 978-0-87420-998-3.

The history of the parking garage and its role as an important and essential structure in modern society is explored from an architect's perspective. Best practices are provided and topics such as sustainability—including green roofs, bicycle garages, and environment-friendly construction methods—and the need for a holistic approach to garage development are examined in detail.

Also presented is a unique analysis of the positive and negative perceptions and realities of the parking garage in industrialized societies, as well as an examination of the structure's evolution and future.

The books in this section are not TRB publications. To order, contact the publisher listed.

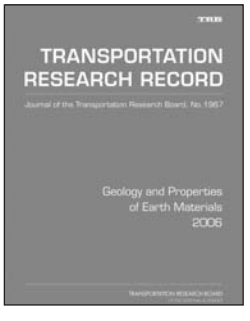
TRB PUBLICATIONS

Geology and Properties of Earth Materials 2006

Transportation Research Record 1967

Papers in this volume are grouped into four sections. Part 1: Low Volume Roads—Climactic and Seasonal Effects on Pavements and Safety addresses such topics as estimating the thermal conductivity of pavement granular materials and subgrade soils and overcoming seasonal truck-weight restrictions for thaw-weakened secondary roads in British Columbia. Part 2: Evaluation of Subgrade Resilient Modulus contains studies on permanent pavement deformation test procedures and correlations developed to estimate the resilient modulus of subgrade soils in Wisconsin. Part 3: Use of Unsaturated Soil Mechanics for Expansive Clay Problems and Pavement Design contains a model to predict pavement roughness caused by expansive soils and traffic, using the serviceability index and the national roughness index, plus case studies of pavement performance on expansive soils. Part 4: Pavement Subsurface Drainage offers research on environmental and traffic impacts on predictions derived from the *Mechanistic–Empirical Pavement Design Guide*, behaviors of drainable pavement base and subbase materials used by the Ohio Department of Transportation, and more.

2006; 180 pp.; TRB affiliates, $43.50; nonaffiliates, $58. Subscriber category: soils, geology, and foundations (IIIA).



Artificial Intelligence and Advanced Computing Applications

Transportation Research Record 1968

Research studies in this volume include a comparison of two trip-forecasting approaches for a multiple-station, shared-use vehicle system; an evaluation of sensor- and image-based technologies for automated pavement condition surveys; a genetic neural network classification method that uses acoustic signals to detect automobile accidents at intersections; the development of an automotive crash prediction model; two artificial intelligence paradigms used as decision support tools for real-time, automotive traffic management; and more.

2006; 125 pp.; TRB affiliates, $36; nonaffiliates, $48. Subscriber category: planning and administration (IA).

TRB PUBLICATIONS

Highway Safety: Law Enforcement; Alcohol; Driver Training; Safety Planning and Management; Commercial Vehicles; and Motorcycles
Transportation Research Record 1969
Authors address such topics as the effectiveness of speed-limit enforcement methods on drivers in Saudi Arabia; how red light cameras affect red light running at signalized traffic intersections; the proneness of motor vehicle operators to red light violation; the effects of alcoholic beverage prohibition and traffic law enforcement on reducing automotive crashes that result in injury; assessing the cognitive impairment of past users of methamphetamine and marijuana and the effects on driving performance; the duration of a driving simulator's effects on young and novice drivers; and more.

2006; 133 pp.; TRB affiliates, $36; nonaffiliates, $48. Subscriber category: safety and human performance (IVB).

Bituminous Paving Mixtures 2006
Transportation Research Record 1970
This two-part volume presents research on such topics as the long-term effectiveness of antistripping additives in asphalt mixes; the correlation between laboratory test results and field performance when a Hamburg wheel-tracking device is used to evaluate the moisture sensitivity of asphalt mixes; a method for quantifying moisture permeability of hot-mix asphalt pavement mixes; a procedure to determine the post-stress healing rate of asphalt mixtures; improving the determination and calibration of the dynamic internal angle of gyration for a Superpave® gyratory compactor using mechanical mixture simulation devices; the evaluation of a uniaxial penetration test for characterizing the shear resistance of hot-mix asphalt mixtures at elevated temperatures; and more.

2006; 222 pp.; TRB affiliates, $46.50; nonaffiliates, $62. Subscriber category: materials and construction (IIIB).

Transit: Bus, Paratransit, and Marketing and Fare Policy
Transportation Research Record 1971
Research in the areas of bus, paratransit, and marketing and fare policy composes this volume's three parts. Authors examine topics that include a framework to evaluate New York City corridors for bus rapid transit demonstration projects; automated methods for designing optimal shuttle and feeder bus routes for urban networks; a model for locating bus stops and optimizing passenger bus frequencies in congested local public transport networks; changes in passenger activity and operating performance after completion of a bus stop consolidation project in Portland, Oregon; a conceptual model of alternative organizational structures for implementing brokerage paratransit services; access and usage patterns among Chicago Transit Authority smart-card users; students' responses to a proposed mandatory transit pass program at Western Washington University, Bellingham; and more.

2006; 148 pp.; TRB affiliates, $41.25; nonaffiliates, $55. Subscriber category: public transit (VI).

Travel Survey Methods, Information Technology, and Geospatial Data
Transportation Research Record 1972
Papers include an examination of the characteristics of proxy respondents to self-completed questionnaire travel diary surveys in Australia; driver demographics, travel characteristics, and household travel survey protocol considerations that affect survey underreporting; an integrated global positioning system–geographic information system to automate the processing of personal travel survey data; a Virginia archived data management system; and more.

2006; 150 pp.; TRB affiliates, $41.25; nonaffiliates, $55. Subscriber category: planning and administration (IA).

Traffic Control Devices, Visibility, and Rail–Highway Grade Crossings 2006
Transportation Research Record 1973
Determining the effectiveness of transverse rumble strips in warning motor-vehicle operators approaching rural, stop-controlled intersections; demonstrating the effective use of the flashing yellow arrow permissive indication; assessing the short- and long-term effectiveness of speed-monitoring displays for speed reduction in school zones; reducing animal–vehicle collisions by placing advisories on dynamic message signs; and an investigation of the lighting levels required for crosswalk illumination in Europe are among some of the topics covered in this volume.

2006; 156 pp.; TRB affiliates, $41.25; nonaffiliates, $55. Subscriber category: highway operations, capacity, and traffic control (IVA).

Pavement Management; Monitoring, Evaluation, and Data Storage; and Accelerated Testing 2006
Transportation Research Record 1974
Studies address the ability of neural networks and recurrent Markov chains to model pavement crack

TRB PUBLICATIONS

performance, using the Florida Department of Transportation's pavement condition data; funding for New Jersey Interstate rehabilitation; a process to facilitate informed decision making on the use of cost-effective base materials in highway construction projects; the performance of dowel bar retrofit joints; the development of a realistic model for predicting deterioration in cement-stabilized base course layers of semirigid pavements; and more.

2006; 144 pp.; TRB affiliates, $39; nonaffiliates, $52. Subscriber category: pavement design, management, and performance (IIB).

Soil Mechanics 2006
Transportation Research Record 1975
This gathering of papers is divided into three parts. Part 1: Performance of Soil Structures, Modeling of Foundation Elements, and Monitoring of Integral Abutment Bridges addresses such topics as quantifying 40-year-old concrete bridge pile damage levels; structural capacity and centrifuge tests for measuring the horizontal bearing capacity of rigid suction piles; and more. Part 2: Transportation Earthworks: Compaction, Specification, and Construction with Nontraditional Materials and Methods includes research on sustainable specifications of materials and methods used in earthworks and foundations for highways, railways, and airfield runways; intelligent soil compaction test results; and more. Part 3: Geosynthetics: Soil and Aggregate Reinforcement Testing contains information on geosynthetic reinforcement of highway construction working platforms; a deformation-resistance model for unpaved roads reinforced with geogrid; the effect of soil friction angle on geosynthetic reinforcement layer embedment depth in granular-reinforced foundations; and more.

2006; 162 pp.; TRB affiliates, $41.25; nonaffiliates, $55. Subscriber category: soils, geology, and foundations (IIIA).

Design of Structures 2006
Transportation Research Record 1976
Presented in 7 parts—General Structures, Steel Bridges, Concrete Bridges, Dynamics and Field Testing of Bridges, Seismic Design of Bridges, Culverts and Hydraulic Structures, and Structural Fiber-Reinforced Plastics—are papers on such topics as integrating computer-aided design, engineering, and manufacturing to aid bridge design–build project delivery; the influence of residual crash damage on fatigue performance of heat-straightened steel bridge girders; the design of a hammerhead bent cap using procedures in the American Association of State Highway and Transportation Officials' Bridge Design Specifications; improving the performance of a deteriorated bridge with carbon fiber–reinforced polymer; and more.

2006; 206 pp.; TRB affiliates, $45; nonaffiliates, $60. Subscriber category: bridges, other structures, and hydraulics and hydrology (IIC).

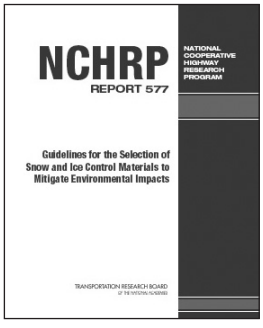
Travel Demand and Land Use 2006
Transportation Research Record 1977
An exploratory analysis of children's travel patterns; estimating traveler behavior in the context of transport mode choice using a stochastic neuron–fuzzy inference system model; the use of a tour-based travel demand microsimulation model to estimate the impact on mobility and accessibility for differing populations in support of a national transportation plan; an examination of residential location choice in Austin, Texas; a mixed logit framework for tracking land cover change; research to improve the Baltimore Metropolitan Council's ability to incorporate land use considerations into its regional transportation planning process; and the relationship between transportation accessibility and land value represent some of the topics covered in this volume.

2006; 291 pp.; TRB affiliates, $50.25; nonaffiliates, $67. Subscriber category: planning and administration (IA).

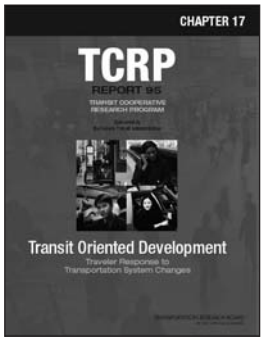
Guidelines for the Selection of Snow and Ice Control Materials to Mitigate Environmental Impacts
NCHRP Report 577
This report evaluates the impact on the environment and infrastructure, cost, and performance of snow and ice control materials. Guidelines for the selection of these materials are included: a decision tool to enable the selection of snow and ice control materials to suit the specific needs of a highway agency; a purchase specification, usable by an agency once materials have been selected for use; and a quality assurance monitoring program that includes procedures and standard test methods to characterize snow and ice control products before their purchase or use.

2007; 194 pp.; TRB affiliates, $37.50; nonaffiliates, $50. Subscriber categories: energy and environment (IB); maintenance (IIIC).

Evaluating Air-Entraining Admixtures for Highway Concrete
NCHRP Report 578
A procedure is recommended for evaluating air-entraining admixtures used in highway concrete. Cri-



TRB PUBLICATIONS



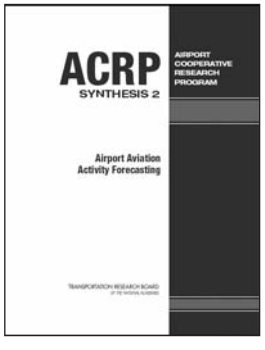
teria are proposed for acceptance of admixtures for use in either highway pavements or structures. Recommended procedure and acceptance criteria will guide materials engineers in evaluating and selecting air-entraining admixtures that can contribute to appropriate freeze–thaw durability, good performance, and long service life.

2007; 49 pp.; TRB affiliates, $27; nonaffiliates, $36. Subscriber category: materials and construction (IIIB).

Technologies for Improving Safety Data
NCHRP Synthesis 367

Information is provided on new technologies for the acquisition, processing, and management of crash, roadway inventory, and traffic operations data. The synthesis summarizes the current state-of-the-practice, as well as state-of-the-art technologies for efficient and effective collection and maintenance of data for highway safety analysis.

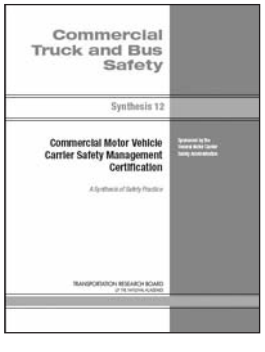
2007; 102 pp.; TRB affiliates, $33.75; nonaffiliates, $45. Subscriber categories: planning and administration (IA); safety and human performance (IVB).



Traveler Response to Transportation System Changes: Transit-Oriented Development
TCRP Report 95, Chapter 17

The TCRP Report 95 series comprehensively documents various transportation system changes, policy actions, and alternative land use and site development design approaches. This third edition covers 18 topic areas—9 are new. Chapter 17 focuses on the transit-oriented-development land use strategy and its transportation impacts, organized by regional context, land use mix, and primary transit mode.

2007; 138 pp.; TRB affiliates, $36.75; nonaffiliates, $49. Subscriber categories: planning and administration (IA); highway operations capacity, and traffic control (IVA); public transit (VI).



Guidebook for Evaluating, Selecting, and Implementing Suburban Transit Services
TCRP Report 116

The status of suburban transit services and land use environments and the relationship between the two are examined. Also investigated are ways to help policy boards and transit agencies better understand service options and attributes.

2006; 33 pp.; TRB affiliates, $22.50; nonaffiliates, $30. Subscriber category: public transit (VI).

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Bus Transit Service in Land Development Planning
TCRP Synthesis 67

The relationship between bus transit service and land development planning is described, and strategies for incorporating bus transit service into land development are identified, along with related challenges. Information is provided on the use of transit agency development guidelines and their components.

2006; 62 pp.; TRB affiliates, $24; nonaffiliates, $32. Subscriber category: public transit (VI).

Methods of Rider Communication
TCRP Synthesis 68

This synthesis documents effective methods of communicating with transit customers in a variety of situations. Five dimensions determine successful communication: (*a*) the demographics of the agency's target audience; (*b*) the content, form, and accessibility of the communication; (*c*) the communication's timing and frequency; (*d*) the media used; and (*e*) the capital and operating costs involved.

2006; 91 pp.; TRB affiliates, $26.25; nonaffiliates, $35. Subscriber category: public transit (VI).

Airport Aviation Activity Forecasting
ACRP Synthesis 2

Current practices and methods in airport activity forecasting in the United States are reviewed. Ways in which airport forecasts are used are examined, and common aviation metrics, aviation data sources, issues in data collection and preparation, and special data issues at nontowered airports are identified. Also provided are assessments of forecast accuracy, issues of optimism bias, and options for resolving differences when a variety of forecast data are available.

2007; 32 pp.; TRB affiliates, $33; nonaffiliates, $44. Subscriber categories: planning and administration (IA); aviation (V).

Commercial Motor Vehicle Carrier Safety Management Certification
CTBSSP Synthesis 12

This synthesis documents commercial motor vehicle safety certification, self-evaluation, benchmarking, and best-practices programs; identifies major common elements and protocols; and critically assesses evidence for the crash-reduction effectiveness of the programs.

2007; 52 pp.; TRB affiliates, $33.75; nonaffiliates, $45. Subscriber categories: operations and safety (IV); freight transportation (VIII).

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