JANUARY–FEBRUARY 2013
NUMBER 284

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

TR NEWS

Sharing the Spirit of Innovation

Examples from the States

Plus:

Solving Highway Congestion
Lessons for Climate Change
Mapping Natural Hazmats

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

National Academy of Sciences
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The **Transportation Research Board** is one of six major divisions of the National Research Council, which serves as an independent adviser to the federal government and others on scientific and technical questions of national importance, and which is jointly administered by the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The mission of the Transportation Research Board is to provide leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal. The Board's varied activities annually engage about 7,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities.

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COVER: Schoolchildren in Waltham, Massachusetts, form a "walking school bus," one of many innovative initiatives under the state's exemplary GreenDOT program. (Photo: Massachusetts DOT)

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.

***TR News* is produced by the Transportation Research Board Publications Office**
Javy Awan, Editor and Publications Director
Lea Camarda, Assistant Editor
Jennifer J. Weeks, Photo Researcher
Juanita Green, Production Manager
Michelle Wandres, Graphic Designer

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Editorial Correspondence: By mail to the Publications Office, Transportation Research Board, 500 Fifth Street, NW, Washington, DC 20001, by telephone 202-334-2972, by fax 202-334-3495, or by e-mail jawan@nas.edu.

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The expansion of incompatible land uses raises serious threats to the U.S. freight transportation system. Research under the National Cooperative Freight Research Program (NCFRP) has developed tools and strategies to resolve or minimize the conflicts between nonfreight land use and freight corridors and facilities, implementing the principle of freight-compatible development.

A comprehensive guide from NCFRP for planners and decision makers explains the importance of urban freight movements to the economic health of local communities, the impact of local regulations on efficient freight movement, and ways to accommodate and expedite urban goods movement while minimizing environmental impacts and adverse consequences for the community.

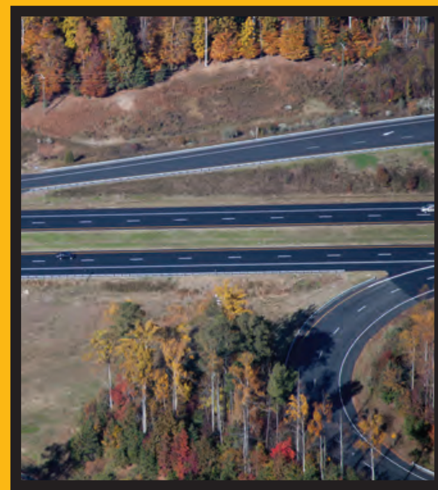
ALSO IN THIS ISSUE:

COMING NEXT ISSUE

Photo: Risdon Photography

Photographic highlights of sessions, events, presentations, meetings, exhibits, awards, and more from TRB's 92nd Annual Meeting—including valedictory speeches by two major transportation leaders—is accompanied in the March–April issue of *TR News* by feature articles on the promise of connected vehicle technology; the accomplishments and vision of more than two decades of TransTech Academy, preparing urban students for careers in transportation; and practical insights from TRB's first-ever virtual conference.

U.S. Secretary of Transportation Ray LaHood spoke at two TRB Annual Meeting events in January, reviewing initiatives, programs, and progress under his term. A record-setting attendance explored the theme of "Deploying Transportation Research: Doing Things Smarter, Better, Faster."



IMPLEMENTERS *of* INNOVATION

Findings from the Transportation Research Board's 2012 State Partnership Visits Program

Specialists in the Transportation Research Board'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 hundreds of organizations and thousands of individuals provide TRB staff with information from the public and private sectors about all modes of transportation.

A major source of this information is TRB's annual state partnership visits program. Transportation professionals on the TRB staff meet on site with representatives of state departments of transportation (DOTs) and with representatives of universities, transit and other transportation agencies, and industry. In addition, TRB staff is involved with planning and delivering conferences, workshops, and meetings. This report summarizes what the TRB staff learned from visits and activities during the past year.

Photo: Massachusetts DOT

The "walking school bus" and other GreenDOT initiatives from Massachusetts Department of Transportation (DOT) increased awareness of pedestrian safety and alternatives to automobile transportation.

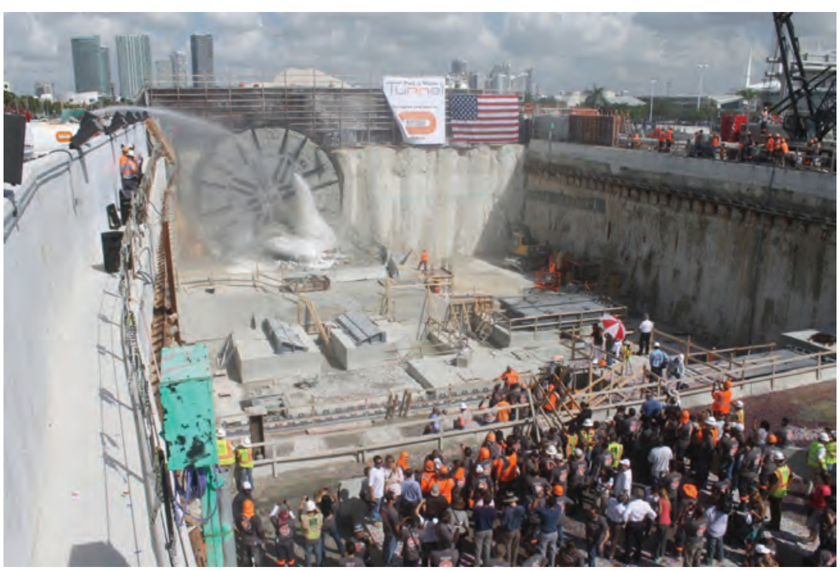


Photo: Florida DOT

A tunnel-boring machine emerges from the ground, after excavating a section of the Port of Miami Tunnel in Florida. The project, a public–private partnership between the State of Florida and Miami Access Tunnel Concessionaire, LLC, is partially funded with a Transportation Infrastructure Finance and Innovation Act loan.

The year 2012 was a rollercoaster of good news and bad news for the economy in general and for transportation funding in particular. The good news included a slowly improving economy, with increases in tax receipts. The Fiscal Survey of States, released in early December by the National Association of State Budget Officials and the National Governors Association, found that state revenues for the fiscal year surpassed prerecession levels for the first time.[1] In addition, voters approved a majority of the transportation revenue issues on the November ballots. At the national level, the signing of the multiyear transportation authorizing legislation, the Moving Ahead for Progress in the 21st Century Act (MAP-21), established certainties about funding for federal-aid surface transportation programs.

Nonetheless, many uncertainties persist. The MAP-21 legislation only covers two years. As 2012 ended, Congress and the Administration grappled with the potential sequestration of federal funding. Most observers expect a reduced level of federal spending on discretionary programs, including transportation, in the coming years. At the state and local government levels, revenues are growing at a slower rate than health care costs, which could diminish the funding for transportation, infrastructure, education, and public safety.

State DOTs and other transportation organizations are meeting the challenge of these continued economic uncertainties by implementing innovative solutions to transportation problems.

Institutional Issues

Policy, Management, and Leadership

Enacted in July 2012, MAP-21 provides $105 billion in funding for fiscal years (FY) 2013 and 2014 to address a multimodal surface transportation program of improvements to mobility for passengers and freight, safety, efficiency, and environmental protection.

Among its major provisions, MAP-21 emphasizes a performance-based approach. Rulemaking is still under way, but many states have created and implemented their own performance measures. For example, Massachusetts DOT's GreenDOT Policy features a variety of measures designed to achieve the state's environmental objectives.

MAP-21 significantly increased the funds available under the Transportation Infrastructure Finance and Innovation Act (TIFIA), an innovative finance tool, providing $750 million in FY 2013 and $1 billion in FY 2014. The program provides a means for eligible projects to leverage limited federal resources through supplemental or subordinate debt.

States continued to pursue public–private partnerships and establish high-occupancy toll (HOT) lanes. Los Angeles County, California, and the Washington, D.C., area's Capital Beltway were among those opening HOT lanes in 2012.

With the expectation of long-term constraints on federal funding, stagnant or declining revenues from fuel taxes, and other competing demands for scarce dollars, states and local agencies are relying more on their own sources of revenue. In November, voters approved more than 70 percent of the state and local transportation bond issues and referenda on the ballot.

[1] www.nasbo.org/sites/default/files/Fall%202012%20Fiscal%20Survey%20of%20States.pdf.

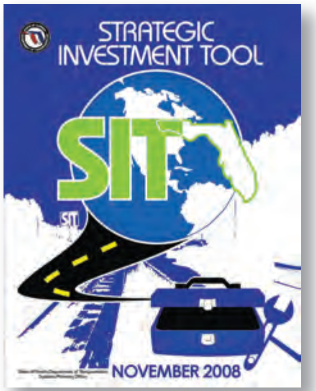
Photo: Charlie Gannon, courtesy Walsh Construction

When planning the Milton Madison Bridge project, Indiana DOT analyzed the economic impacts of bridge closure on area businesses as well as the impacts of construction spending.

Planning

Transportation planning historically has considered economic factors in evaluating project alternatives and investment programs. This approach has become increasingly critical, as transportation agencies at all levels work to improve local economic conditions. Agencies have adopted innovative techniques to incorporate economic impacts, competitiveness, growth, and diversification, as well as benefit–cost analysis, development potential, and other related factors, into the decision-making process.

Indiana DOT's economic analysis of the Milton Madison Bridge, a critical connection between Indiana and Kentucky, not only addressed the economic impact of construction spending—a traditional consideration—but also the regional economic impact on businesses and industries during the bridge closure, an innovative approach. The analysis of the impact on regional businesses, which included a discussion of the advantages of ferry service during the construction, was critical in deciding between alternatives.



Florida DOT developed its Strategic Investment Tool to evaluate highway projects and plans to extend it to other modes as well.

Florida DOT developed the Strategic Investment Tool (SIT) to select and prioritize projects. The online web tool evaluates each project against five goals and 24 measures; "enhanced economic competitiveness and economic diversification" is a sample goal. SIT includes three components—a system viewer, analyzer, and reporter. Florida DOT uses the tool for highway projects but plans to expand use to other modes.

As these examples demonstrate, transportation agencies are employing new tools and evaluations to ensure optimal economic returns from projects.

Legal Issues

Transportation agencies are expanding their use of social media, raising legal and operational concerns about the use of social media to expedite the delivery of transportation programs, particularly for legal notifications and public involvement. Connected and driverless vehicles—especially the challenges and opportunities for highway authorities—are other technologies attracting the attention of the transportation legal community.

MAP-21 includes new provisions that affect the environmental review process, by accelerating project delivery. For example, the new procedures combine the final environmental impact statement with the record of decision under the National Environmental Policy Act. This will permit federally funded advance acquisition of real property before the completion of review and will further integrate the planning and environmental review processes. The full effects of the MAP-21 provisions remain to be seen.

The impact of the 2009 *Manual on Uniform Traffic Control Devices* on state traffic and highway safety operations and the perceived loss of flexibility to

PHOTO: KEVIN STILLMAN, TEXAS DOT

Maribel Chavez and Bill Hale, Texas DOT, test a pickup truck powered by compressed natural gas. The agency is piloting a program to determine the cost-effectiveness of natural gas vehicles.

apply engineering judgment in decisions about traffic control devices remain a continuing legal concern for state DOTs.

Environment, Energy, and Climate Change

Managing stormwater runoff remains an issue for states, particularly in evaluating Municipal Separate Storm Sewer System permit requirements and in preparing for audits. Culvert management and providing passages for protected aquatic species, particularly in critical habitat areas, are other water-related areas of focus.

States also are evaluating the effectiveness of programs and policies to reduce greenhouse gas emissions from transportation networks. Some are exploring ways to engage in carbon markets and to integrate climate change considerations into transportation project development.

Other environmental issues that states are addressing include the use of natural gas and hydrogen fuel cell technologies; identifying and evaluating the historic significance of post– World War II housing in compliance with the National Historic Preservation Act; and the effects of transportation-related noise on wildlife.

Critical Infrastructure Protection and Security

Superstorm Sandy provided a compelling example of the devastating impact disasters can have on the nation's transportation infrastructure, with cascading failures crippling freight and passenger transportation, as well as a region's and the nation's economy. Although the area most affected by Sandy is regarded as well-prepared for such situations, flooding shut down virtually every component of the transportation system into and out of New York City. The superstorm issued a wakeup call to officials at all levels in all areas of the country that more must be done to find ways to harden transportation systems against damage and to prevent a disaster from taking systems offline.

Emergency management agencies have connected with nongovernmental organizations, private industry, and supply chain companies to coordinate relief aid, cleanup efforts, and fuel needs. Florida and Louisiana have enacted laws requiring motor fuel facilities—including terminals, wholesalers, and service stations—to be able to switch to an alternative source of energy during a power outage. At West Virginia University, research funded by the Department of Homeland Security is developing an inflatable plug to hold back floodwaters from transportation tunnels—a less expensive alternative to retrofitting tunnels with metal floodgates or other more expensive structures.

Providing real-time observations and data to authorities and responders in affected areas is critical to the resumption of traffic across all modes. Social media are taking on an increasingly important role in preparation, response, and recovery.

Data and Information Technologies

Data to support enterprise approaches such as asset management and performance measurement—as well as investment strategies that consider more than pavement and bridges—are a focus among states. Utah DOT learned from its early asset management work that statewide, automated data collection was necessary to provide the data quality needed to support decisions.

PHOTOS: PATRICK CASHIN, METROPOLITAN TRANSPORTATION AUTHORITY

Employees from Metropolitan Transportation Authority–New York City Transit worked to restore the South Ferry subway station after it was flooded by seawater during Superstorm Sandy.

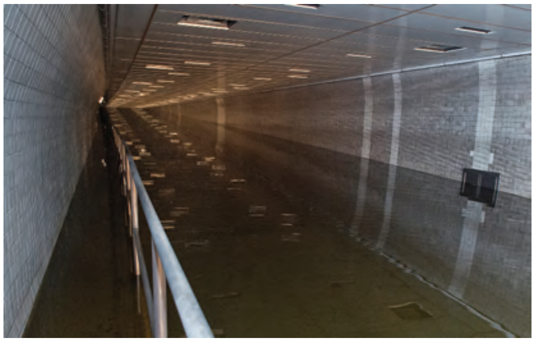


Photo: Patrick Cashin, Metropolitan Transportation Authority

The Hugh L. Carey Tunnel, formerly known as the Brooklyn Battery Tunnel, flooded during Superstorm Sandy. Destruction and severe delays caused many transportation officials to reexamine emergency procedures.

Recent technology advances, such as lidar, have enabled states to inventory more than pavement data by including signs and other roadside features, as well as to incorporate additional functions, such as maintenance. Spreading the cost over several functions also ensures the necessary annual updating of the inventories.

To manage investment levels across assets—including information technology services, fleets, maintenance, bridges, and pavements—Colorado DOT is developing a system that generates life-cycle spending forecasts to support integrated analysis. Colorado policy makers have required that budget presentations include alternative investments.

Demonstrating the critical role of transportation in state economies is a key task. Through the shared use of private-sector supply chain data, for example, public agencies can strengthen freight planning without having to gather new data. The success of such an arrangement depends on the private sector's understanding of the value to be gained from public use of the data and on the public sector's respect for proprietary concerns.

California's program to improve trade corridors demonstrated the importance of key freight gateways for the state and the nation. The efforts also demonstrated that improved use of private supply chain data can support public investment decisions and can minimize supply chain costs for the public and private sectors alike.

Aviation

The passage of the Federal Aviation Administration (FAA) Modernization and Reform Act early in 2012 was intended to provide support for the implementation of NextGen technologies. Although the legislation relieved many uncertainties, anticipated requests for budget and staffing cuts from all facets of the federal government, including FAA, leave the future of many programs in doubt. States are concerned about the effects of pending budget cuts on local and regional aviation systems, particularly for projects at general aviation airports—even a small budget reduction could prevent the implementation of much-needed improvements.

In the meantime, the industry continues to evaluate new technologies and other opportunities to support aviation. Research continues on the production, use, and distribution of alternative aviation fuels; the development of inventories, registries, and credit systems for greenhouse gas accounting; the integration of the Unmanned Aerial System market into civil, nonmilitary airspace and airports; and the improvement of response and recovery from irregular operations after natural disasters or other events.

Freight Systems

MAP-21 recognizes the importance of the freight system and calls for a national freight policy and strategic plan and for incentives for states to engage in freight planning through dedicated state plans and advisory committees.

In October, Superstorm Sandy exposed the fragility and challenged the resilience of freight systems, affecting 24 states and causing mass disruptions and severe damage in the Northeast. This populous region is a major cargo gateway, consumer market, and energy hub. The storm created a complex array of response and recovery problems, including power outages, fuel shortages, and damaged infrastructure and rolling stock, sending ripple effects throughout the supply chain. Seaports as far south as Norfolk, Virginia; Charleston, South Carolina; and Savannah, Georgia, accepted cargo originally destined for the affected areas.

The effects of climate change on freight systems and infrastructure, as well as on preparedness and recovery practices, remain priority concerns for states.

The retired spacecraft *Discovery* was flown from Cape Canaveral, Florida, to the Stephen F. Udvar-Hazy Center in Virginia in April 2012.

Photo: Christine Gerencher

Photo: Trevor Wrayton, Virginia DOT

Virginia DOT has implemented innovative technologies such as quiet pavements, here on Route 199 near Williamsburg.

Highways

Design

Design engineers at state DOTs are key players in the development and deployment of innovation—defining research needs, implementing new codes and specifications, learning about innovations via conferences and webinars, and assisting field personnel in implementing new products and processes.

Engineers and scientists at the Virginia Center for Transportation Innovation and Research, for example, identify opportunities for implementing innovation by working through Virginia DOT district offices. The center provides funding to help cover additional construction costs, offers technical support during implementation, and assists with troubleshooting during implementation. Recent efforts to implement innovation include warm-mix asphalt, quieter pavements, and road kill composting.

Similarly, Oklahoma has taken an innovative approach in implementing the *Mechanistic–Empirical Pavement Design Guide*; Utah has taken the lead in accelerated bridge construction innovations; Minnesota has had success with living snow fences; and Montana has produced a new design guide that improves the environmental impact and decreases the cost of rest areas.

In all cases, the state DOTs note that the implementation of innovation begins during the scoping of the research; that collaboration between designers, researchers, field personnel, and industry partners is necessary; and that someone in the field has to champion the innovation.

Highway Construction and Materials

State agencies are facing the challenge of replacing or improving their deteriorating infrastructure despite the uncertainty in revenue. Many states recognize that construction of larger projects is changing, with an assortment of alternative project delivery methods, with techniques that are faster and less inconvenient to the public, and with increasing use of intelligent construction systems and technologies.

Several states have adopted accelerated bridge construction and are developing a statewide policy for selecting appropriate projects. A few states have applied intelligent compaction for pavement projects.

The acceptance of recycled and reclaimed materials in pavement structures is increasing. Caltrans is moving to a statewide standard that allows asphalt pavements with up to 25 percent recycled asphalt pavement, taking advantage of the high-quality aggregate. Michigan has developed a guide for the use of recycled concrete aggregate in various paving layers. A national pooled-fund study is under way on the use of processed recycled asphalt shingles. Warm-mix asphalt is gaining momentum as research on its long-term performance continues.

Alkali–silica reactivity in new and existing concrete structures remains an issue; research is exploring prevention and mitigation. Research also is under way to improve concrete curing products and application methods; Arkansas is experimenting with a lithium cure on bridge decks. Interest is growing in the application of nanotechnology in asphalt and concrete materials.

Photo: Missouri DOT

In Missouri, roofing shingles are recycled into pavement aggregate. State DOTs increasingly are incorporating reclaimed and recycled materials into pavement structures.

Photo: Lee Galliyan, FHWA

Intelligent compaction density evaluation in Utah.

Geotechnical Engineering

Geologic hazards such as landslides and rockfalls that affect transportation corridors are a concern for state DOTs. In 1996, TRB published Special Report 247, *Landslides: Investigation and Mitigation*; in 2012, TRB published a companion volume, *Rockfall: Characterization and Control,* prepared by a task force of experts. These two resources offer a wealth of practical information.

Aggregates comprise a major volume of the asphalt and concrete mixes used for the construction of transportation infrastructure; aggregate properties—such as shape, size, chemistry, and surface characteristics—influence the performance of infrastructure and are subjects of ongoing research. With state DOTs concerned about protecting the environment, reducing transportation's carbon footprint, and increasing sustainability, interest has increased in using marginal aggregates or recycled material found close to the construction sites. These approaches offer economic and sustainability benefits by reducing greenhouse gas emissions, energy use, congestion, and stress on pavements.

More states are using the lightweight deflectometer (LWD) in construction quality assurance. The LWD provides in situ measurements of the properties of soil and layered systems for the design and construction of transportation facilities. A recognized standard for interpreting the load and deflection data obtained during construction quality assurance testing is needed, however, as well as guidance relating the measurements to the material properties used for pavement design. A pooled-fund study is addressing this gap in knowledge in 2013, with Maryland DOT in the lead.

Highway Operations

Vehicle-to-vehicle and vehicle-to-roadway technologies may yield the next major breakthrough in operations and safety. Federal and state agencies, the automobile industry, and other private-sector partners have been researching the effectiveness and feasibility of connected vehicle technology, which allows vehicles to communicate with other vehicles, to traffic signals, and to other roadside devices via short-range wireless communications.

Deployment of this technology could enable cooperative solutions to advance real-time operations and prevent crashes. Drivers who have participated in field tests have given the connected vehicle technologies an overwhelmingly positive response.

Managing demand and optimizing system operations are cost-effective solutions to reduce delays and improve travel-time reliability. Many state DOTs are working to use the entire roadway to improve the

Photo: Brian Diefenderfer, Virginia Center for Transportation Innovation and Research

A core sample from an in-place pavement recycling project on I-81 near Staunton, Virginia. Virginia DOT combined full-depth reclamation, cold central-plant recycling, and cold in-place recycling in the project. Many states are experimenting with recycled pavement material for environmental sustainability.

Photo: National Park Service

Road crews remove debris from a rockfall in January 2012 that closed Highway 120 in Yosemite National Park for more than a month.

Photo: U.S. DOT

Research into connected vehicle technology, incorporated into the dashboard and console above, could lead to safer roads and reductions in travel delays.

performance of specific lanes or of the entire freeway or highway. This management of the cross section and operation of a freeway or arterial is becoming commonplace.

An active management approach distinguishes this new focus on managed lanes from the traditional forms of freeway management—the operating agency proactively manages demand and available capacity on the facility by applying new operational countermeasures or by modifying strategies. These strategies could include dynamic speed limits; restricted lanes—for example, for high-occupancy vehicles or trucks only; variable pricing based on the level of congestion; access controls such as express or reversible lanes; motorist information—for example, through electronic variable messaging and lane control signs; temporary shoulder use; ramp metering, and more.

Infrastructure Preservation

Preservation of the transportation infrastructure and operating systems requires expertise in management, engineering, and economics, as well as the establishment of strategic performance goals. An assortment of routine maintenance, preventive maintenance, and minor rehabilitation activities also is needed to progress toward network goals for pavements, bridges, drainage structures, roadsides, traffic control systems and devices, rest areas, and more.

Infrastructure preservation is a management approach based on scientific principles. The goal is to maintain the functioning of infrastructure elements through the timely application of cost-effective preventive maintenance designed to safeguard the integrity of each element and to extend performance life.

A recent AASHTO report advocated for national-level performance measures that reinforce an asset management approach in implementing MAP-21; specifically to be avoided are measures that promote or support a "worst-first" approach.[2] Many studies in the past 20 years have documented that a preservation project can provide up to a 14-fold difference in benefit–cost ratio, depending on the condition of the element and the preservation action selected.

A balanced, three-pronged approach of preventive maintenance, rehabilitation, and reconstruction synergetically can improve network condition, optimize available funds, and balance the remaining service life of the network features. Successful implementation requires extensive training for staff to develop a good understanding of how the preservation approach works and to increase confidence throughout the organization in the effectiveness of an infrastructure preservation program based on asset management. The intent is to minimize the cost of ownership and operations in providing the short- and long-term benefits of safety and mobility to users.

A vehicle involved in a rollover collision is pulled upright. Vehicle safety technologies, such as electronic stability control, can increase highway safety.

Photo: Matthew Fern

Highway Safety

Early estimates for the first six months of 2012 show increases in U.S. highway fatalities compared with the numbers for the previous five years. The increases do not constitute a trend, but states are interpreting the findings as a call to strengthen efforts to update and implement Strategic Highway Safety Plans, a goal reinforced by MAP-21. Many states are employing new methods to identify problems and to develop solutions with the greatest potential for reducing fatalities and serious injuries.

To achieve the goal of improving safety on all public roads, federal legislation enhances states' roles and interests in local roads. Through a unique three-year program, Minnesota DOT developed a crash data and analysis guidebook for every county in the state. With this resource, plus technical assistance on request, each county created its own SHSP and is now working on implementation with Minnesota DOT and the Governor's Office for Highway Safety. Iowa DOT provides local agencies with data on crashes and locations, along with assistance in conducting data analysis and interpretation. A "circuit rider" program offers on-site assistance in safety program development and implementation.

[2] *SCOPM Task Force Findings on National-Level Performance Measures*, AASHTO, Washington, D.C., November 9, 2012.

Photo: Panama Canal Authority

Construction continues on the Panama Canal expansion project. Coastal states with deep-draft ports are investing in increased infrastructure capacity for the larger ships enabled by the expansion, as well as dredging and intermodal connectivity projects.

Vehicle safety is another part of the highway safety equation and continues to contribute to saving lives. Electronic stability control (ESC), for example, saved an estimated 863 lives in 2010, according to the National Highway Traffic Safety Administration, a substantial increase over recent years. Additional increases are expected as ESC penetrates the vehicle fleet. Other vehicle safety systems—for example, vehicle connectivity—are being field-tested in Ann Arbor, Michigan.

Ports and Waterways

The Panama Canal's third set of locks is scheduled to open in 2015; states with deep-draft ports along the East and Gulf Coasts are investing in landside and waterside infrastructure capacity to qualify as gateways for the new cargo. Some states are increasing contributions to expedite dredging projects and are complementing these investments with intermodal connectivity projects.

In Florida, Miami has embarked on an innovative multimodal investment strategy—a dredging project has received $70 million in state funding; the Miami Tunnel, which connects the seaport to Interstate 95, has benefited from a TIFIA loan from U.S. DOT; and an intermodal rail yard is funded in part with a U.S. DOT Transportation Investment Generating Economic Recovery grant. Georgia has committed $231 million to the Savannah Harbor Expansion Project, has expanded Savannah's main intermodal container transfer facility, and has funded multiple, intermodal connector road projects for the port. West Coast states and ports continue to make investments to enhance their market share of cargo by balancing expansion projects with environmental stewardship.

In addition to the perennial funding challenge of maintaining the aging system of locks and dams on the inland waterways, drought conditions in the Midwest have created extremely low water conditions on the Mississippi River. Without assistance from the U.S. Army Corps of Engineers in removing rock formations and in releasing additional water from the Missouri River reservoirs, barge traffic between St. Louis, Missouri, and Cairo, Illinois, risks a shutdown.

Photo: John Vlanakis

Some rail corridors offer high-speed service such as *Acela*; policy makers are debating the future of high-speed rail in the United States.

PHOTO: NORFOLK SOUTHERN

Double-stacked freight trains travel Norfolk Southern's Crescent Corridor, a 2,500-mile rail network from Memphis, Tennessee, and New Orleans, Louisiana, to New Jersey.

Rail

Passenger Rail

As passenger rail ridership increases, state and national leaders continue to debate over high-speed rail (HSR). Is HSR the next great transportation investment for the United States? Is the vision of a nationwide network achievable? What roles should the federal government, state governments, and the private sector play? Where should the funding come from? Do the costs outweigh the potential benefits? Should investments in HSR be limited to a few high-payoff corridors? Should expectations about speeds be scaled back? The answers will determine the vision for passenger rail transportation in the United States.

Freight Rail

States continue to form gateway and corridor partnerships with the freight rail industry. The CSX National Gateway and Norfolk Southern's Heartland and Crescent Corridors are examples of projects to create capacity for double-stacked container movements to distribution and transfer sites in the Midwest. In California, BNSF and the Port of Los Angeles are partnering on the Southern California International Gateway Project, which promises to eliminate more than 1.5 million truck trips from Interstate 710 each year.

Public Transportation

With increased interest in active transportation—walking and bicycling—and changes in travel preferences, many transit agencies are forming bicycle partnerships to balance the needs of all riders. Customers seek choices, convenience, flexibility, speed, affordability, safety, and fun. The integration of transit and bicycles expands mobility, increases ridership, and improves connections.

Sound Transit and King County Metro in Seattle, Washington, for example, have installed bike racks on buses and hooks and racks inside vehicles and have launched bike-sharing programs. In Portland, Oregon, Tri-Met has developed Bike & Ride for bicycle parking at transit stations. North Carolina DOT is leveraging technology and partnerships to knit together public transportation, ferry terminals, pedestrian and bicycle access, and rail.

Transit agencies across the country are launching innovative campaigns to promote ridership through social media, ads on buses and vehicles, television commercials, and improved communications with customers. To increase revenue, transit agencies are partnering with companies to provide innovative advertising to entertain and surprise customers. On Southeastern Pennsylvania Transportation Authority's regional rail, for example, transit riders can travel in full-wrap Jazz Age interiors and décor, installed to

PHOTO: JENNIFER ROSALES

Light rail transit in Salt Lake City, Utah.

Photo: Heather Redfern, SEPTA

The Southeastern Pennsylvania Transportation Authority decorated the interiors of *Silverliner* rail cars to promote an exhibit on the Prohibition era at Philadelphia's National Constitution Center. Organizations are forming advertising partnerships with transit agencies across the country.

promote a Philadelphia museum exhibit. Raleigh's Capital Area Transit System and the City of Raleigh Arts Commission have partnered to leverage advertising resources for an art-in-transit program.

Transit agencies are looking to apply results from research on emergency preparedness. Of particular interest are the tests of inflatable plugs similar to airbags to hold back floodwaters from transit tunnels, noted earlier.

Photo: Jennifer Rosales

A bus stop in Long Beach, California, features a bike station.

Smarter, Better, Faster

Inspired by these and other examples, TRB chose "Deploying Transportation Research: Doing Things Smarter, Better, Faster" as the spotlight theme for its recently concluded 2013 Annual Meeting in Washington, D.C. More than 40 sessions explored the theme—a testament to the spirit of innovation that pervades the transportation community. TRB salutes these implementers of innovation.

Did You Know?

◆ North Carolina ranks second among states with ferry operations; Washington State ranks first.

◆ Desert tortoises are an endangered species found in Arizona, California, Nevada, and Utah. The desert tortoise population in Nevada is listed as threatened. Because desert tortoises move slowly and have a limited home range, attaching tracking tags or passive integrated transponders to their shells was fairly easy. Powered with a solar battery, the tags helped track the tortoises' use of underpasses along state facilities.

Photo: North Carolina DOT

Photo: U.S. Fish and Wildlife Service

◆ State Routes 1804 and 1806 in South Dakota trend north–south in various segments along the east and west banks, respectively, of the Missouri River. The routes were designated in 1976 to commemorate Lewis and Clark's 1804 expedition up the Missouri River to the Pacific Ocean and the return in 1806. North Dakota also uses the route numbers.

◆ California's approximately 1,400 miles of high-occupancy vehicle lanes are the most in in any state.

(*Far left:*) Motor Vessel *Sea Level*, the North Carolina Ferry Division's newest vessel, was christened in Cedar Island in May 2012.

(*Above, left:*) Before heading to an underpass, a desert tortoise stares down a Nevada DOT attempt to attach a transponder.

Photo: Brett Weinstein

NEW SHRP 2 REPORT

Institutional Architectures to Improve Transportation Systems Management and Operations

Guidance for State Departments of Transportation

STEPHEN LOCKWOOD

The author is Senior Vice President, Parsons Brinckerhoff, Washington, D.C.

(*Above*:) Traffic congestion can be managed by transportation systems management and operations (TSM&O) strategies, including preferential lane use, advanced traveler warnings, and efficient signal timing. (*Right*:) Bad weather and a truck crash caused delays on I-5 southbound in Eugene, Oregon. Transportation agencies can use TSM&O strategies for incident management to address weather-related emergencies.

As the economy recovers, and congestion, delay, and unreliability increase (*1*), how are transportation agencies addressing their commitments to improve highway performance and maintain mobility, especially when building a way out of congestion is not an option? Recent research indicates that new strategies and supporting institutional arrangements can provide the means to manage congestion—if not banish it.

Managing Congestion

Congestion will never be eliminated but can be managed to minimize delay, maintain speed and throughput, and improve travel time reliability. Reliability is increasingly important—recurring, daily congestion can be planned for, but the unexpected disruptions of nonrecurring congestion extend travel times beyond what is normally anticipated and introduce uncertainties and costs that frustrate travelers and businesses.

A program that focuses on transportation systems management and operations (TSM&O) addresses reliability by implementing strategies that prepare for and respond to specific causes of unexpected delay and disruption—crashes, breakdowns, weather, construction, poorly timed signals, and special events. Together, these account for more than half of roadway travel delay and unpredictability.

TSM&O strategies include incident management,

Photo: Oregon DOT

advanced treatments for snow and ice, appropriately timed traffic signals, effective management of traffic in work zones, variable speed limits, advanced traveler warnings of traffic problems, metering of expressway ramp traffic, preferential lane use, and others. Two decades of experience have shown that these strategies are cost-effective, minimally disruptive, and quickly implemented.

Implementing TSM&O Strategies

Several state departments of transportation (DOTs) have moved aggressively to capitalize on the potential of these strategies. Nonetheless, the general rate of TSM&O implementation has been modest, and the scope and effectiveness of the strategies vary. In many congested metropolitan areas, the options for adding capacity are limited, yet an aggressive mainstreaming of TSM&O to improve the management of capacity is lacking.

A recent report from the Reliability Focus Area of the Transportation Research Board's (TRB's) Second Strategic Highway Research Program (SHRP 2), *Institutional Architectures to Improve Systems Operations and Management*, has identified the preconditions for implementing TSM&O effectively. The report presents practical guidance for state DOTs and other transportation agencies. The research compared the operations practices and other characteristics of state DOTs and found that the more effective TSM&O programs included features significantly at odds with legacy practices and traditional capacity-oriented programs.

The research suggested that developing the capabilities to support improvements in management and operations requires significant changes in the legacy conventions of the programs, processes, and organization of state DOTs and other transportation agencies. The research specified the capabilities that are needed and identified steps for development.

The report offers guidance to state DOTs in bringing TSM&O into the mainstream as a formal mission and program for managing the highway system (2). The guidance was integrated into a web-based tool and into TSM&O capability improvement workshops sponsored by SHRP 2 and the Federal Highway Administration (FHWA).

Recapturing Capacity and Reliability

Metropolitan highway vehicle travel has increased by 250 percent since 1980—exceeding the design capacity of the highway systems in major metropolitan areas. Congested conditions and low levels of roadway services—even in nonpeak hours—are the result (*3–5*).

Photo: Xiao-Feng Xie

Traffic congestion in Pittsburgh, Pennsylvania. Midsize cities also feel the effects of increased metropolitan highway travel—up 250 percent since 1980.

Only about one-half of delays, however, are caused by recurring congestion—that is, by the regular, daily, peak-hour travel delays that characterize shortfalls in capacity. The other half results from nonrecurring congestion, produced by unanticipated events, such as crashes, adverse weather, construction, and the like. Figure 1 (below) shows the relative contribution of these causes of congestion. The causes of recurring and nonrecurring congestion often arise in combinations that can exacerbate their impacts—for example, rush hour conditions can multiply the impacts of a crash or a work zone; crashes in bad weather during rush hour can have effects that are more severe.

The impact of nonrecurring congestion goes beyond delays. The disruption from unpredictable travel times is significant in a just-in-time economy that highly values individual time and places a premium on schedule and delivery predictability.

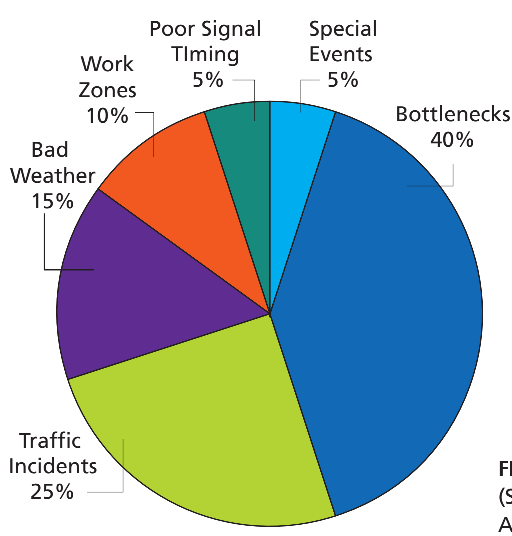


FIGURE 1 Causes of delay. (Source: Federal Highway Administration)

PHOTO: NATIONAL INSTITUTES OF HEALTH

In contrast to expanding roads to deal with increased highway use, TSM&O strategies address potential problems at the source—such as restoring capacity after an incident.

Mobility Strategy

Increasing capacity has only a modest effect on nonrecurring congestion. In contrast, TSM&O strategies focus on the specific causes of congestion and delay at the point of the problem—in real time—to reduce the impacts significantly. Some strategies, such as ramp metering, modify roadway operations as the demand varies; some quickly restore capacity after an event, as in incident management for crashes; some anticipate problems, such as snow and ice control; and others provide travelers with advance information and guidance to improve flow or to support effective route or travel decisions.

Best practice indicates that aggressive TSM&O applications at the network operational level can counter much of the capacity loss caused by congestion and disruptions. The strategies are relatively low in cost compared with adding capacity, can be implemented in two to three years, and offer substantial benefits—for example, a benefit–cost ratio of 10:1 (*6*). Table 1 provides some examples (below).

Institutional Architecture

The research indicated that TSM&O requires a characteristic set of agency capabilities different from those that support capacity programs. Special demands are placed on leadership, organization, staffing, resources, and relationships, as well as on technical and business processes. Although some

TABLE 1 TSM&O Strategy Effectiveness (*2*)

Strategy and Payoff	Example Applications	Benefit–Cost Ratio and Other Metrics
Incident and emergency management	Organize the management and clearance of disruptions and responses to emergencies to reduce delay and driver exposure to secondary accidents; improve reliability and responder safety via incident detection, verification, response, clearance, accident investigation, medical response, and traffic control	2:1 to 42:1; incident duration reduced by 30% to 40%
Road weather information systems	Generate advance and current information about disruptive weather conditions to minimize traveler delay and improve efficiency of agency's weather-related roadway maintenance with a combination of roadway environmental sensing, weather information, treatment and clearance strategies, and weather information dissemination	2:1 to 10:1; up to 50% of travelers in mountainous areas adjust plans
ITS-supported work zone traffic management plans	Provide dynamic, traffic-responsive controls in work zones via lane use and speed control and warnings to improve safety for drivers and construction workers; improve traffic flow for specific projects via detection, surveillance, lane use and speed control, signs, and signals	2:1 to 42:1; 300% reduction in dangerous merges
Traffic-responsive or traffic-adaptive signals	Provide traffic-responsive or -adaptive signal operation at intersections to minimize delay throughout corridors and networks via traffic detection, transit vehicle preemption, and appropriate signal control and network-level regimes	17:1 to 62:1; 2% to 3% reduction in delays
Ramp metering	In accordance with traffic conditions, control the rate and spacing of traffic entering a freeway, to minimize disruptions and safety hazards; improve travel time via freeway volume detection and related traffic-responsive ramp signals	15:1; up to 15% reduction in delay
Freeway operations and active traffic management	Harmonize speeds and balance lane use, including shoulders, to minimize queuing, delay, and secondary crashes via variable speed limits, advisories, and lane use controls, including detection, communications. and dynamic message signs	Up to 25% reduction in crashes and 10% to 20% reduction in delay
Advanced traveler information	Provide current and anticipated travel and weather conditions, route and mode options, and other information to support travelers' optimal choice of route, timing, and mode via multiple media—web, 511 phone, Twitter, e-mail, and text—and via overhead or roadside changeable messaging and in-vehicle information	3% decrease in crashes

Additional sources:

Investment Opportunities for Managing Transportation Performance Through Technology. Intelligent Transportation Systems Joint Program Office, U.S. Department of Transportation, 2009.

Benefits of Using Intelligent Transportation Systems in Work Zones: A Summary Report. FHWA, April 2008.

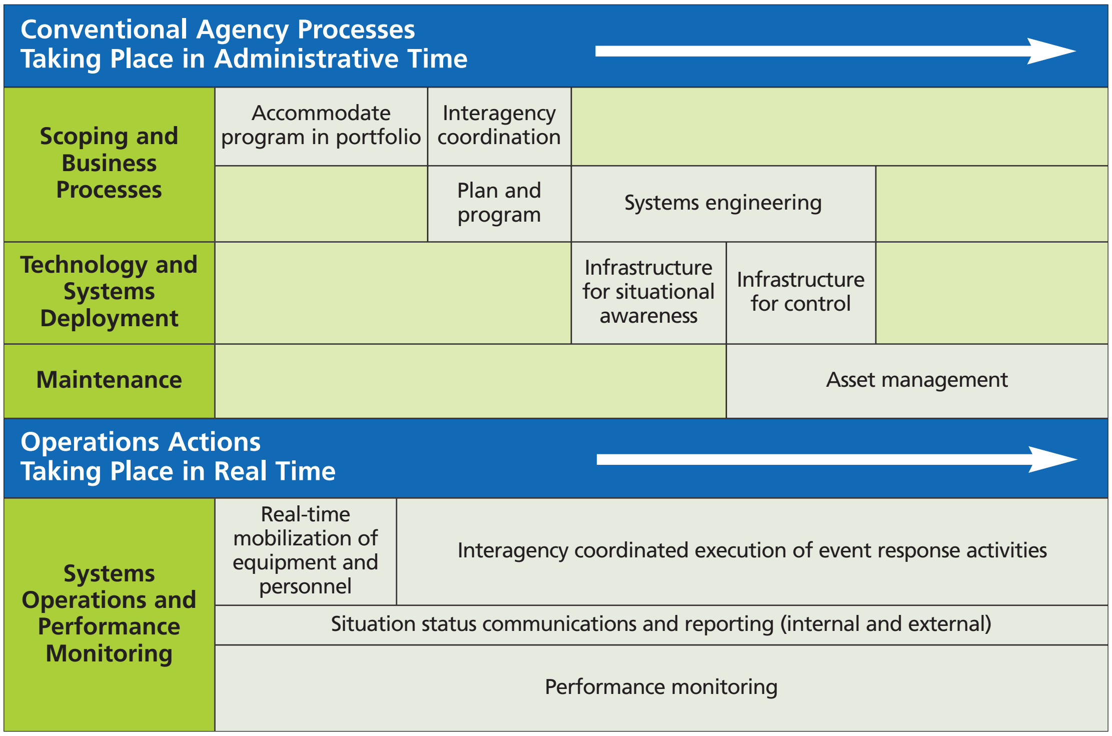


FIGURE 2 TSM&O activity demands (*3*).

TSM&O-related activities fit well into the 9-to-5 culture of a project development–oriented civil engineering entity, the applications take place in real time with extensive ongoing collaboration and performance monitoring on a 24-hour, 7-days-a-week basis. Figure 2 (above) illustrates the unique combinations needed.

The research compared the more- versus less-effective TSM&O programs of state DOTs. The findings suggested that neither technical knowledge nor relative funding levels were the key differences. Instead, the more effective programs customized the business and technical processes of planning, programming, systems engineering, asset management, and performance monitoring. Implementing these processes depended on adjustments to the institutional architecture of the agencies, affecting leadership, organizational structure, staff capabilities, program framework, and resources (Figure 3, right).

Capability for TSM&O

The research traced the relationships between program effectiveness and the associated capabilities and aggregated the key processes and institutional characteristics into six major dimensions that appeared most influential. These relationships were used to develop guidance for state DOTs in improving TSM&O.

Key findings for the six dimensions included the following:

◆ **Business processes, including formal scoping planning, programming, and budgeting.**

TSM&O is not typically integrated into the state or regional planning process, which focuses on allocating federal and state funds within the conventional construction and maintenance programs. TSM&O investments tend to be ad hoc, without a clear and sustainable improvement program; in self-evaluations, state DOTs have given themselves low ratings on formalizing TSM&O as a program (*7*).

Few state DOTs have a clear understanding of what they spend on TSM&O. Of the agencies that track the information, a few spend up to 2 percent of their total budgets on TSM&O despite its potential to address more than half of the causes of delay and most of the causes of unreliability.

FIGURE 3 Dependence of TSM&O program on process and institutional arrangements (*9*).

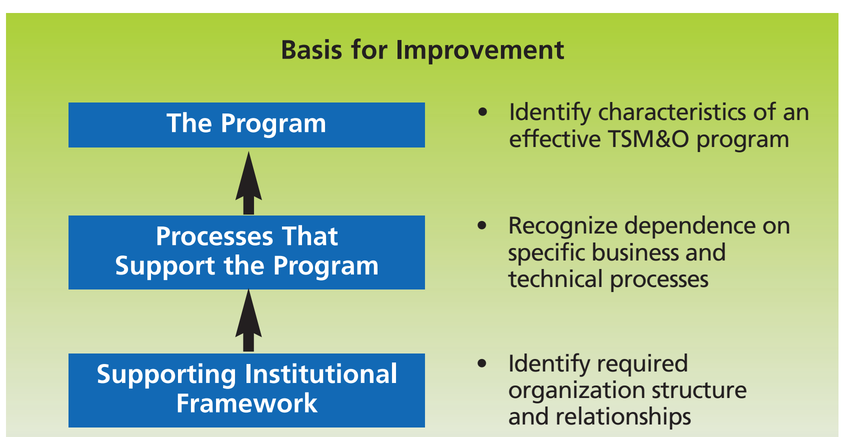


PHOTO: MISSOURI DOT

Missouri DOT applied variable speed limits of between 40 and 60 mph along I-270 in St. Louis.

◆ **Systems and technology, including systems architecture, interoperability, standardization, and documentation.**

State DOT technical staff—especially at the regional or district level—have a well-developed understanding of systems and technology issues, in part because of federal support but also because of professional interest in technology. Most states have developed systems architectures with extensive federal guidance. But states are struggling with standardization, upgrades, and integration, especially with the rapid rate of technology development. In several states, private-sector systems and service providers are playing an increasing role in day-to-day operations and maintenance.

◆ **Performance measurement, including measures definition, data acquisition, analysis, and utilization.**

Improving the effectiveness of any TSM&O strategy depends on performance measurement. Some state DOTs measure their TSM&O by the amount of activities they perform, and they conduct debriefings after major crashes and storms. Nevertheless, state DOTs have limited knowledge of the effects of their routine TSM&O activities in reducing delay, unreliability, and crashes. Even at the national level, information on the benefits of TSM&O activities is fragmentary, which makes improving procedures and protocols difficult and hampers efforts to justify the program.

Changes can be expected, however, with the strong federal emphasis on performance measurement, along with the private sector's growing involvement in supplying such measures as vehicle probe–based traffic information.

◆ **Culture, including technical understanding, leadership, policy commitment, outreach, and program authority.**

In many DOTs, senior executive recognition of the potential of TSM&O is limited, as reflected in formal agency policy and programs. Most DOTs have a legacy culture of public works—the related values, expertise, and practices support a focus on capital improvements. In this context, real-time operational management has not been a focus. Many of the more effective TSM&O programs have been initiated after an external crisis, such as a major crash, a weather-related traffic disaster, or the challenges of accommodating a major event. Many of the more successful programs have depended on middle management champions, who apply extra energy and entrepreneurship to cobble together a coherent program.

◆ **Organization and workforce, including organizational structure, staff capacity development, and retention.**

TSM&O is not yet a top-level unit in state DOT organizational structures. Its key components are often fragmented into intelligent transportation systems, traffic engineering, and traffic operations units—in the third or fourth level of the management hierarchy, reporting to maintenance managers in regional or central offices. As a result, deliberations by senior management about the agency's program, budget, and staffing do not typically include representation from TSM&O, and accountability for operations services is not evident.

TSM&O is often understaffed—not only because of agencywide constraints, but also because of the

Implementation of preferential lanes and other TSM&O measures often require a receptive DOT culture.

PHOTO: OREGON DOT

TABLE 2 Examples of State DOT Innovation (*9*)

Incentivized partnerships	Florida DOT's Rapid Incident Scene Clearance (RISC) program and Georgia DOT's Towing and Recovery Incentive Program (TRIP) are public–private partnerships that use both incentive payments and disincentive liquidated damages to shorten clearance times for heavy vehicle wrecks. RISC and TRIP have reduced the average clearance times dramatically.
Staff training in program development	The 16-state I-95 Corridor Coalition has supported an Operations Academy, a two-week residential program for state DOT middle and upper managers in TSM&O state of the practice.
Formal program and budget	The Maryland State Highway Administration's Coordinated Highways Action Response Team (CHART) program is a formal, multiyear, budgeted ITS and operations program; an advisory board provides oversight and strategic direction for CHART.
High-level reorganization	Virginia DOT has created a senior management post of Deputy Director for Operations and Maintenance, responsible for all TSM&O activities and maintenance resources.
Measuring performance	Washington State DOT has made a strong, transparent commitment to performance measurement; the quarterly *Gray Notebook* tracks performance based on five legislative goals, including mobility and congestion, and includes updates on applying operations strategies such as incident management and high-occupancy toll lanes.

difficulty in finding and retaining qualified staff. TSM&O is not yet established as a rewarding career track within DOTs, with job specifications, competitive positions, and clear opportunities for advancement. Moreover, outsourcing key responsibilities to private entities is a growing trend.

◆ **Collaboration, including relationships with public safety agencies, local governments, metropolitan planning organizations (MPOs), and the private sector.**

Many of the important TSM&O strategies are beyond the scope of transportation agencies alone. The divided jurisdictions and responsibilities for critical actions regarding incident and traffic management prevent state DOTs from capitalizing on the potential of TSM&O on their own. Several of the most important TSM&O strategies require collaboration with law enforcement, emergency services, and private providers of services—such as towing and recovery—or of information, such as vehicle probe–based traffic data. At the regional level, collaboration is often informal and can be disrupted by staff turnover.

Many states are working to transcend interagency differences in missions, resources, and tactical approaches through formal agreements. Some DOTs are using innovative approaches for public–public and public–private collaboration, including coalitions, cross subsidies, cotraining, and incentive and disincentive contracting.

Table 2 (above) provides examples that suggest definitions of best practices in processes and in institutional arrangements. The SHRP 2 project aimed to capitalize on the complete range of experience in developing guidance to improve TSM&O effectiveness.

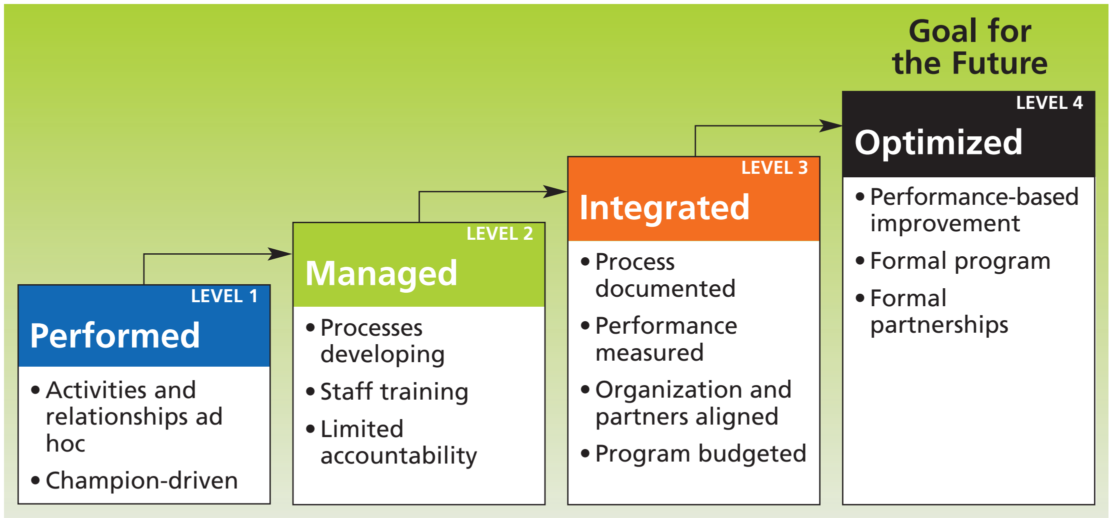
Capability Maturity

Changes in perceptions, practices, and configurations at state DOTs appear to be essential for more effective TSM&O. Guiding the changes presents several challenges, such as reengineering key processes and adjusting the institutional architecture to support them. These adjustments also involve clarifying vague intuitions about culture and organization.

The changes would have to be relevant to agencies at widely varying states of play in each of the key dimensions of capability and provide benchmarks for manageable increments toward improved practice—as evidenced by current best practices. Furthermore, the changes to develop the needed capabilities would have to identify specific actions and levels of improvement. A practical framework was needed.

Information technology managers have used the capability maturity model (CMM) to identify key dimensions of capability and levels of improvement, determined through self-evaluation. The framework focuses on continuous improvement and combines the key features of quality management, organizational development, and business process reengineering long used as strategic management tools in transportation agencies (*8*). The guide adjusts the CMM concept for state DOTs by focusing on the key dimensions of institutional architecture, as well as the specific business and technical processes relevant to TSM&O.

FIGURE 4 Levels of agency capability maturity (*9*, p. 4).



Levels of Capability

The guide defines four discrete levels of agency capability for each dimension, to assess an agency's status and its targets for improvement. The first three levels were observed in actual agency practice; the fourth level represents a theoretical ideal extrapolated from best practice.

The guidance is structured in terms of criteria that define progressively higher levels of effectiveness through successive stages of capability maturity. The steps lead away from informal and ad hoc, champion-based activities to custom-tailored processes that make TSM&O routine, standardized, documented, and performance-driven, supported by appropriate capabilities and organization. Figure 4 (above) illustrates the criteria for each level and the relationships among the levels.

CMM and Guidance Templates

With the concept of dimensions and levels of capability as a framework, criteria were identified to determine the process and institutional capabilities for each level. Logical increments in capability were defined in consistent management steps. Specfic actions were identified for moving from one level to another in each of the six dimensions.

Table 3 (page 21) illustrates the capability levels for each of the dimensions, as defined by the criteria for each level. Three rules governed the development of the guidance:

1. The six dimensions are interlinked. The dimension at the lowest level of capability usually is the principal constraint to improvement in program effectiveness and therefore the highest priority.
2. Each incremental level of maturity within a dimension establishes the basis for the agency's ability to progress to the next level of effectiveness.
3. Each of the dimensions is essential—all are interrelated, and all must be addressed. Omitting improvement in any one dimension inhibits continuous improvement.

To identify practical management actions, the six key dimensions were disaggregated into more concrete elements of capability. Each dimension was subdivided into three to four elements (Table 4, page 22), each with its own capability improvement strategy. A high-level version provides agencies with a framework for strategy development driven by self-evaluations.

Validation of the Guidance

The scope of services for the SHRP 2 project included validation of the criteria for the dimensions and the levels of capability. Fifteen state and regional workshops have been conducted for the key participants in TSM&O activities, including staff from state DOTs, MPOs, regional and other local agencies, law

PHOTO: OHIO DOT

Private tow operators and police help to clear an accident scene in Ohio. A second Strategic Highway Research Program (SHRP 2) project conducted 15 workshops in TSM&O strategies.

enforcement, and the private sector (*9*).

Workshop participants applied the criteria to evaluate the strengths and weaknesses of their agencies' capabilities in each of the six dimensions. The consensus view of the level of capabilities became the point of departure for identifying strategies to move up to the next level.

The workshops produced action plans that participants are using to improve their agencies' TSM&O activities. The CMM workshop has become a core activity in the SHRP 2 Reliability Implementation Program to be conducted by SHRP 2, FHWA, and the American Association of State Highway and Transportation Officials (AASHTO).

TABLE 3 General Strategies to Advance to the Next Level of Capability (*9*)

Capability Dimension	Level 1	Level 2	Level 3	Level 4
Business processes (planning, programming, implementation)	Processes related to TSM&O activities, ad hoc and unintegrated	Multiyear statewide TSM&O plan and program in place, with deficiencies, evaluation, and strategies	Programming, budgeting, and project development processes for TSM&O standardized and documented	Processes streamlined and subject to continuous improvement
Systems and technology (systems engineering and technology interoperability)	Ad hoc approaches outside systems engineering	Systems engineering employed and consistently used for concept of operations, architecture, and systems development	Systems and technology standardized, documented, and trained statewide, and new technology incorporated	Systems and technology routinely upgraded and utilized to improve efficiency and performance
Performance measurement (measures, data and analytics, and utilization)	No regular performance measurement related to TSM&O	TSM&O strategies measurement largely via outputs, with limited after-action analyses	Outcome measures identified and consistently used for TSM&O strategies improvement	Mission-related outputs and outcomes data routinely utilized for management, reported internally and externally, and archived
Culture (technical understanding, leadership, outreach, and program authority)	Value of TSM&O not widely understood beyond champions	Agencywide appreciation of the value and role of TSM&O	TSM&O accepted as a formal core program	Explicit agency commitment to TSM&O as key strategy to achieve full range of mobility, safety, livability, and sustainability objectives
Organization and workforce (organizational structure and workforce capability development)	Fragmented roles based on legacy organization and available skills	Relationship among roles and units rationalized and core staff capacities identified	Top-level management position and core staff for TSM&O established in central office and districts	Professionalization and certification of operations core capacity positions including performance incentive
Collaboration (partnerships among levels of government and with public safety agencies and private sector)	Relationships on informal, infrequent, and personal basis	Regular collaboration at regional level	Collaborative interagency adjustment of roles and responsibilities by formal interagency agreements	High level of operations coordination institutionalized among key players, public and private

TABLE 4 Guidance Topics

Business Processes	Systems and Technology	Performance Measurement
• Planning • Scoping • Programming and budgeting • Project development and procurement	• Regional architectures • Project systems engineering; testing and validation • Standards and interoperability	• Definition of measures • Data acquisition • Utilization of measures
Culture	**Organization and Workforce**	**Collaboration**
• Technical understanding • Leadership and championship • Outreach • Program status and authorities	• Program status • Organizational structure • Recruitment and retention • Staff development	• Public safety agency collaboration • Local government, MPO, and regional transportation planning agency cooperation • Outsourcing and public–private partnerships

Source: *AASHTO Guide to Systems Operations and Management Improvement*, www.aashtosomguidance.org.

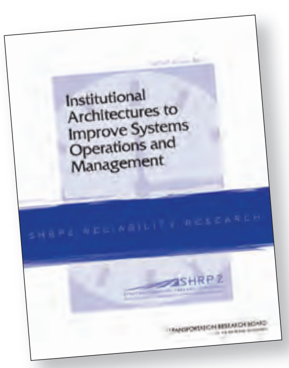
Web-Based Guidance

Through a partnership with AASHTO's Subcommittee on Systems Operations and Management and the National Cooperative Highway Research Program, a detailed version of the SHRP 2 TSM&O guidance is available online as the AASHTO Systems Operations and Management Guidance (www.aashtosomguidance.org).

The web-based resource, including online self-evaluations, allows users to tailor the guidance to their agency and context. The user's responses to a set of nested questions in three areas generate an evaluation of agency-level maturity for each of the six major dimensions of the CMM. The guidance then provides a set of action plan steps for each dimension, to enable the agency to move up to the next levels of capability.

Practical Approach

Improved TSM&O is essential for reducing delay and unreliability and for improving throughput and safety. The SHRP 2 guidance presents a comprehensive approach to help state DOTs and their partners succeed in improving levels of service. Many of the improvements do not require additional capital or staff but necessitate a clear understanding of the TSM&O strategy, features, and applications—and of the capabilities that are preconditions to success. These capabilities can be managed; the SHRP 2 guidance presents a research-based, practical approach.



More information about SHRP 2 Report S2-L06-RR-1, *Institutional Architectures to Improve Systems Operations and Management*, is available at www.trb.org/Main/Blurbs/165285.aspx.

Acknowledgments

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How Vulnerable Is Alaska's Transportation to Climate Change?

Managing an Infrastructure Built on Permafrost

BILLY CONNOR AND JAMES HARPER

Climate change is affecting transportation systems across the country, and scientists and policymakers are working to clarify the trends. Alaska's transportation community, however, has direct experience to verify the impacts of climate change. Geography and extreme climate have made the state a kind of climate-change classroom for the rest of the nation in predicting the effects on transportation infrastructure.

The wear and tear of climate change on Alaska's transportation systems is evident. The state has more than 6,600 miles of coastline, and approximately 80 percent of the land mass has an underlayer of ice-rich permafrost. Alaska has 17 of the nation's 20 largest mountain ranges and experiences extremes in precipitation, snowfall, and temperature swings that are unique to the arctic and northern latitudes.

With warming permafrost, coastal erosion, and increasingly dramatic storms and flood events, Alaska's highways, runways, and other infrastructure are frequently icing, cracking, and washing away. Although these adversities challenge all of the state's major transportation systems—maritime, aviation, and surface—the most acute and costly damage occurs within the road system.

Climate change in Alaska is forcing engineers and planners to adapt both to warming and to cooling trends. Engineers and planners are addressing knowledge gaps in thermal and hydrological dynamics and are translating the findings into new and more robust designs.

(*Right:*) Differential settlement on an abandoned section of the Richardson Highway, south of Fairbanks, one year after maintenance ceased.

Connor is Director, and Harper is Communication Specialist, Alaska University Transportation Research Center, University of Alaska, Fairbanks.

PHOTO: B. CONNOR, ALASKA UNIVERSITY TRANSPORTATION CENTER

Alaska's Climate Change History

Approximately 50,000 years ago, tropical plants dominated Alaska's more than 660,000 square miles. The ice age changed that landscape—glaciers grew and permafrost formed. Humans appeared in Alaska 11,000 years ago, evidenced by the mummified remains of a child on the northwestern coast (*1*). Glaciers began retreating approximately 10,000 years ago, leaving behind a scarred landscape, permafrost, and remnant ice buried in moraines that are regularly encountered today.

Permafrost

Permafrost—generally defined as soil continuously frozen for two or more years—has been a source of frustration for Alaska's engineers and plays a key part in today's surface transportation challenges. Most permafrost was not formed by glaciers; in some areas, a dry climate prevented glacial formation, so that much of Alaska—the North Slope, western areas, and the low-lying central region known as the Tanana Valley—has never experienced a glacier.

Even without glaciers, however, these regions present some of the most problematic permafrost formations. For example, a great portion of the permafrost in the Tanana Valley was formed by airborne silt; glaciers to the south deposited the material throughout the valley and into the hills to the north in thin layers that later froze to form syngenetic permafrost, which is characterized by small, horizontal, lenticular ice lenses and large ice wedges.

These dynamics stem from the interplay between thermal and hydrologic forces. Climate change, with its associated impacts on heating and thawing trends, has intensified the engineering challenges of permafrost from season to season.

Thawing permafrost along the Dalton Highway, showing the ice layer just below the vegetation layer. Engineers classify permafrost by performance, temperature, and frequency.

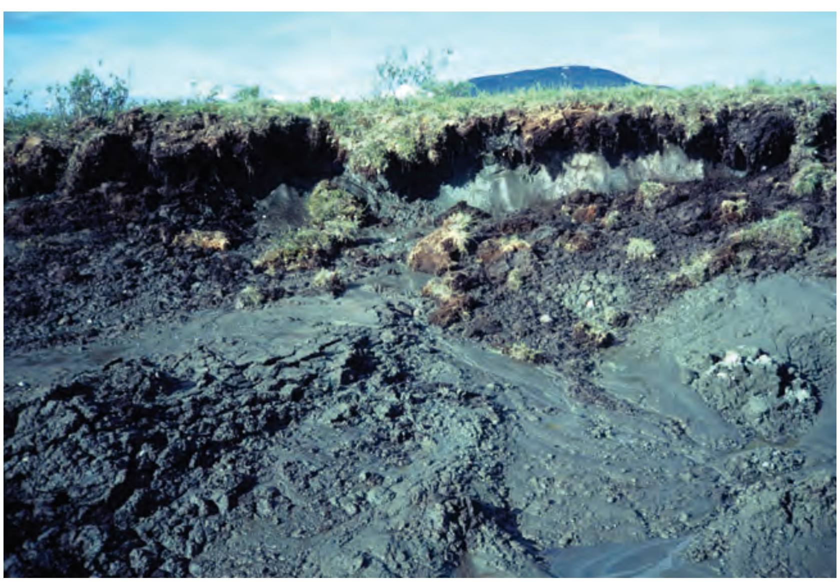

Photo: Mikhail Kanevskiy, Institute of Northern Engineering

Photo: B. Connor, Alaska University Transportation Center

Breakup on the Yukon River; ice thickness usually exceeds 3 feet.

North Slope

On Alaska's North Slope, seasonal stream flows and ice melt are among the variable hydrologic features affecting transportation. The region is home to the famed Dalton Highway, Prudhoe Bay, and the Arctic National Wildlife Refuge. Planners need a variety of hydrologic data to evaluate, design, and eventually manage roads and other infrastructure. The task involves designing and protecting infrastructure on or near ice- and snow-fed streams and rivers. Each spring brings a phenomenon known as breakup, when snowpack and snow melt create a peak flow of discharge that can descend over the North Slope.

Designing bridge pilings to cross a river that has unknown water and sediment flows is a difficult task; then add 3-foot-thick ice chunks the length of a house. Researchers, engineers, and planners are addressing these issues as they work to extend the state's road system across the invariably inhospitable terrain.

A new transportation corridor will run west from the Dalton Highway across the slope toward the community of Umiat—crossing several ice and snow-fed rivers that flow north out of the Brooks Range. The Alaska University Transportation Center, the Water and Environmental Research Center, and the State of Alaska are conducting a major research project to characterize water flow volumes, sediment transfer, and ice flow patterns in these rivers and streams.

Photo: Margaret Darrow, University of Alaska Fairbanks

Researcher Margaret Darrow of the Alaska University Transportation Center checks a thermal modeling data collection station along the Dalton Highway. Thermal and hydrological research enables transportation engineers to gain a better understanding of the effects of permafrost on road embankment stability.

Thermal Trends

Thermal trends at and below the surface are another area of interest. Studying trends in soil temperatures, ice content, soil strength, and slope stability clarifies the failure mechanisms of unstable soil slopes in permafrost regions. Subsurface conditions are a typically complex mixture of frozen and unfrozen areas, affecting groundwater flow and slope stability. The areas also vary in depth and may have only one active layer or may be more deep-seated.

Warming trends exacerbate these dynamics. Heat changes affect permafrost, in turn increasing subsurface water flow, which affects roads. Many research projects are focusing on the impact of Alaska's temperature changes on groundwater flow, permafrost degradation, and the resulting instability in road surfaces and slopes.

Costly Impacts

Alaska's recent climate variations are significantly different from those in the rest of the nation. Alaska has warmed at more than twice the rate of the continental United States in the past half-century, and the annual average temperature has risen by 3.4°F (*2*). The impacts on infrastructure include the following:

- Damage to roadways, airports, and bridges from melting permafrost;
- Culvert movement and damage from melting permafrost or flooding;
- Road and infrastructure loss from flooding; and
- Loss of roadways from slides caused by melting permafrost.

Permafrost appears to be the cause of the most severe and costly of these issues. In a newspaper interview, Mike Coffey, Chief of Statewide Maintenance and Operations for the Alaska Department of Transportation and Public Facilities, estimated that the state spends $11 million annually on permafrost-related issues with roads (*3*)—the estimate did not include airport runways, railways, and municipal infrastructure.

The remoteness of Alaska's infrastructure increases the maintenance and operations costs. In Anchorage or Fairbanks, gravel and crushed aggregate may cost approximately $20 per yard, but in the more damaged and remote areas, such as Savoonga, the costs can soar up to $1,000 per yard with increased transport, fuel, materials placement, and labor expenses (*3*). The costs of permafrost damage to Alaska's publicly owned infrastructure are expected to grow by an estimated 10 to 20 percent, or $3.6 billion to $6.1 billion, by 2030. By 2080, these costs could grow by $5.6 billion to $7.6 billion (*3*).

Types of Permafrost

Alaska's engineers encounter two types of permafrost: syngenetic and epigenetic. One type of syngenetic permafrost, yedoma, has a high frozen moisture content, often exceeding 300 percent. In other words, yedoma is soil suspended in ice and turns mostly into water when it thaws. To the untrained eye, yedoma looks like frozen silt. Syngenetic permafrost typically is found north of the Alaska Range.

Epigenetic permafrost is often found on Alaska's North Slope, above the Brooks Range and south of the Alaska Range. This permafrost was formed simply by freezing in place. The properties and moisture content vary with the soil type and moisture content.

Yedoma, a type of syngenetic permafrost, has a frozen moisture content often exceeding 300 percent; photo shows lenticular ice formations of yedoma with ice-rich silt layers between the visible ice.

Photo: Mikhail Kanevskiy, Institute of Northern Engineering

PHOTO: MIKHAIL KANEVSKIY, INSTITUTE OF NORTHERN ENGINEERING

Ice wedge in permafrost on the North Slope; permafrost often contains ice wedges formed by repeated cracking in the earth; the thawed wedges leave large voids, which can be disastrous below structures.

The ice structure is distinct, with the ice features concentrated near the surface of each soil layer as it freezes.

Both epigenetic and syngenetic permafrost may contain ice wedges, formed by repeated cracking in the earth. The thawed wedges leave large voids in the earth, which become disastrous for any structures built above.

Although these two types of permafrost are fairly easy to identify, classification is a more complex process.

Classifying Permafrost

Engineers classify permafrost by three attributes—performance, temperature, and frequency—and define permafrost by how it performs when it thaws:

◆ *Thaw-stable permafrost* retains most of its strength as it thaws and generally is not a problem for engineers. Thaw-stable permafrost typically is found in granular soils or in silts and sands with low moisture content.

◆ *Thaw-unstable permafrost* loses almost all of its strength with thawing; yedoma is an example, as are ice-rich silts and sands, ice wedges, and frozen peat. Epigenetic permafrost may or may not be thaw unstable, depending on the content—gravels or silts. Syngenetic permafrost is almost always thaw unstable, because the layers consist of silts.

Permafrost also is classified by temperature—warm permafrost is between 30°F and 32°F, and cold permafrost is below 30°F. Warm permafrost typically is found south of the Yukon River, the locations of the Elliott, Richardson, and Parks Highways that connect Fairbanks, Anchorage, and Canada's Yukon Territory. The average permafrost temperature in the Fairbanks area in central Alaska is approximately 31°F. In southern Alaska's Copper River Basin, much of the permafrost is 31.5°F. In these areas, any warming will melt the permafrost. Both epigenetic and syngenetic permafrost can be warm or cold, depending on the location.

Construction almost always leads to warming.

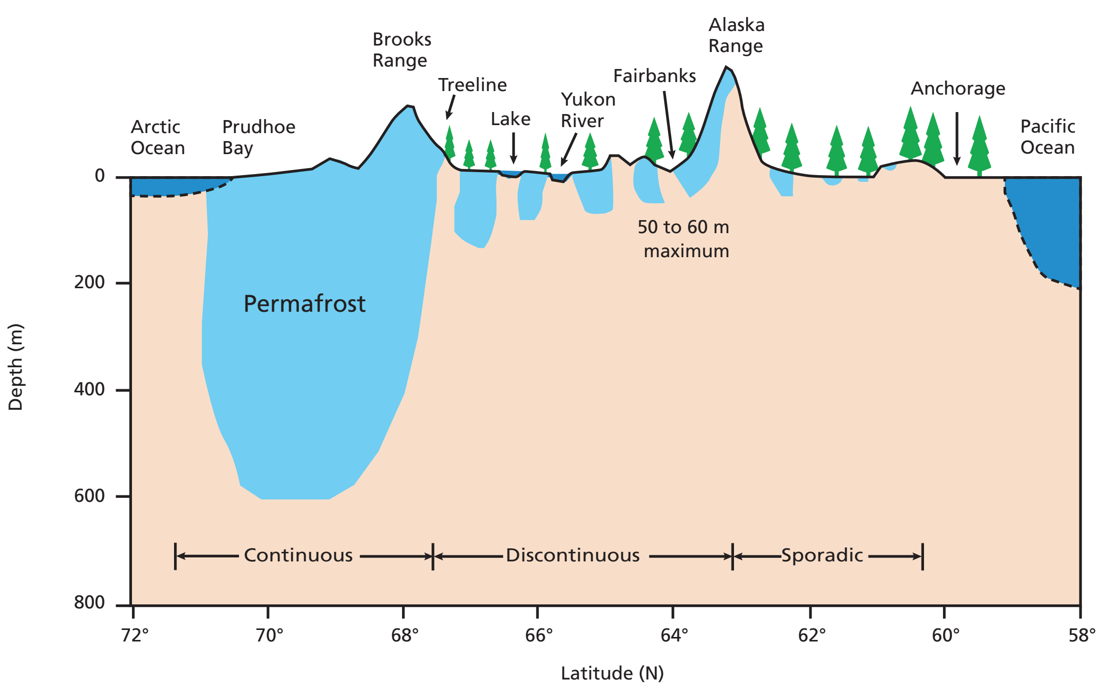

FIGURE 1 Transect of Alaska, showing the frequency and depth of permafrost. (Source: Larry Hinzman, International Arctic Research Center)

Photo: Paul Perreault, University of Alaska Fairbanks

Alaska's western shoreline in 2008, near Newtok, showing the quick erosion that led to relocation of the village.

Building a roadway over the permafrost, for example, often raises the temperature enough to cause melting. An increase in air temperature also accelerates thawing.

In contrast, cold permafrost, like that typically found on the North Slope, is around 27°F. Although only slightly colder than permafrost found to the south, the few degrees of difference dramatically increase the strength of the ice and provide a buffer against a warming climate.

Finally, engineers classify permafrost by its frequency at a given location—sporadic, discontinuous, or continuous:

- *Sporadic* permafrost is found in isolated areas. Glacier National Park in Montana, for example, has many examples of sporadic, warm permafrost.
- *Discontinuous* permafrost contains areas with and without permafrost.
- *Continuous* permafrost appears in areas that are completely frozen year-round. The graphic in Figure 1 (page 26) indicates the distribution of permafrost in Alaska. Sporadic and discontinuous permafrost—whether epigenetic or syngenetic—are almost always warm permafrost.

After classifying the permafrost at a location, engineers derive any number of combinations to describe it. The descriptions help engineers make categorical distinctions to facilitate adaptive designs.

Permafrost Design Challenges

Permafrost design typically encounters difficulties with changes in temperatures or moisture, and the costs are long term. Engineers must decide whether to keep the permafrost cold or to adopt another strategy. Often, the choice is to move forward and accept the increased maintenance costs.

The greatest and most costly impacts of warming appear in the transition zones between warm and cold permafrost and in coastal areas prone to erosion. In these areas, Alaska's transportation infrastructure is most fragile; because the transition zone is predominately yedoma, the impacts of thawing are severe.

As climate warms, permafrost degradation becomes a challenge for embankment designers and maintenance crews. The transition areas show how permafrost may transform from cold to warm between rehabilitation or reconstruction periods. Groundwater and advective heat transfer have increasingly affected permafrost degradation below embankments. In addition, research shows that groundwater flow along the permafrost tables accelerates permafrost degradation. To monitor the subtleties of the subsurface dynamics requires thermal imaging and modeling technology.

Thermal modeling of Alaska's problematic road embankment configurations has led to more thermally stable embankment designs. The design strategies seek to reduce the thawing of ice-rich permafrost. Modeling also assists researchers and engineers in exploring how surface temperatures affect the stability of permafrost below roadway embankments. The improved embankment designs have reduced maintenance and mitigation costs dramatically.

In coastal regions, climate-related erosion is a primary threat. The U.S. Army Corps of Engineers identified erosion threats in 180 Alaska communities. In the Yupik village of Newtok on Alaska's western shore, shoreline erosion swallowed the dump site, the barge landing, and other infrastructure. The village is being relocated to higher ground on an island 8 miles away, at an estimated cost of $130 million, which includes a new barge facility, a new roadway,

Researchers record glacial measurements at a remote location; findings on snowmelt, river flow, precipitation, and other hydrologic forces help planners charting new transportation corridors on Alaska's North Slope and in other regions adapt designs to a changing climate.

and a new airport. The cost of relocating or protecting all 180 threatened communities could exceed $23 billion.

Uncertain Predictions

As research explores these issues, many questions remain. Decade-to-decade warming and cooling trends, for example, complicate the forecasting to address these issues.

Despite rising temperatures, climate models predict that parts of the globe will experience both long- and short-term cooling trends. The Pacific Decadal Oscillation (PDO) indicates that changes in Pacific and Atlantic Ocean currents will cause warming and cooling trends in Alaska on a 30-year cycle (*4*). The last change occurred in the mid-1970s, with high temperatures, and the next cycle in the PDO has begun a drop in temperatures.

Some climatologists maintain that the upcoming PDO will be shorter but will lower the depth of the cooling trend beyond past cycles (*4*). Others predict a deeper and perhaps longer PDO, similar to the beginnings of the last ice age.

This uncertainty causes a dilemma, as the planning and decisions made in the past 30 years may not be appropriate for the next 30. For example, if permafrost thawing reverses, what new and unseen design challenges will arise? Nevertheless, many of the associated transportation infrastructure challenges will stem from permafrost—what it is and how it behaves.

TABLE 1 Adapting Designs to Permafrost

Design Option	Consider Using
Keep frozen	When warming is not likely to occur; permafrost temperature is below 30°F; permafrost is thaw stable
Thaw permafrost	When permafrost is warm and sporadic; designers anticipate warming; permafrost is thaw stable
Thermal design	When foundation movement is unacceptable
Remove and replace	When permafrost is shallow, or the thickness layer is low; thin layer of thaw-unstable permafrost sits on top of thaw-stable permafrost; project involves critical infrastructure; permafrost is sporadic

Permafrost Design Strategies

Specific cases illustrate that the formation of the permafrost will determine its engineering properties and the possible design strategies. Because thaw-stable permafrost typically does not produce the most problematic design challenges, and cold permafrost does not pose a threat until extreme warming, solutions can focus on the remaining classes of permafrost. An engineer has several design options:

- Keep the permafrost frozen;
- Thaw the permafrost;
- Design the structure for anticipated thermal variation—that is, for freezing and thawing; or
- Remove and replace the frozen soil.

All of these options are expensive. The choice is compounded by permafrost's ambiguity and complexity; classification helps to clarify. Table 1 (below left) illustrates the kinds of designs that can be useful, depending on the class of permafrost.

Many considerations influence design choices. Thaw-unstable permafrost loses strength with thawing—leading to structural damage, whether to a roadway, bridge, building, or embankment. In areas of sporadic permafrost, keeping the permafrost frozen is not a good option, because the structure is likely to warm the ground enough to melt the permafrost. Research has shown that the side slopes of these roadways stay at approximately 6°F, because the snow insulates against the cold winter air (*5*). In this case, a warming climate may help in the long term by eliminating the sporadic permafrost and the impacts of thawing permafrost on infrastructure.

In areas with permafrost categorized as discontinuous, warm thaw, and unstable, a warming climate generally may not prove as helpful. The temperature of the permafrost ranges between 30°F and 32°F, but in areas of discontinuous permafrost, the temperature of the permafrost is slightly colder. Consequently, the decision to keep the permafrost frozen depends on the predicted temperatures. If the temperatures will remain the same or lower, keeping the permafrost frozen makes sense.

Preserving Permafrost

Keeping permafrost cold, however, is expensive. The warming caused by the construction of a roadway will likely cause thawing, even without climate

Photo: William Schnabel, Institute of Northern Engineering

A research team prepares to conduct river gauging for a major hydrologic study for the new North Slope transportation corridor; understanding the effects of flow rates, sediment transfer, annual runoff, and ice floes on potential river crossing sites is a key issue.

change. In most cases, because of the cost, engineers accept the effects of thawing permafrost and use annual maintenance to level and patch these areas. Consequently, climate change accelerates thawing, so that discontinuous permafrost moves northward into areas dominated by cold continuous permafrost.

The most common methods to keep permafrost cold include insulation, air convective embankments, thermosyphons, and air duct systems:

◆ Insulation typically is placed 3 feet below the road surface to reduce the heat going into the permafrost (*6*).

◆ Air convective embankments consist of uniformly sized rocks stacked up. Convective cells are created within the rocks during the winter and cool the permafrost below (*7*).

◆ Thermosyphons, like those used on the Trans-Alaska Pipeline, remove ground heat during the winter by turning a liquid into gas inside a pressurized tube. The gas rises to the top of the tube, releasing heat into the cold air above ground; the liquid condensate then falls back to the bottom of the tube (*8*).

◆ Air ducts apply the chimney effect—a horizontal pipe laid in the roadway slopes is equipped with a vertical chimney at the outlet.

Continuous thaw, unstable, cold permafrost is generally not a problem, because it will not melt in the near term or eventually become discontinuous, warm permafrost. Climate warming is not likely to have a significant impact on the performance of roadways and bridges in cold permafrost areas, because the predicted climate changes will not melt the permafrost sufficiently within the life of the roadway structures. Consequently, the best alternative is to keep this type of permafrost cold.

Adapting to Change

Although the impact of climate change on infrastructure is more severe in Alaska than in other regions, Alaska demonstrates important lessons for engineers and planners in adapting to both warming and cooling trends. This entails addressing the emerging gaps in knowledge through thermal and hydrological research and then integrating the findings into new and more robust designs.

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New Solutions for Road Condition Management Problems in Cold Climate Areas

ROADEX Projects, 1998–2012

TIMO SAARENKETO AND RON MUNRO

Saarenketo is Managing Director, Roadscanners Oy, Rovaniemi, Finland. Munro is Director, Munroconsult Ltd., Brora, Scotland, United Kingdom.

The rural areas of Northern Europe share the common problems of sparse populations, remote settlements, difficult terrain, poor ground conditions, long winter seasons, seasonal change, low traffic volumes, and long distances to markets. Reliable roads are lifelines for the local communities, providing access to housing, employment, hospitals, schools, and other community facilities and serving as vital transport links for the local heavy industries of fishing, farming, forestry, and mining.

Most of the roads in these areas are low-volume roads, with traffic of fewer than 500 vehicles per day, and little guidance is available on how to keep the roads serviceable under increasing numbers of heavy transports. At the same time, the road administrations in these areas have worked to keep the networks functional despite continually reduced funding.

Filling Gaps in Knowledge

The collaborative ROADEX project was created in 1998, with partial funding from the European Union (EU) Northern Periphery Programme, to address gaps in knowledge about roads in cold climates. Project partners from Greenland, Iceland, Scotland, Ireland, Norway, Sweden, and Finland are sharing their experiences of dealing with lightly trafficked roads and are applying the findings from the 14 years of joint research.

A key aim of the ROADEX project is to use and test the latest technologies that have the potential to increase understanding of the basic issues behind the problems, instead of attempting to fix the symptoms seen on the road surfaces year after year. This focus also applies resources to the weakest sections of road instead of to the whole road network.

PHOTO: ROADEX

A ROADEX drainage analysis survey vehicle in Iceland; a laser scanner system (behind the vehicle) measures the shape of the road's cross section and the bottom level of the ditch; a digital video logging system with 2 to 3 cameras records the condition of the road and ditches. The survey technician can add oral comments on any drainage deficiencies identified.

The results of the ROADEX projects have exceeded expectations, with the introduction of new solutions and techniques to road condition management in the partner areas. These include the following:

- The use of ground-penetrating radar, laser scanners, thermal cameras, and falling weight deflectometers, allowing rehabilitation investments to focus on the weakest areas;
- A new design method that counters permanent deformation;
- Cost-effective techniques for the management of roads on peat;
- New policies and techniques to manage weakening caused by spring thaw;
- New road-friendly tire pressure technologies that offer major savings for road users and road owners;
- New technologies and policies for improved management of road drainage, increasing pavement service life and offering major savings for road owners;
- New hydrophobic treatment agents for road materials susceptible to permanent deformation during the weakening periods of spring thaw; and
- New information about the relationship between poor-quality roads, traffic accidents, the effects of vibration on the human body, and other health concerns.

In addition, the ROADEX projects have published valuable information packages on road drainage, roads built on peat areas, spring thaw weakening and load restrictions, environmental considerations for road projects, and more. The projects also have created four e-learning lessons for students and engineers on permanent deformation and its management, drainage management, roads on peat, and environmental issues in the management of low-volume road conditions.[1]

[1] For more information about the e-learning programs, see the ROADEX website, www.roadex.org.

Photo: ROADEX

A 30.5-m, 90-ton timber truck, called “en trave till,” undergoes testing in Sweden for hauling timber on specified routes. Longer and heavier truck combinations for transporting timber and mining products are a challenge for low-volume roads in the Nordic countries. ROADEX research has identified axle and tire configurations and tire pressures to make the trucks more road-friendly than standard trucks and to reduce haulage costs and carbon dioxide emissions per haulage ton.

Recent Findings

The most recent ROADEX project, ROADEX IV (2009–2012), carried out research in three areas: climate change and its effects on the maintenance of low-volume roads, problems related to road widening, and poor road condition and its effects on driver health and traffic safety.

The ROADEX projects have highlighted several areas of road condition management in which small improvements or changes in techniques or practices can result in major cost savings to road owners, increased pavement service life, and safer roads that are healthier for users.

For example, the ROADEX research revealed that the maintenance of road drainage systems on most low-volume roads generally has been ignored or has been ineffective, and the roads have deteriorated at a faster rate than if the drainage had functioned correctly. The findings showed that improving the drainage system and keeping it in good condition can extend the service life of paved road networks by a factor of 1.5 to 2.5—which translates to a savings of 10 percent to 30 percent in annual paving costs.

Similarly, road-strengthening projects using technologies and design methods recommended by ROADEX have realized cost savings ranging from 10 percent to 55 percent These methods also produce lower emissions of carbon dioxide and are more sustainable than traditional methods.

Owners lacking the funds to strengthen roads against seasonal changes can adopt the ROADEX recommendations for trucks equipped with road-friendly tire pressure technology. The ROADEX areas have favored this approach for many reasons, but particularly because the lower tire pressures can reduce vehicle vibrations that are harmful to truck drivers. ROADEX researchers measured the impact of rough roads on human body vibration, and the results showed that, in most cases, the vibration exposure exceeded the EU limit for an 8-hour journey.

The projects have published additional new information relating to truck accidents and road conditions. For example, one project identified outer curves with a changing cross, or superelevation, as critical causes of truck crashes.

The results from the ROADEX projects have been presented in the United States, Canada, Russia, and China. Despite warmer weather conditions, countries in the Mediterranean area are applying the solutions to the shared, basic problems of rural road condition management.

Northern Research Partnership

ROADEX is a transnational European collaboration among the northern roads districts in Finland, Iceland, Ireland, Greenland, Norway, Scotland, and Sweden. The program aims to share knowledge among the partners and to develop new ways for managing low-volume roads across the northern periphery of Europe.

Partners in ROADEX are the Highland Council, the Forestry Commission, and the Western Isles Council of Scotland; the Centre for Economic Development, Transport, and the Environment for Lapland; the Northern Region of the Norwegian Public Roads Administration; the Northern Region of the Swedish Transport Administration; the Icelandic Road Administration; the National Roads Authority and the Department of Transport of Ireland; and the Government of Greenland.

The primary consultant for ROADEX is Roadscanners Oy of Finland. For more information about the project, see www.roadex.org.

Mapping Naturally Occurring Hazardous Materials in Oregon

Project Aims to Protect Transportation Personnel and Public Health

Photo: Oregon DOGAMI

MATTHEW A. MABEY AND CLARK NIEWENDORP

Mabey is Research Engineer, Oregon Department of Transportation, Salem, and Niewendorp is Geothermal Resources Evaluator, Oregon Department of Geology and Mineral Industries, Portland.

(*Photo above:*) A road-cut exposure along the eastbound lane of I-84 at Milepost 356, Malheur County, eastern Oregon, provided an opportunity to examine the hydrothermal alteration of minerals in a fossil hot-spring system.

A diverse array of naturally occurring hazardous materials (NOHMs) is found across the United States—elements, minerals, and other materials of varied geologic character. Examples include arsenic, asbestos, and coal. NOHMs can be disturbed, crushed, or exposed by weathering and erosion or by human activities that create dust, raising a risk to human health and the environment.

NOHMs are easily overlooked in standard environmental assessments and geologic investigations for transportation projects. The Oregon Department of Transportation (DOT) partnered with the Oregon Department of Geology and Mineral Industries (DOGAMI) to identify the NOHMs of greatest concern, delineate the likely occurrences in the state, and establish how to detect them. The next step is to establish policies and procedures to address the hazards.

Naming the NOHMs

Through a literature review, DOGAMI compiled a list of 42 candidate NOHMs, supplemented with information about the associated health hazards. Focusing on primary health threats, DOGAMI sorted the list into the carcinogenic risk categories developed by the International Agency for Research on Cancer (*1*):

Group 1. Carcinogenic to humans,
Group 2A. Probably carcinogenic to humans,
Group 2B. Possibly carcinogenic to humans,
Group 3. Carcinogenicity in humans not classifiable, and
Group 4. Probably not carcinogenic to humans but may have other health outcomes—for example, because of toxicity.

An Oregon DOT Technical Advisory Committee reviewed the list and identified 19 NOHMs for further study (see box, p. 33).

NOHM Indications and Characteristics

The next step was to identify the geologic settings. NOHMs are formed through a variety of geologic processes and mineralizing events; in Oregon, these processes include weathering, erosion, sedimentation, hot springs, volcanic activity, intrusions, and the formation of island arcs and oceanic crust.

NOHMs are created through specific, localized geologic processes; this provides a way to identify areas where a given NOHM was likely to occur. Figure 1 (below) illustrates the distribution of the known precious, metallic, and nonmetallic mineralization in Oregon.

The final report presented the full details for each NOHM, including geologic occurrence, health hazards, exposure scenarios, and regulations. A summary of two of the NOHMs follows.

Asbestiform Asbestos

Asbestos is the generic name for a group of six fibrous silicate minerals found in natural deposits or as contaminants in other natural materials. According to the U.S. Department of Health and Human Services, “asbestos and all commercial forms of asbestos are known to be human carcinogens” (2).

Naturally occurring asbestos (NOAs) are present in at least eight of Oregon’s 36 counties (3), with 23 documented asbestos-bearing sites scattered throughout the Blue Mountains and Klamath Mountains (Figure 2, below, right). The nearby soils and alluvium derived from the source rocks containing NOAs also are an important component of the hazard. In some cases, the concentrations of NOAs found in this unconsolidated material may exceed 1 percent.

Complicating the matter is the relationship between the concentration of NOAs in a source material and the concentration of fibers in air that results when the source is disturbed. No method reliably predicts the concentration of NOAs in the air from the concentration of NOAs in the source material.

NOHMs Included in the Project

Arsenic and its compounds
Asbestiform asbestos
Beryllium and its compounds
Cadmium and its compounds
Chromium VI and its compounds
Erionite
Nickel and its compounds (including nickel laterites)
Radionuclides
Talc with asbestiform component
Lead and its compounds
Mineral fuels (including bitumen)
Antimony and its compounds
Mercury and compounds
Cobalt and its compounds
Chromium III and its compounds
Copper and its compounds
Lithium and its compounds
Selenium and its compounds
Tin

NOTE: Many elements (e.g., arsenic, selenium, and mercury) occur in a multitude of molecular forms. The comprehensive presence of these chemical forms is designated by the element name.

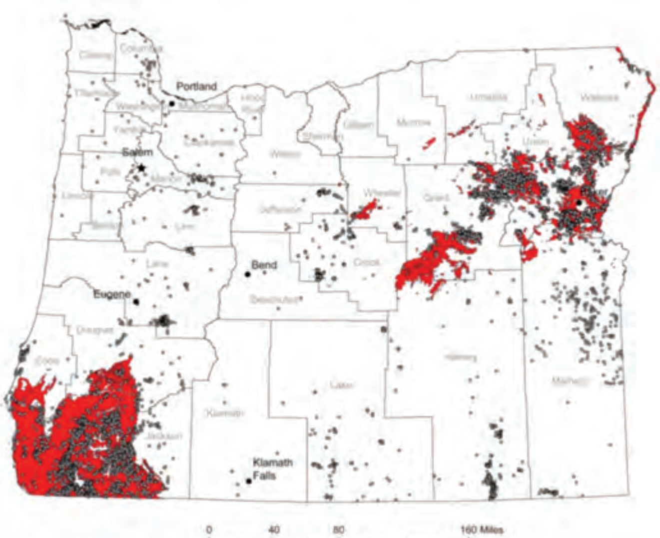


FIGURE 1 Metallic and nonmetallic mines, prospects, and occurrences (dark gray dots) shown in relation to older, pre-Tertiary rocks (red).

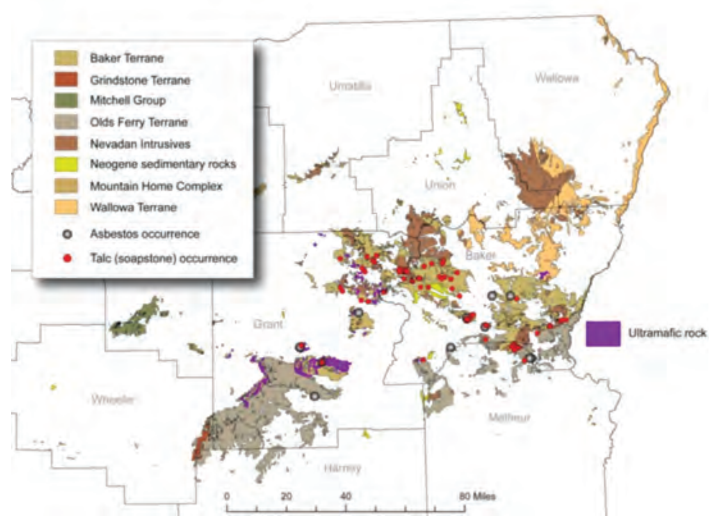


FIGURE 2 Map of the pre-Tertiary rocks of the Blue Mountains, northeastern Oregon, showing locations of naturally occurring asbestos.

Erionite's "woolly" crystalline habit; specimen collected from Swayze Creek near Durkee, Baker County, Oregon. Scale at bottom of image is 1 inch with a rule at 1 cm.

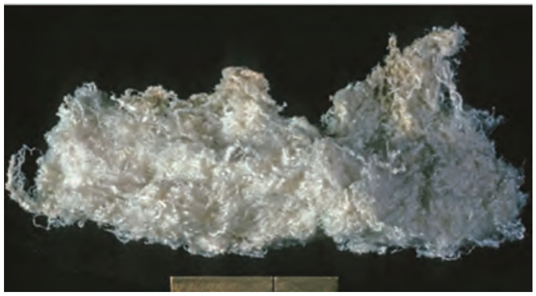


PHOTO: WWW.MINDAT.ORG/PHOTO-304278.HTML

Erionite

Erionite is a fibrous zeolite mineral (see photo, above). Zeolites are a class of minerals that repeatedly can give off water on heating and then rehydrate. Their internal structure selectively adsorbs molecules according to size and shape. Zeolites have a variety of commercial applications, including laundry detergents and the refining of petroleum.

IARC considers erionite a Group 1 carcinogen, a known cause of mesothelioma. Exposures to erionite fibers occur during any disturbance of zeolite beds and soil that raises dust.

In Oregon, zeolites are found mostly in volcanic and sedimentary-type deposits formed by the alteration of volcanic ash (*4*). Figure 3 (below) shows the general distribution of volcanic ash and related sediments, along with the known sedimentary-type zeolite deposits.

Sedimentary zeolite deposits are microscopic (*5*). Consequently, X-ray diffraction analysis is commonly employed to determine which zeolites may be present.

Assembling Data Sets

By combining information about the geologic occurrences of the various NOHMs with general geologic information about a region, researchers identified areas where a given NOHM was likely to be encountered. In Oregon, a range of data sets was available; presumably similar data are available throughout the United States. With geographic information system (GIS) technology, the geologic information can be combined with information about the various NOHMs to produce an overview of the hazards across the state.

The project used five GIS data sets—in some cases with modifications—to create hazard maps for each of the 19 NOHMs:

◆ The Mineral Information Layer for Oregon (MILO–Release 2), a published statewide geospatial database that stores and manages information about 21,201 of Oregon's mineral occurrences, prospects, and mines (*6*);

◆ The Geoanalytical Information Layer for Oregon (GILO–Release 2), an unpublished statewide GIS layer that stores and manages Oregon's geo-

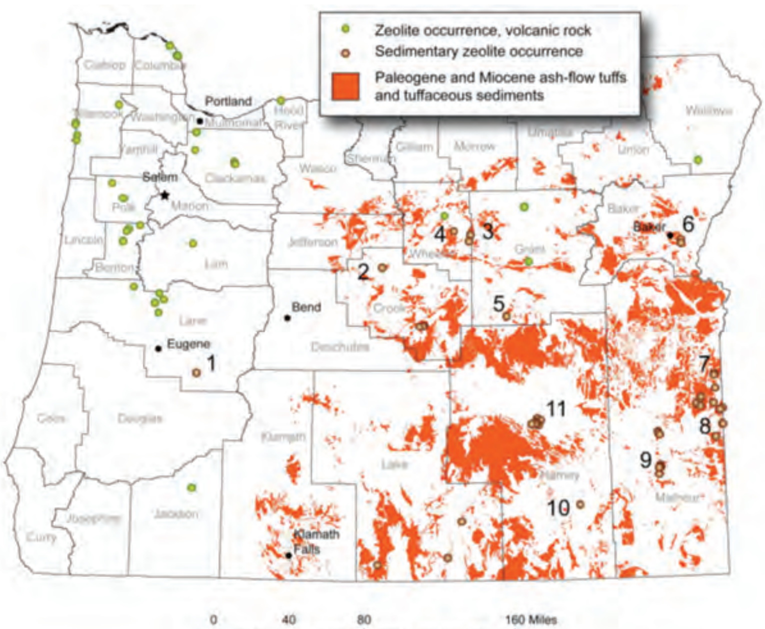


FIGURE 3 Locations of sedimentary zeolite deposits (brown dots); zeolite deposits associated with volcanic, primarily basaltic rocks (green dots); and the general distribution of Paleogene and Miocene volcanic ash and related tuffaceous sediments (orange). Zeolite potential and erionite potential in the orange areas is unknown. Numbers refer to Table 3.7 in the project's final report: 6, Durkee deposit; 8, Sheaville deposit; 9, Rome deposit; and 11, Harney Lake deposit.

PHOTO: OREGON DOGAMI

A road-cut exposure of metavolcanics near Sexton Mountain Pass; samples were taken along the northbound lane near the summit, because of scattered patches of alteration associated with a near-vertical shear zone.

TABLE 1 NOHM Hazard Classification (*9*)

Class	Description of Area
Most likely	NOHM occurrence or geologic, geochemical, and geophysical characteristics that indicate an environment favorable for a NOHM occurrence; interpretations of data indicate high likelihood of NOHM accumulation; data support mineral-deposit models indicating presence of a particular NOHM; and evidence indicates that NOHM concentration has occurred. Mineral-forming processes have been active in at least part of the area.
Moderately likely	Geologic, geochemical, and geophysical characteristics indicate an environment favorable for NOHM occurrence; data indicate high likelihood of NOHM accumulation; and application of mineral-deposit models indicates favorable ground for the specified type(s) of deposits.
Least likely	Geologic, geochemical, and geophysical characteristics indicate an environment that would permit NOHM occurrence; NOHM-bearing rock is dispersed and insignificant; obvious site limitations and little or no indication of potential NOHM.
No	Presence of a NOHM is unlikely.

chemical data for more than 39,300 sites;

◆ The Geothermal Information Layer for Oregon (GTILO–Release 2), an unpublished statewide GIS layer that stores and manages the state's geothermal resource information, including records for hot and warm springs, low-temperature wells, geothermal wells, and geothermal prospect wells;

◆ The Oregon Geologic Data Compilation, depicting the surface geology of the entire state, derived by DOGAMI from 345 of the best-available geologic maps from state and federal agency sources, student thesis work, and consultants (7); and

◆ The Soda Spring database, an unpublished statewide GIS layer showing 35 springs from the Willamette Valley to the Snake River that emit soda water containing dissolved carbon dioxide—all of these springs leak natural carbon dioxide, and some emit free gas (8).

Making the Map

One of the objectives of the project was to create a NOHM-GIS data layer that could convey an awareness of NOHMs to Oregon DOT personnel. The NOHM-GIS Information Layer (NGIL) portrays problem areas for NOHM hazards in a spatial context and provides a basis for proactive decision making. For example, the GIS information could be used to plan extra dust abatement procedures or the use of respiratory protection before a construction project even goes out to bid.

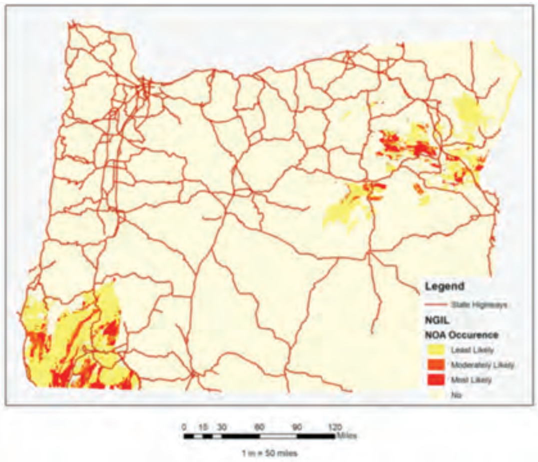
TABLE 2 Data Rules for Assessing Hazard Potential of Geologic Units (*9*)

Hazard	Most Likely	Moderately Likely
Asbestos*	• A mine, prospect, or occurrence of asbestos or talc • Ultramafic rock containing dunite, peridotite (harzburgite, lherzolite, and wehrlite), pyroxenite (bronzite, clinopyroenite, orthopyroxenite, websterite), serpentinite (metaserpentinite), metatrocolite, and others • Lateritic soil	• Amphibolite, blue schist or glaucophane schist, and metamorphosed limestone or marble • Melange rocks, gabbro, and metagabbro, associated with ultramafic rock types • Shear zone
Zeolite**	• A mine, prospect, or occurrence of zeolite minerals • Rock type of lacustrine, lake, pluvial, playa, obsidian, and pillow lavas • Rocks that are Little Butte Volcanics and Late High Volcanics	• Rock type clearly rhyolite and rhyodacite, claystone, and tuffaceous, including palagonite tuff, silicic tuff, ash flow tuff (welded and nonwelded), and sedimentary tuffaceous rocks • Volcanic rocks favorable to zeolite formation • A bentonite (expansive clays) mine, prospect, or occurrence

* Includes both fibrous asbestos and talc.

** Includes sedimentary and other zeolite (volcanic) deposits.

FIGURE 4 Sample map created for the NOHM research project from the NGIL, showing the statewide distribution of naturally occurring asbestos.



NGIL presents NOHMs according to their relative hazard potential, expressed in qualitative terms of most, moderate, or least likely and "no" (Table 1, page 35). To determine classifications of NOHM hazards as most likely or moderately likely, DOGAMI devised data rules based on geological factors, expert knowledge, and information from the five databases; Table 2 (page 35) shows examples of the data rules. The criteria for the least likely classifications were generic and broad and were not included in the research report. Figure 4 (above) presents an example of a hazard map for asbestos.

The NGIL is an empirical model, identifying the geologic units with a relative likelihood of NOHM occurrence or hazard. The hazard classes were not based on quantitatively defined weight- and normalized-values or statistical analysis. As with any hazard assessment based on subjective information, the inclusion of some geologic unit polygons for a particular NOHM hazard could be questioned.

The intent was to guide the application of thoughtful policies and procedures. For example, a policy may require the analysis of soil or rock materials from a construction site within a most likely polygon to confirm or refute the presence of the associated NOHM.

The relative NOHM hazard potential indicated in a polygon for a geologic unit indicates only how favorable the conditions are for the NOHM to occur. NOHMs are localized and usually only occur over a fraction of a geologic unit polygon; an occurrence may not be representative of the entire unit.

Sample Collection

The NGIL allows policies and procedures to focus NOHM mitigation efforts on limited areas of the state; however, to conclude that a NOHM is actually present requires that material samples be collected and laboratory analyses be performed. The project collected and analyzed a few samples as a proof of concept for developing the final policies and procedures for NOHMs.

The sampling methods designed and used for the project emphasized practicality and the sustainable investment of time and funds. Sampling can be kept to a minimum by targeting altered or mineralized rock, secondary minerals such as zeolites, or rock associated with asbestos. These "spot tests" could consist of a single piece or chunks of rock, or a potential NOHM specimen chiseled from a rock exposure or quarry wall, or a scoop of rubble from below the suspected NOHM occurrence.

In general, multiple samples from a site can be combined into one representative or composite laboratory sample. Random or profile sampling was conducted at sand and gravel pits, generally within a predetermined area. Similar sampling methods were used at road cuts, but the sampling strategy depended on the slope material and whether it was unconsolidated or rock.

Simple sampling tools consist of a small shovel, plastic scoop, rock hammer and chisel, and sieves. Laboratory samples can be collected in 1-quart, resealable plastic bags.

The project sampled 10 sites, some selected for the likelihood of a positive NOHM detection, others with the likelihood of a negative or unknown result. The sites included five quarries that extracted hard rock aggregate, two gravel pits, and three slopes cut above highways.

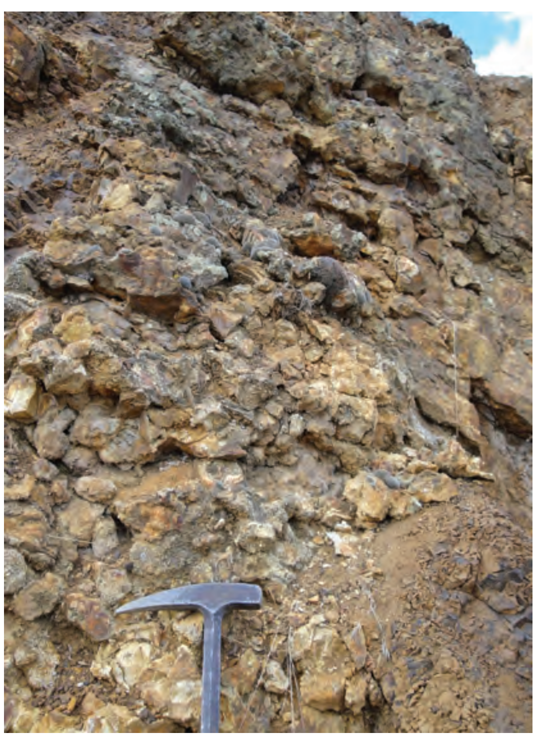


PHOTO: OREGON DOGAMI

Close-up of some of the features of the fossil hot springs.

Sample Analysis

Three types of analyses were selected for the NOHMs included in the study:

- ◆ Geochemical, to determine the relative abundance of multiple elements in a sample;
- ◆ Asbestos, to determine the presence of specific asbestos minerals; and
- ◆ Mineralogical, to determine the presence and species of zeolite minerals, particularly of erionite.

Of the 15 samples collected, 4 were submitted for geochemical analysis, 2 for asbestos analysis, and 10 for mineralogical analysis. One sample underwent more than one type of analysis.

Geochemical Analysis

With a variety of methods available for extracting and analyzing multiple elements in geologic materials, the choice was based on cost, sensitivity, speed, precision, and utility. An expensive, high-precision analysis, for example, offers no advantage in a first-pass screening.

The selected 35-element analysis[1] included the elements of most concern, except lithium, selenium, and tin. Other analytical packages that can assess a greater number of elements are commercially available.

Asbestos Determination

The project tested for asbestos according to the National Institute for Occupational Safety and Health analyzing method, NIOSH 9002 (*10*), working with an asbestos testing laboratory certified by the U.S. Environmental Protection Agency (EPA). The NIOSH 9002 method is a polarized light microscopy with dispersion staining, a qualitative and semiquantitative means for determining asbestos in soil or solid materials. A range of analyses for asbestos is available.

Erionite Determination

Determining the presence of erionite requires more than a single, simple test; an interpretation of a suite of analyses and tests sometimes is necessary. X-ray powder diffraction (XRD) is most often employed, supplemented with scanning electron microscopy or transmission electron microscopy; both can be equipped with energy-dispersive spectrometry (EDS) to quantify elemental compositions. Often both the XRD results and the EDS chemical ratios are necessary to distinguish erionite from other zeolites.

[1] Inductively coupled plasma–atomic emission spectrometry analysis with trace mercury by cold vapor–atomic absorption spectrometry using an aqua regia leach.

PHOTO: OREGON DOGAMI

Panoramic view of Sears Creek Quarry; the sampling addressed the possibility of zeolites in joints and cooling fractures.

Analytical Results

The project was not intended to conduct a full site characterization. Although spot tests only can yield subjective interpretations, the synoptic sampling approach was appropriate for a proof-of-concept study.

Elemental Analysis

The four elemental analyses confirmed the presence of some NOHMs. The concentration of elements in the samples was compared with EPA soil industrial standards and mean soil concentrations for the western United States, measured by the U.S. Geological Survey (*11*).

One sample exhibited elevated levels of arsenic, calcium, iron, mercury, molybdenum, nickel, and sulfur. These elements, especially arsenic, indicated hydrothermal systems—already suspected at the site, a quarry. In all samples, arsenic exceeded the EPA risk-based concentration (*12*). The most striking sample had an arsenic content of 479 ppm, far exceeding the risk-based concentration value of 1.7 ppm and the mean western U.S. concentration of 5.5 ppm. Two other samples also exhibited anomalous geochemical zones, with elevated levels of zinc, barium, silver, and arsenic.

Erionite Determination

Samples from three sites contained fibrous material in suspension, a preliminary indicator of zeolites. The fibrous material was similar in chemistry to erionite or offretite, a zeolite closely associated with erionite. Although the EDS chemical ratios were consistent with erionite, the XRD yielded an inconclusive or negative result.

Asbestos Testing

Asbestos results from polarized light miscroscopy are reported as a percentage of the total sample. Chrysotile asbestos fibers were detected in one sample, with a field-of-view count of 15 for 400 fields, roughly 0.75 percent.

PHOTO: OREGON DOGAMI

Chancellor Quarry, with a section of the Interstate visible in the background. The serpentinite ledge in the quarry face was sampled; the peridotite—brown soil and rocks—surrounding the serpentinite contains a vein-like mass of anthophyllite.

Anthophyllite was present in another sample. The field-of-view count was 4 for 400 fields. Small, chunky fiber bundles with an aspect ratio of more than 3:1, with moderately high birefringence, also were counted in this sample, with 11 field-of-view counts for 400 fields.

The presence of chrysotile and anthophyllite in the samples does not necessarily indicate that the source rock or the quarry is hazardous. Nevertheless, the results raise concerns, and additional representative sampling is warranted. If the additional sampling determines that the asbestos levels hold true, then Oregon DOT will determine the asbestos impact and the appropriate response.

When a site analysis finds conditions indicating the potential presence of NOHMs, proper investigation and testing are necessary to confirm or refute the indications. Confirming results would guide a variety of steps to mitigate or avoid the hazard.

Applying the Findings

The joint project of Oregon DOT and DOGAMI compiled a list of NOHMs for Oregon; looked at the occurrence, hazard, and risk of a subset in greater detail; and devised and tested methods for analyzing and detecting the NOHMs. The project compiled the NGIL, a spatial data map, to help Oregon DOT consider the presence of NOHMs in relation to its field activities. Combined with other information gathered for the project, as well as online information about NOHMs, the NGIL can be used to devise policies and procedures to ensure the health and safety of agency personnel, construction workers, and members of the traveling public.

Automating the NGIL can make compliance with NOHM-related policies and procedures simple and straightforward. Until then, the NGIL and its supporting data can be accessed with simple desktop GIS tools to find the following information:

◆ Sites where NOHMs are likely to be encountered,

◆ The health hazards that the NOHMs present,

◆ Protection against the effects of the NOHMs, and

◆ How to test for the presence of NOHMs.

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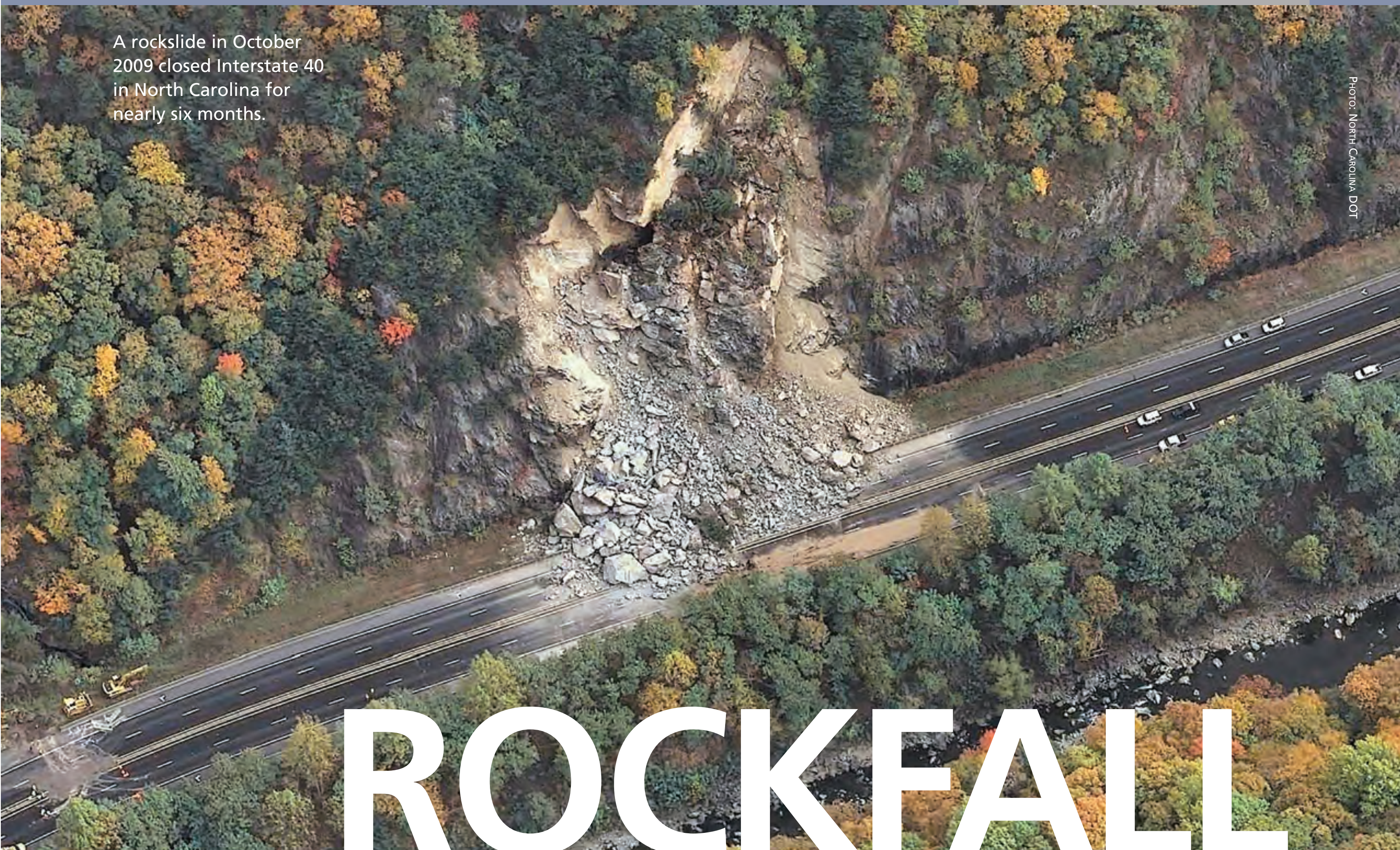


A rockslide in October 2009 closed Interstate 40 in North Carolina for nearly six months.

PHOTO: NORTH CAROLINA DOT

ROCKFALL
CHARACTERIZATION AND CONTROL

A. KEITH TURNER AND G. P. JAYAPRAKASH

Turner is Emeritus Professor of Geological Engineering, Colorado School of Mines, Golden, and 2010 recipient of the TRB Roy W. Crum Distinguished Service Award. Jayaprakash is TRB Senior Program Officer and Soils, Geology, and Foundations Engineer.

Rockfall: Characterization and Control, a five-year effort of a Transportation Research Board (TRB) task force, examines all aspects of rockfall characterization, analysis, and mitigation. Authored by a dozen internationally recognized rockfall experts, the book's 18 chapters address the state of knowledge about rockfall, the available procedures for rockfall investigation, and the regulatory and economic climates affecting rockfall investigations and corrective actions.

The 650-plus page book was directed by the same editorial team that produced TRB Special Report 247, *Landslides: Analysis and Mitigation*, published to acclaim in 1996 and still in demand. *Rockfall: Characterization and Control* provides critically important information about methods of analyzing rockfall phenomena and about selecting rockfall mitigation options that have emerged in the years since the publication of Special Report 247.

Hazards and Countermeasures

In the past decade or so, rockfall has gained recognition as a significant socioeconomic issue—rockfalls have had destructive effects on transportation infrastructure and operations worldwide. With growing populations and an associated increase in the demands for energy, mining, forestry, agricultural products, and recreational activities, communities and civil infrastructure have expanded into marginal lands; in many of these areas, evaluations of the potential rockfall hazards and appropriate countermeasures are difficult. In addition, many transportation agencies are experiencing increased costs for maintenance and operations, as rock exposures constructed 30 to 40 years ago are degrading, posing rockfall hazards and triggering rockfall events.

The economic and public-safety consequences of rockfall-induced traffic disruptions, accidents, and injuries have spurred improvements in procedures

Photo: Colorado DOT

Large rockfall blocks severely damaged a bridge deck on Interstate 70 in Glenwood Canyon, Colorado, closing the highway for four days and leading to extended travel restrictions.

for rockfall evaluation and mitigation and the adoption of new technologies for the evaluation and quantification of rockfall hazards and for protections from rockfalls. Information about these technologies, however, has not been widely available; the new TRB volume remedies a critical lack.

Topic Areas

The 18 chapters of *Rockfall: Characterization and Control* address four main topics. The first two topics comprise 60 percent of the book and describe rockfall hazard and the methods of rockfall analysis and investigation. The last two topical sections present information about mitigation options.

1. **Recognition of Rockfall Hazard** (five chapters) provides an overview of rockfall phenomena, including an historical overview, rockfall definitions and research, and examples of significant rockfall events. A summary of rockfall failure types and mechanisms is followed by a chapter describing the Rockfall Hazard Rating System (RHRS), developed in Oregon and supported by the Federal Highway Administration since 1990.

Typical field setup of terrestrial LiDAR unit scanning a rock slope along a road in Catalan Province, Spain; umbrella keeps scanner cool and makes digital display easier to read.

More than 25 transportation agencies in North America, as well as many jurisdictions throughout the world, have adopted the RHRS. Several agencies have modified the system to reflect specific topographic, climatic, or geological characteristics or to expand the evaluation of mitigation alternatives and of the economic impacts of rockfall events.

An additional chapter provides details about eight systems that have made working adjustments to the original RHRS. The concluding chapter of the first section offers an in-depth discussion of alternative approaches to the assessment, evaluation, and quantification of rockfall hazards and risks and to the selection of rockfall mitigation measures.

2. **Fundamentals of Rockfall Analysis and Investigation** (five chapters) defines the rockfall investigation process and its organization, with an emphasis on gathering the appropriate descriptive data during field investigations. New technologies are presented for measuring and monitoring rockfalls, including systems that apply photogrammetry, LiDAR, radar, and Geographic Positioning System–based surveying. The fundamentals of Newtonian mechanics and their use in describing motions of falling, bouncing, and rolling rock blocks are reviewed.

The next chapter discusses and compares approaches to the quantitative modeling and prediction of rockfall. These include empirical models based on field observations to establish hazard zones, computer-based approaches incorporating the empirical relationships, 2-D simulation models that provide data on energy and bounce height for the design of mitigation measures, and recently developed 3-D models that allow a full spatial evaluation of rockfall events. The final chapter of the section describes in detail how to conduct rockfall field tests.

3. **Rockfall Mitigation** (six chapters) begins with an overview of mitigation options, including engi-

Photo: Caltrans

Earthen berm constructed from on-site materials is a low-cost and effective protection measure capable of withstanding moderate- to high-energy impacts.

WWW. ARIZONARAILS.COM/CN-DERAILMENT.HTML

Small rockfall debris pile on tracks near Lytton, British Columbia, caused a train derailment in January 2007.

neered versus nonengineered solutions, as well as discussions of criteria for selecting an option. The five chapters that follow examine the major mitigation options in detail: avoidance of rockfall areas, stabilization of rockfall, protections, flexible rockfall fences, and drapery systems.

4. **Rockfall Maintenance and Management Programs** (two chapters) explores the role of maintenance and monitoring systems and rockfall management programs. Appropriately designed maintenance or monitoring activities may significantly reduce the risk associated with rockfall and can improve public safety. Several state departments of transportation (DOTs), notably Washington and Tennessee, have implemented rockfall management programs. The final chapter discusses the importance of rockfall management programs and their integration into broader asset management approaches to achieve significant cost savings.

The book also contains two appendices: the first includes stereographic projections for structural analysis; and the second provides an overview of the contents of the DVD accompanying the book.

Rockfall Videos

The DVD provides valuable supplemental information to the text. The disk contains 29 short video clips of rockfall field tests, illustrating rockfall impact energies and testing procedures, and four longer video presentations. The longer videos include the historic 1963 film of the rockfall testing procedures conducted in Washington State by pioneering researcher Arthur Ritchie; field tests conducted by Caltrans in 1990 to evaluate rockfall restraining nets; field tests conducted for Oregon DOT in conjunction with the 2001 rockfall catchment design guide; and rock-slope scaling techniques recorded by Colorado DOT.

In addition, the DVD holds digital copies of all the book illustrations, including color versions of most of the photographs and technical drawings.

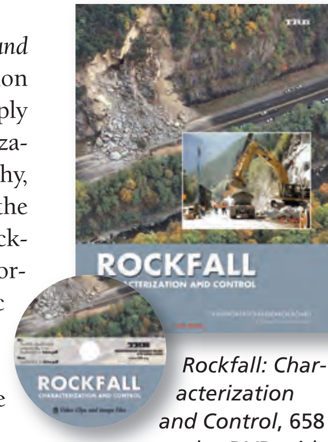
Definitive Resource

Although the focus of *Rockfall: Characterization and Control* is on rockfall events along transportation facilities, most of the discussions and examples apply to any situation that requires rockfall characterization and control. The factors of geology, topography, and climate that interact to cause rockfalls are the same; the same methods apply for evaluating rockfall hazards; and the methods for preventing or correcting rockfall hazards—within economic limits—remain largely independent of nearby land uses. As a result, anyone involved in the evaluation of rockfall hazards will find this volume useful.

The text addresses a diverse audience, including

- Geologists and engineers responsible for rockfall investigations,
- Students in geoscience and geotechnical fields with an interest in rockfall, and
- Researchers who need a definitive source for rockfall investigation and mitigation procedures.

Many students and researchers seek comprehensive references to the literature and discussions of case studies, state-of-the-art techniques, and research directions. Accordingly, the authors have identified suitable literature citations and have provided discussions of recent developments.



Rockfall: Characterization and Control, 658 pages, plus DVD with video clips of rockfalls and field tests, can be ordered at www.TRB.org/Rockfall; hardcover edition (ISBN 978-0-309-22306-5), $110; softcover edition, ISBN 978-0-309-22312-6, $100; or contact TRBSales@nas.edu or visit TRB's online bookstore: http://books.trbbookstore.org/.

PHOTO: WASHINGTON STATE DOT

Use of movable rockfall barriers to provide protection for traffic when the roadway was reduced from four to two lanes following a large rockfall on Interstate 90 near Snoqualmie Pass in the Cascade Mountains, Washington. Barrier consists of a proprietary rockfall fence mounted to specially fabricated, interconnected steel plates that are easily secured to pavement and provide full design capacity for the fence to absorb rockfall impacts.

Guidebook for Sustainability Performance Measurement for Transportation Agencies

JOSIAS ZIETSMAN AND TARA RAMANI

Zietsman is Head, and Ramani is Program Manager, Environment and Air Quality Division, Texas A&M Transportation Institute, Texas A&M University System, College Station. Zietsman chairs the TRB Transportation and Sustainability Committee.

Transportation agencies are recognizing the importance of sustainability in balancing environmental concerns, quality-of-life issues, and economic development now and into the future. Agencies often struggle, however, in applying sustainability concepts in their core activities. Performance measures can help in achieving this goal. The National Cooperative Highway Research Program has produced NCHRP Report 708, *A Guidebook for Sustainability Performance Measurement for Transportation Agencies*, to help transportation agencies understand sustainability and apply that understanding to their core functions.

The guidebook provides resources for state departments of transportation (DOTs) and other agencies to tailor a performance measurement program for sustainability that is relevant to their specific needs and contexts. Agencies can adapt and use the generally applicable framework in ongoing performance measurement programs or as a part of a new sustainability initiative. The recently enacted transportation legislation, Moving Ahead for Progress in the 21st Century (MAP-21), emphasizes performance measurement.

The guidebook includes the following features:

◆ A practical approach to sustainability and to identifying and applying sustainability-related performance measures;

◆ Discussion of ways to link sustainability to an agency's mission and strategic plan;

◆ Guidance on integrating sustainability measures into other programs and business practices;

◆ A compendium of sustainability performance measures, with a menu of goals and objectives, which agencies can use as a starting point—the compendium is also available as an Excel-based tool that allows the filtering and sorting of measures; and

◆ Real-world examples from transportation agencies and private industry in the United States and other countries.

The framework can be applied to evaluate progress, assess current conditions, develop forecasts, make decisions, or communicate with stakeholders.

PHOTO: DOUG KERR

The replacement of Lake Champlain Bridge in Crown Point, New York, received recognition from New York State DOT's transportation environmental sustainability rating program GreenLITES. Transportation agencies can use real-world examples to set up their own sustainability initiatives.

Applying Sustainability

Most discussions of sustainability are rooted in the 1987 Brundtland Commission Report, which defined sustainability as meeting present needs without compromising the ability of future generations to meet the same needs. In the context of transportation, sustainability generally incorporates three dimensions: environment, economy, and equity—also known as the three E's—and addresses present and future needs.

State DOTs and other transportation agencies increasingly are applying performance measures, but mostly with a focus on system operations and asset management. Nevertheless, performance measures can help agencies address the broad concepts of sustainability in a manner relevant to their core functions and can help track their progress.

Sustainability cuts across planning, design, and implementation of transportation projects, as well as day-to-day operations and maintenance. Although no policy or regulation specifically addresses sustainability, elements of the concept are expressed in environmental, social, and sector-specific regulations, such as the National Environmental Policy Act, the Americans with Disabilities Act, and MAP-21, which lists environmental sustainability as a national performance goal. In response to these regulations, agencies already are—or soon will be—addressing sustainability.

The NCHRP project team assembled case studies and conducted interviews with transportation agencies to understand how to address sustainability and performance measurement. The case studies identified the following factors as contributing to the successful implementation of programs for sustainability, including performance measures:

◆ A big-picture view of sustainability as a comprehensive concept;

◆ A strong commitment from leadership and a readiness to work with other agencies;

◆ A commitment to a long-term effort and to setting appropriate goals and targets;

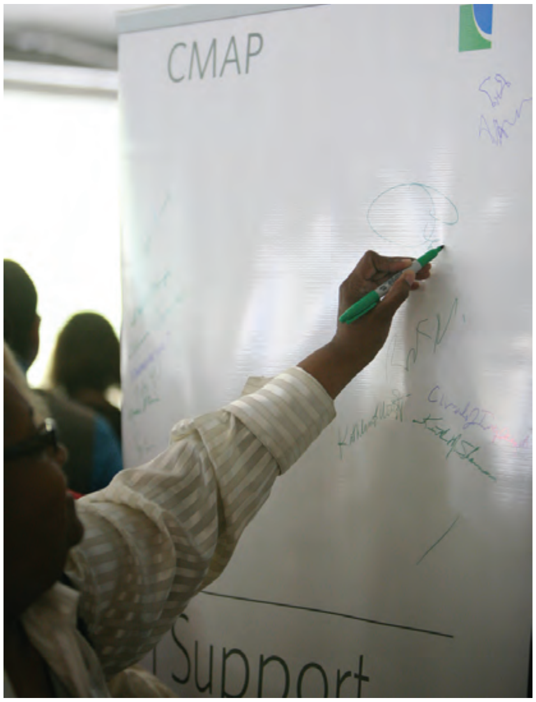
◆ Allocation of sufficient resources; and

◆ The linking of sustainability to funding.

Principles of Sustainability

The guidebook recommends that agencies take a holistic view of sustainability—transportation in support of sustainability—instead of adopting a narrow focus on sustainable transportation. According to this approach, the principles of sustainability include meeting human needs for the present and future, while

PHOTO: CHICAGO METROPOLITAN AGENCY FOR PLANNING



The Chicago Metropolitan Agency for Planning introduced GO TO 2040, a comprehensive regional plan that incorporates livable communities and sustainability, in 2010. A holistic view of sustainability focuses on transportation's role supporting environmental health.

◆ Preserving and restoring environmental and ecological systems,

◆ Fostering community health and vitality,

◆ Promoting economic development and prosperity, and

◆ Ensuring equity between and among population groups and over generations.

These broad principles were developed from a review of the foundational literature on sustainability, sustainable development, and sustainability in transportation.

Sustainability Performance Measurement

These general principles of sustainability need to be translated into transportation-related goals, objectives, and performance measures. The guide presents a framework to help transportation agencies apply sustainability concepts in six focus areas:

◆ Planning,

◆ Programming,

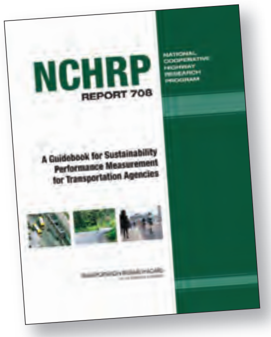
◆ Project development,

◆ Construction,

◆ Maintenance, and

◆ Operations.

In general, sustainability performance measures are said to differ from conventional performance measures in their linkage to sustainability goals and objectives. The guidebook emphasizes, however, that



NCHRP Report 708, *A Guidebook for Sustainability Performance Measurement for Transportation Agencies*, is available electronically at www.trb.org/Main/Blurbs/166313.aspx or from the TRB Bookstore, http://books.trbbookstore.org/nr708.aspx.

PHOTO: LAURA SANDT

The framework presented in NCHRP Report 708 promotes the holistic consideration of transportation in support of sustainability.

no single performance measure can truly be a sustainability performance measure—by definition, sustainability requires an integrated set of measures.

The basic sustainability performance measurement framework (see Figure 1, below) consists of the following:

◆ **Fundamental components**—the elements required for the step-by-step application of the framework: understanding the basic principles of sustainability; developing appropriate goals, objectives, and performance measures; and implementing the performance measures.

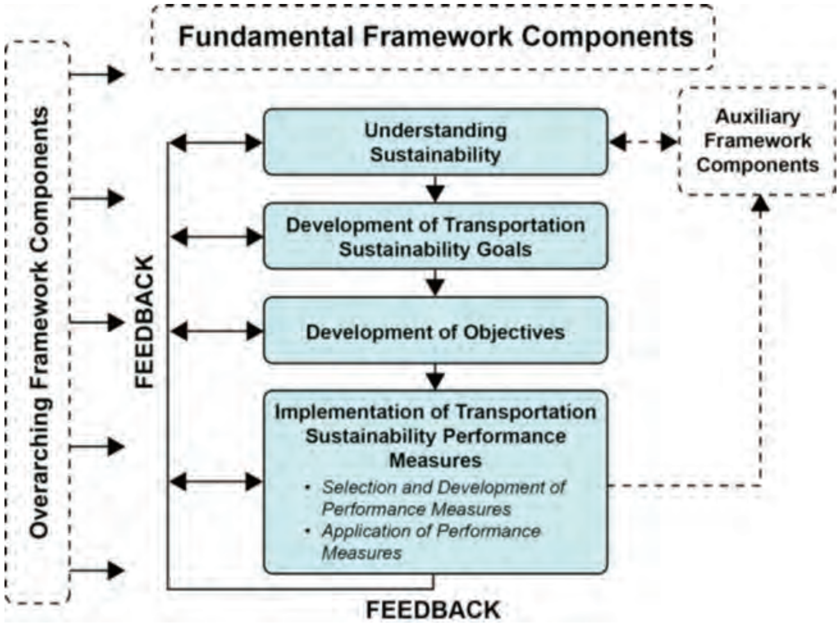


FIGURE 1 The sustainability performance measurement framework.

◆ **Overarching components**—elements to consider throughout the framework application process, such as stakeholder involvement.

◆ **Auxiliary components**—related but optional elements that can supplement the framework application process—for example, an organizational definition of sustainability or employee-based initiatives for sustainability.

Practical Approach

In presenting the case studies, best practices, and contexts, the guidebook emphasizes a practical, phased approach to implementing sustainability performance measurement. Resources include a compendium of performance measures, available in spreadsheet format, to provide agencies with proposed goals, objectives, and performance measures for applying the framework. The compendium offers examples of possible objectives and measures and indicates how they may fit together. An agency can adjust the goals, objectives, and measures to fit its context, focus, organizational structure, and localized need.

The guidebook also contains a sustainability checklist and identifies the sustainability performance measures for different types of applications: description, evaluation, accountability, decision support, or communication.

The framework presented in NCHRP Report 708 promotes the holistic consideration of transportation and sustainability and defines transportation goals that can be broken down into a menu of objectives and performance measures to cover various contexts. The guide describes the application of sustainability performance measures and identifies examples, tools, and approaches. The report equips transportation agencies with background information on sustainability in the context of transportation and with the information and resources to tailor and implement a sustainability performance measurement system successfully.

Acknowledgments

Joanne Potter, Virginia Reeder, and Joshua DeFlorio were coauthors of the guidebook, which was produced as part of an NCHRP project led by the Texas A&M Transportation Institute in collaboration with Cambridge Systematics, CH2M Hill, High Street Consulting, Henrik Gudmundsson of the Technical University of Denmark, Greg Marsden of the University of Leeds, Ralph Hall of Virginia Polytechnic Institute and State University, and Steven Muench of the University of Washington. Wayne Kober chaired the project panel, which was staffed by Lori Sundstrom, Senior Program Officer, TRB.

Preserving and Protecting Freight Infrastructure and Routes

MARK E. MEITZEN

The author is Vice President, Christensen Associates, Madison, Wisconsin.

A smoothly functioning freight transportation network is part of the nation's critical infrastructure and is essential to the U.S. economy. Transportation services deliver raw and intermediate materials to producers and final products to retailers and customers. Freight and its transportation are an integral part of supply chain management (see Figure 1, below).

According to the most recent U.S. Commodity Flow Survey, on average, 42 tons of freight worth $39,000 were delivered to every person in the United States in 2007. In terms of distances traveled, that approximates 11,000 ton-miles of freight per person. This is equivalent to carrying one ton of freight for every man, woman, and child in the United States 11,000 miles.

The shares of domestic ton-miles of truck and rail freight increased significantly between 1980 and 2007, as shown in Figure 2 (above, right). Associated with the increases were significant pieces of legislation that largely deregulated these industries—the Staggers Rail Act of 1980 and the Motor Carrier Act of 1980. Intermodal shipments also are growing, particularly for truck and rail, in terms of ton-miles, and for truck and air for higher-value and time-sensitive shipments.

In addition, the freight transportation system is a major employer. In 2008, 4.5 million people were employed in transportation and warehousing industries in the United States, a little more than 3 percent of total U.S. employment.

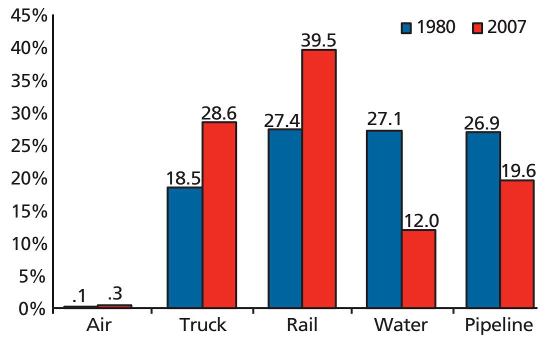


FIGURE 2 Shares of domestic ton-miles by mode, 1980 and 2007.

Conflicts in Land Uses

Population growth, rising incomes, and other aspects of economic growth have led to increased competition for the land resources around freight corridors and facilities. Competing and incompatible land uses in close proximity often interfere with each other, leading to conflicts—this has become a significant problem for freight transportation operations. The expansion of incompatible land uses, especially in America's burgeoning megaregions, raises serious threats to the freight transportation system.

National Cooperative Freight Research Program (NCFRP) Report 16, *Preserving and Protecting Freight Infrastructure and Routes*, provides a perspective on the importance of the freight transportation system and presents tools and strategies to resolve or minimize conflicts that arise when nonfreight land uses

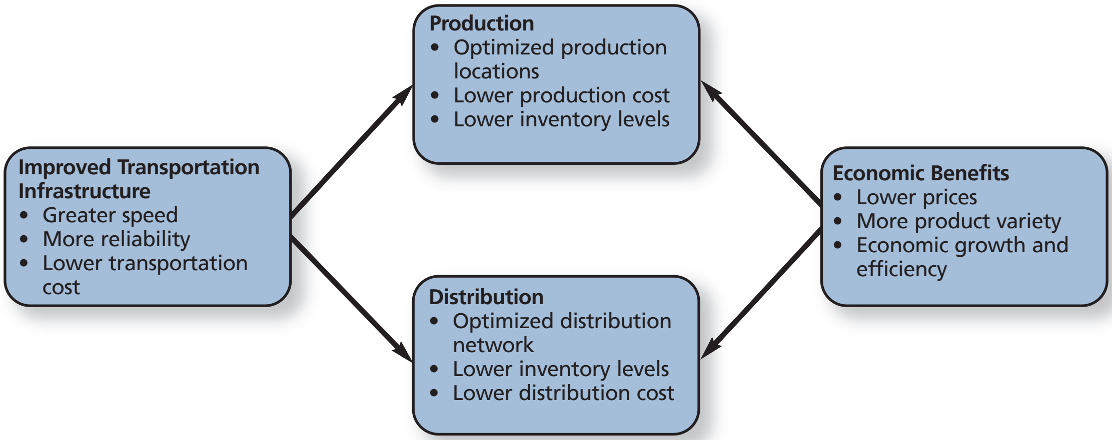


FIGURE 1 Role of freight transportation in production and distribution.

TABLE 1 Conflicts Between Freight and Other Land Uses

Noise-sensitive uses	Dwelling units (residential, motels, etc.); educational (childcare, schools, colleges, etc.); libraries; hospitals and other residential health care providers; playgrounds
Light-sensitive uses	Dwelling units; hospitals and other residential health care providers
Vibration-sensitive uses	Dwelling units; educational; vibration-sensitive industries (e.g., precision high-tech); buildings not constructed to withstand fatigue caused by rail vibrations
Pollution- and air quality–sensitive uses	Dwelling units; medical (hospitals and other residential health care providers); educational (childcare, schools, colleges, etc.); park and recreational facilities
Uses requiring potentially incompatible at-grade crossings	Dwelling units; educational; libraries; hospitals and other residential care providers; commercial; emergency services; park and recreational health facilities
Uses associated with the potential for dangerous trespass	Dwelling units; education uses (especially childcare facilities and schools); libraries; playgrounds; commercial
Time-sensitive uses	Nighttime-sensitive dwelling units; hospitals and residential care facilities
Traffic- and congestion-sensitive uses	Dwelling units; emergency services; residential health care facilities
Height-sensitive uses	Residential and commercial, with possible impact on flight paths at approach and landing

are in proximity to freight corridors and facilities. The project also produced the EnvisionFreight website (see box, below), which provides detailed information on the tools and strategies. Table 1 (above) shows the conflicts that arise when various land uses are adjacent to freight corridors and facilities.

Causes of Conflict

The NCFRP project identified the following factors as underlying causes of conflict between freight and nonfreight land uses:

- Planning for freight is generally inadequate;
- Zoning approaches to freight are typically inadequate;
- Funding for planning, corridor preservation, and conflict mitigation is often lacking or insufficient; and
- Communication among stakeholders is lacking.

From the perspective of freight interests, conflicts with other land uses often impede economically effi-

EnvisionFreight

Online Information for a Range of Users

The NCFRP project developed the EnvisionFreight website[a] for a range of stakeholders working to prevent, consider, and deal with the conflicts that arise because of the proximity of incompatible land uses to freight facilities.

For planners and elected officials, the website explains the role of freight in the local, national, and global economy; the issues and impacts that may arise from land use conflicts; and the kinds of tools, scenarios, communication, and educational outreach that can improve freight planning and preservation.

For developers, the website assists in identifying freight activities that may affect and intersect with residential and other types of land uses, in choosing appropriate sites, and in incorporating construction and mitigation components to reduce conflicts.

For freight entities, EnvisionFreight provides education and assistance in land use planning and zoning processes.

For individual citizens or community groups, the website provides basic information about the various freight modes, the impacts of freight activity and proximity to incompatible land uses, and the tools available to plan for freight effectively.

For state legislators and staff, EnvisionFreight provides information and ideas for potential legislative changes to facilitate the integration of freight and land use planning.

[a]www.envisionfreight.com.

Photo: John Donges

Freight-compatible development ensures that rail facilities and residential or other community land uses can coexist successfully.

cient freight transportation. In addition, barriers can arise from insufficient funding for the maintenance or expansion of freight facilities and corridors and from public policy decisions that impede or do not sufficiently accommodate the needs of freight transportation. Impediments include the following:

◆ Speed restrictions,
◆ Restrictions on hours of operation,
◆ Physical encroachment into freight corridors, and
◆ Impacts on transportation routing decisions.

Local jurisdictions have an incentive to maximize property and sales tax revenues. This can create pressure to change zoning designations to generate greater tax revenues. Demand for affordable land near city and downtown amenities has aggravated this issue, because many freight facilities—especially railroads and rail yards—historically are situated in these areas.

Freight-Compatible Development

The project developed the concept of *freight-compatible development* as a guiding principle for land use planning and development. The main objectives are as follows:

◆ Ensure that freight transportation–related services are not affected by, or do not affect, other land uses that are placed close to the freight corridor or facility;
◆ Reduce and minimize community impacts that arise from the proximity of sensitive land uses, including residences, schools, hospitals, and emergency services; and
◆ Incorporate the preservation and protection of freight facilities and corridors as a forward-looking component of general planning and economic development policies.

Tools for achieving freight-compatible development fall into four main areas: long-range planning,

TABLE 2 Tools to Achieve Freight-Compatible Development

Long-Range Planning	Zoning and Design	Mitigation	Education and Outreach
State enabling acts	Zoning standards	Buffer areas	Informal negotiations
Regional visioning	Buffer areas	Noise and vibration treatment	Public involvement
Comprehensive plans	Overlay districts	Track treatment	Multijurisdictional agreements
Freight facility inventories	Lot orientation	Yard realignment	Public outreach and education
Official maps	Property design	Grade-crossing management	Stakeholder roundtables and freight–community committees
Purchase and advance acquisition	Construction standards	Port gate management	
Land swaps	Soundproofing standards	Environmental measures	
Protective condemnation		Zoning measures	
Permit development		Public outreach and education	
Access rights		Relocation	

An intermodal train of double-stacked containers and trailers passes a commuter rail station near Lisle, Illinois, along the BNSF Chicago Subdivision railroad. New freight megaregions that cross state and national boundaries require new tools to address land use conflicts.

PHOTO: VXLA, FLICKR

zoning and design, mitigation, and education and outreach (Table 2, page 47). The project's analysis of these tools led to suggestions for preserving and protecting freight infrastructure and routes. Mitigation is often a final resort in resolving conflicts, and most mitigation activities are expensive to implement and have uncertain outcomes. In contrast, planning is a proactive tool that suggests actions for freight-compatible development.

New Planning Dialogue

Land use planning is the primary forum for avoiding conflicts between freight and other land uses and for helping in the preservation of freight corridors and facilities. In general, however, land use planning processes inadequately accommodate freight needs.

Because the primary responsibility for land use planning lies with local jurisdictions, any planning for freight needs is piecemeal; most freight transportation corridors transcend jurisdictional boundaries. State and regional planning agencies typically do not have the land use planning authority to fill the gap in freight planning. For example, metropolitan planning organizations are not authorized to conduct transportation planning outside of their areas, and regional visioning exercises generally do not deal adequately with freight. This problem is often exacerbated by a lack of effective communication among freight and land use and transportation planning stakeholders.

No single entity at the federal level has responsibility for freight planning, financing, or project implementation. Multiple federal agencies oversee different aspects of the U.S. freight network, but none has authority over land use planning. Federal funding for freight preservation and protection activities has been sporadic; moreover, significant portions of the U.S. freight network are privately owned.

With the emergence of freight megaregions overlapping state and national boundaries, a new planning dialogue is necessary. Tools and strategies to minimize and resolve conflicts between freight and other land uses are needed in long-range planning, zoning and design, mitigation, and education and outreach.

Planning decisions in the next decade will be critical to future transportation system efficiencies and regional competitiveness. Local and regional freight planning will require highly skilled freight transportation planners, new planning strategies and tools, community support, longer-term regional visioning, and legislative authority.

A significant research effort is needed. Until the findings are put to practical use, the conflicts between freight and nonfreight interests will not subside.

Suggested Actions

1. Amend state enabling acts to require states, local jurisdictions, and planning agencies to account

for freight in transportation planning and land use planning.

2. Provide guidance to land use planners about planning and zoning practices that relate to freight. For example, zoning overlays and industrial protection zones can be put in place not only for the industrial areas serviced by freight, but also for linking corridors.

3. Accurately map freight facilities and corridors as part of the comprehensive planning process.

4. Include freight entities as key stakeholders—and make freight issues a focus—in cooperative regional planning and visioning efforts.

5. Through state and national associations, provide appropriate education and tools for city and county planners for freight planning and development.

6. Encourage freight entities to participate as stakeholders in local, regional, and state planning and visioning processes.

7. Encourage private-sector groups, including local chambers of commerce, to keep freight issues on the agenda and to gain buy-in from the business community when a preservation project is proposed.

8. Include the principles of freight activity in graduate and undergraduate curricula in planning, architecture, policy, engineering, business, and law, through partnerships between private-sector and governmental freight groups and educational institutions.

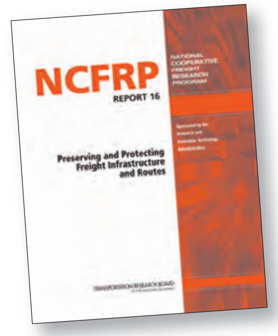
9. Encourage port authorities to quantify the congestion and noise impacts outside the immediate port area, in addition to tracking port-related job impacts throughout the region. Port master plans can illustrate affiliated congestion and chokepoints beyond the port properties. Other freight operations that cannot easily relocate can undertake similar activities.

10. Implement innovative funding practices—including public–private partnerships and rights of first refusal—for freight planning and preservation projects.

11. Include in real estate contracts—and in other documents provided to purchasers and lessees—discussions of the possible freight-related impacts that may occur as a consequence of living in proximity to freight activities.

Acknowledgments

The research team for NCFRP Project 24, Preserving and Protecting Freight Infrastructure and Routes, was led by Christensen Associates and included staff from the Center for Transportation Research–University of Texas at Austin and from Grow & Bruening. The team also received valuable input and assistance from consultant Kathryn Pett.



NCFRP Report 16, *Preserving and Protecting Freight Infrastructure and Routes*, with supplemental material on CD-ROM, is available electronically at www.trb.org/Main/Blurbs/166831.aspx or from the TRB Bookstore, http://books.trbbookstore.org/fc016.aspx.

Photo: Don Wilson, Port of Seattle

Cyclist commutes through truck traffic at Port of Seattle Terminal 18. NCFRP Report 16 offers suggestions for port authorities, such as measuring congestion and noise impacts of port activities, as well as port-related job impacts.

Guidebook for Understanding Urban Goods Movement

SUZANN S. RHODES

The author is Principal, CDM Smith, Columbus, Ohio, and a Fellow of the American Institute of Certified Planners. She served as principal investigator for National Cooperative Freight Research Program Project 15, Understanding Urban Goods Movements.

The efficient flow of goods is essential for the economic well-being of U.S. urbanized areas. The performance of the freight system also affects the productivity of the nation, the costs of goods and services, and the global competitiveness of industries.

Local land use regulations and zoning decisions determine in part the location of the origin or destination of goods and the access, times, and routes for pickups and deliveries. These local regulations and decisions, however, often are framed without full understanding or consideration of the effects on commercial motor vehicles and urban goods movements. As a consequence, planners and local leaders unknowingly may affect the logistical needs and practices of businesses and consumers, overlook opportunities for economic development, and allow freight movements to detract from quality of life by contributing to congestion and emissions.

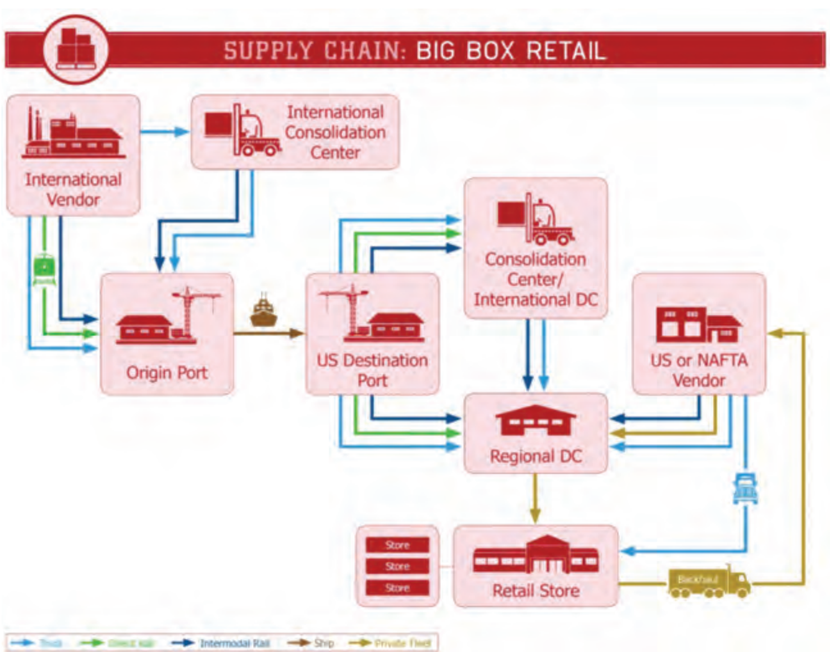
To assist planners and decision makers, the National Cooperative Freight Research Program developed and published NCFRP Report 14, *Guidebook for Understanding Urban Goods Movement*. The comprehensive guide concisely explains the importance of freight movements to the economic health of local communities, the impact of local regulations on efficient freight movement, and ways to accommodate and expedite urban goods movement while minimizing environmental impacts and adverse consequences for the community.

Poster from a campaign by New York City DOT to address bridge strikes by trucks. One of the case studies in NCHRP Report 14, the campaign included enforcement of truck routes, education and outreach, reflective signing of low bridges, and the use of technology to monitor vulnerable bridges.

The guidebook identifies local land use and zoning policies and practices that can affect the movement of trucks inside urban areas, focusing on transportation infrastructure and operations; land use and site design; and laws, regulations, and ordinances. Information and suggestions are presented for integrating freight movement analysis into the urban planning process and for modifying regulations and improving public decisions that affect the movement of urban commercial motor vehicles for goods delivery.

Case studies of nine urban areas and 12 supply chains explore how goods are moved and reveal the connections to the urban economy, infrastructure, and land use patterns. The case studies also illustrate the impacts that land use codes and regulations can have on metropolitan goods movement and on private-sector freight providers. Planning strategies are offered for improving mobility and access for goods movements in urban areas.

Accompanying the guidebook are an eight-page overview for local officials and a CD-ROM that includes a self-assessment matrix, reference materials, and two PowerPoint presentations with speaker notes. Transportation planners can use these resources to educate staff and local decision makers about the importance of goods movement and about ways to improve mobility and access for goods movements in their area.



Example of the urban supply chain diagrams explained in NCFRP Report 14.

NCFRP Report 14, *Guidebook for Understanding Urban Goods Movement*, is available electronically at www.trb.org/Main/Blurbs/166828.aspx or from the TRB Bookstore, http://books.trbbookstore.org/fc014.aspx.

The Asphalt Binder Cracking Device Test

SANG-SOO KIM

The author is Associate Professor of Civil Engineering, Russ College of Engineering and Technology, Ohio University, Athens, and is a member of the university's Ohio Research Institute for Transportation and Environment. He is the inventor of the asphalt binder cracking device.

Low-temperature thermal cracking is a major type of asphalt pavement failure. State departments of transportation (DOTs) allocate significant financial resources to repair or replace cracked pavements. Properly grading asphalt binders for the expected climatic environment, however, can minimize premature pavement failure from thermal cracking.

Problem

Two grading schemes are used to measure the low-temperature performance of asphalt binders:

◆ The bending beam rheometer (BBR) test, which measures creep properties [American Association of State Highway and Transportation Officials (AASHTO) specification M320, Table 1], and

◆ The bending beam rheometer–direct tension (BBR-DT) test, which measures creep and failure properties (AASHTO M320, Table 2).

The grading based on the BBR test works fairly well with most unmodified binders, but the results for chemically or physically modified binders are not reliable. The BBR grading process assumes the same tensile strength for all asphalt binders, although binder modification—such as adding polymer—has a significant effect on the binder tensile strength.

The Elk County Test Road in Pennsylvania is one of the best-documented field studies evaluating the low-temperature performance of asphalt binders (*1*). To grade the pavement according to Table 1 of AASHTO M320, BBR test results were obtained from the project binders, which had been stored in a freezer for more than 25 years (2). The correlation between the severity of the thermal cracking in the pavement and the grade temperature in AASHTO M320, Table 1, was very poor ($R^2 = 0.21$).

Table 2 of AASHTO M320, the BBR-DT test, was introduced to consider both the stiffness and the strength of the asphalt binder in grading low-temperature performance. The accurate determination of binder strength, however, has proved to be a challenge. The BBR-DT test does not provide reliable results for the tensile strength of the binder, and the AASHTO M320 table has not been used routinely. In addition, the strain rate used in the DT test is faster than the field thermal strain rate by orders of magnitude; the measured tensile strength may not represent the field strength value.

The BBR-DT method does not directly measure the binder's cracking temperature. Instead, the method employs an analytical procedure that requires the coefficients of thermal expansion (CTEs) of the binders as an input, as well as the stiffness from the BBR test and the strength from the DT test. No standard test method determines the binder's CTE; this leaves some uncertainty when using current test methods to select the asphalt binder that will be most resistant to cracking at low temperatures.

Solution

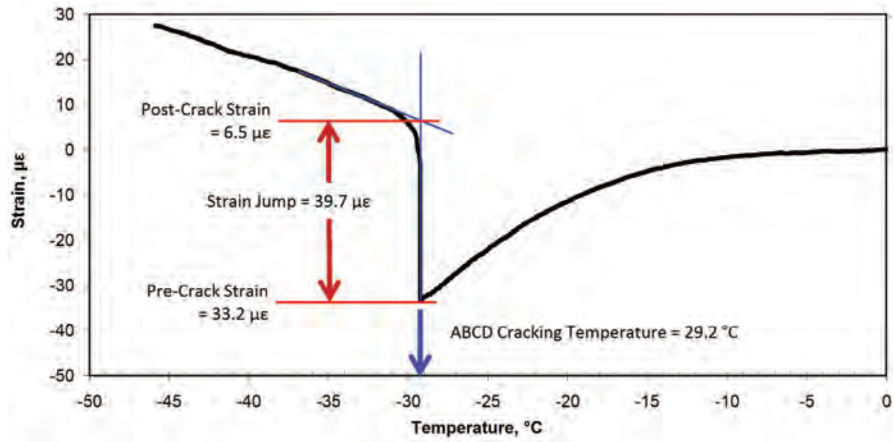
The asphalt binder cracking device (ABCD) test, developed under an NCHRP IDEA project,[1] directly determines the low-temperature cracking potential of asphalt binders in field-like conditions; the thermal contraction of the asphalt binder is restrained, to generate thermal tensile stress to failure. The empirical test makes no assumptions in estimating the cracking temperature and requires no prior knowledge of the binder's rheological properties—such as creep stiffness—or tensile strength and CTE. The ABCD test is especially useful for evaluating the low-temperature performance of unfamiliar asphalt binders, supplementing the current specifications.

(a) (b)

Asphalt binder cracking device (ABCD): (*a*) mold and (*b*) cooling chamber.

[1] National Cooperative Highway Research Program–Innovations Deserving Exploratory Analysis Project 99, Development of Asphalt Binder Cracking Device, www.trb.org/studies/idea/finalreports/highway/NCHRP99Final_Report.pdf.

FIGURE 1 Typical ABCD test results.



In the ABCD test, a binder sample is poured into a circular mold outside of a 2.0-in. (50.8-mm) diameter Invar ring. Invar is a steel alloy with a near-zero CTE. The ring with the specimen is placed in a cooling chamber (see photographs, page 51). As the temperature steadily decreases, the binder specimen contracts and compresses the ABCD ring. Sensors inside the ABCD ring measure and record the temperatures and strains throughout the test. When the binder specimen cracks, the strain is relieved abruptly; the temperature at that moment is the ABCD cracking temperature (Figure 1, above).

The test was further refined and evaluated with support from the Federal Highway Administration's (FHWA's) Highways for LIFE program (*3–5*). The refinements included ring covers to protect against the accidental spilling of binder; a change in the shape of the silicone mold from rectangular to round, to create a uniform thermal gradient during cooling; and the introduction of a pouring device to eliminate the trimming process and to minimize intervention by the operator.

The estimated cost of the complete setup for the ABCD test is $40,000, which is likely to decrease significantly with wider use. No operating costs are involved, except for the purchase of ordinary laboratory supplies.

Application

The ABCD test was applied on the asphalt binders used in three well-studied test pavements—the Elk County Test Road and the Lamont Test Road and Highway 17 in Ontario, Canada. The correlations between the crack severity of the three test roads are consistently better with the ABCD cracking temperatures than with the AASHTO M320 critical temperatures (Table 1, below, left).

The ABCD test also measured the effects of polymer modification on the asphalt binder's low temperature cracking more reliably than the BBR test did. The addition of polymer generally lowers the cracking temperature of asphalt pavements in cold environments. In tests on asphalt binders modified with styrene-butadiene-styrene (SBS), however, the BBR test indicated no visible lowering of the binder cracking temperature; in contrast, the ABCD test showed a gradual but distinct decrease of cracking temperature—that is, an improvement—with an increased concentration of polymer (Figure 2, page 53) (*3*).

The ABCD test also can measure the fracture strength of asphalt binders. The difference between the compressive strains of the ABCD ring before and after thermal cracking (see Figure 1) defines the strain jump, which allows an estimate of the fracture strength at the cracking temperature, using force equilibrium.

The test can be used for monitoring changes in fracture strength as the polymer concentration in the binder changes (*3*). Asphalt binders perform well at low temperatures by staying flexible—that is, with a low modulus—or by having a high strength. The fracture strength provides a clue about how the binder will perform at low temperatures.

TABLE 1 Coefficient of Determination (R^2) Between Cracking Index of Test Pavements and Binder Cracking–Critical Temperatures

Test Road	ABCD	AASHTO M320, Table 1	AASHTO M320, Table 2
Elk County, Pa.	0.94	0.21	0.95
Lamont, Ontario	0.92	0.79	0.76
Highway 17, Ontario	0.80	0.92	0.56

Interlaboratory Evaluation

The asphalt pavement community has expressed keen interest in the ABCD test—31 laboratories volunteered to take part in the interlaboratory evaluation, including 16 from state DOTs, two from FHWA, one from a regional Superpave® Center, one from a

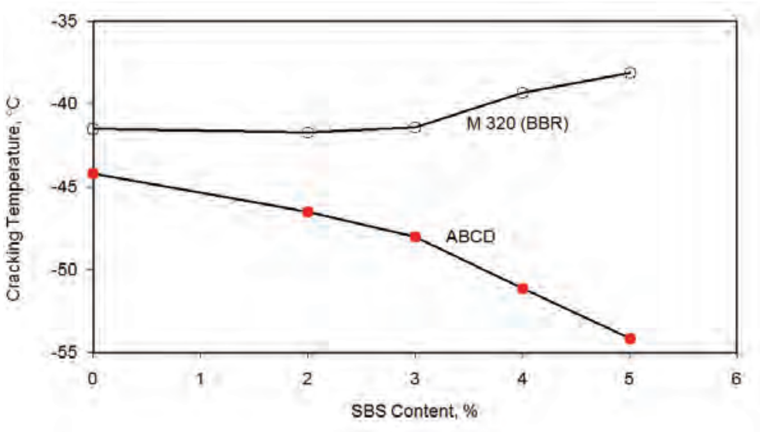


FIGURE 2 Effect of SBS concentration on binder cracking temperature measured by ABCD and BBR (AASHTO M 320, Table 1) tests.

Canadian provincial ministry of transportation, six from universities, and five from private industry. Although the evaluations were limited to approximately one week, the interlaboratory study confirmed that the test was simple, reproducible, and repeatable.

The evaluation indicated that the cracking temperature determined by the ABCD test was somewhat less precise than that determined from the BBR test's critical temperature (*5*). Computing the BBR cracking temperature, however, requires combining the BBR critical temperature results with the fracture strength data from the DT test; when the variability of the fracture strength is added to the variability of the BBR critical temperature, the precision levels of the ABCD and BBR tests are comparable.

AASHTO has adopted the test as a provisional standard, TP 92-11: Determining the Cracking Temperature of Asphalt Binder Using the Asphalt Binder Cracking Device (ABCD).

Benefits

The ABCD test complements test methods that make the characterization and grading of asphalt binders more reliable for determining low-temperature crack resistance and minimizing the low-temperature cracking of asphalt pavements. The ABCD test is simple and provides reproducible results.

The device directly determines cracking temperature without requiring additional calculations and assumptions and allows the simultaneous testing of up to 16 specimens, saving time and money. Because the ABCD test determines the cracking temperature of an asphalt binder in field-like conditions, the results correlate consistently better with the performance of test pavements than do the results from the current AASHTO procedures.

The ABCD test can reliably measure the effect of polymer modification on cracking and the fracture strength of asphalt binders at low temperatures. Quantifying the benefits of the ABCD test in dollar amounts will require more extensive applications of the test; nonetheless, the adoption of the ABCD test as an AASHTO provisional standard indicates the potential for payoff.

For additional information, please contact Sang-Soo Kim, Department of Civil Engineering, Ohio University, Athens, OH 45701, at kim@ohio.edu, or 740-593-1463.

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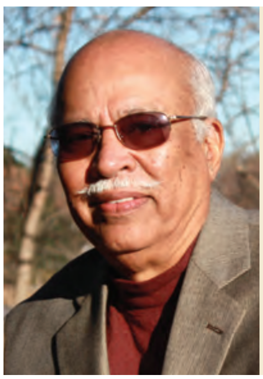
Suggestions for Research Pays Off topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, Keck 488, 500 Fifth Street, NW, Washington, DC 20001 (202-334-2952; gjayaprakash@nas.edu).

Ramankutty Kannankutty

Minnesota Department of Transportation

Active in TRB since the early 1980s, Ramankutty Kannankutty has nearly 50 years of experience in transportation and public works, serving the Minnesota Department of Transportation (DOT) and the City of Minneapolis. His expertise includes intergovernmental processes for the planning and design of public works and transportation infrastructure, what he calls the "10 P's" of public works—managing projects, products, procurement, process, politics, policy, programs, performance, people, and the press.

After graduating in 1964 from Madras University in India, Kannankutty received a master's degree in structural concrete technology from the Indian Institute of Science in Bangalore in 1968 and a master's degree in civil engineering from the South Dakota School of Mines and Technology in 1969. Kannankutty started his career in the United States with the Minneapolis Department of Public Works (DPW) the following year. He has been a registered Professional Engineer in the state of Minnesota since 1972.



"At TRB, I saw the fundamental tenet of research at work: ask why and why not continuously."

When Kannankutty joined Minneapolis DPW, the city started implementing a long-term infrastructure improvement plan for its roads and bridges. Since his student years, bridge engineering had been a particular research interest. "I realized that I could have a career in public works but still have an opportunity to practice bridge engineering and transportation," he recalls, adding that his supervisors encouraged him to continue his research interest while focusing on public works. "Those two bosses were my first real mentors," he notes.

Kannankutty joined the American Public Works Association (APWA) in 1972, and spent most of the next decade focused on public works issues. In the early 1980s, to stay current on bridge transportation research, he attended his first TRB Annual Meeting.

"At TRB, I saw the fundamental tenet of research at work: ask why and why not continuously," he observes. "Research needs statements became my educational route to becoming current. The die was cast. My research interests were rekindled—the bridge area."

Appointed to the TRB Field Testing and Nondestructive Evaluation of Transportation Structures Committee in 1986, Kannankutty began to focus on bridges in his professional life. In the 1980s, he managed the design and construction of the upper Midwest's first segmental concrete bridge across the Mississippi River. He developed and implemented Minneapolis' Bridge Replacement Program as well as a system to maximize the use of federal funds. Beginning in the early 1980s, Kannankutty directed Minneapolis' bridge construction efforts, shepherding approximately 80 bridge projects and conducting more than 500 yearly bridge inspections.

From 1988 to 2001, Kannankutty was director of engineering services at Minneapolis DPW. He represented the city's interests on many major Minnesota DOT highway improvement projects; his work with DOT peers helped him hone his transportation planning and engineering design skills. He directed design management of the city's award-winning Combined Sewer Overflow Program; initiated a major Flood Control Program; and was part of the effort to implement the next-generation Street Renovation Program, a 40-year project that covered more than 600 miles of road in Minneapolis.

In the late 1980s, Kannankutty joined the TRB Construction of Bridges and Structures Committee. He served as committee chair from 1991 to 1997 and, in 2010, was elected emeritus member. "The committee members demonstrated a leadership quality that clearly sent a message—in a volunteer organization, it is not about who you are but about a cause, a research problem that is worth exploring," he observes. In 1997, he joined the Utilities Committee, General Structures Committee, and the Application of Emerging Technologies to Design and Construction Committee, which he currently chairs. He also has served on two expert task groups for the second Strategic Highway Research Program.

Kannankutty was named one of the Top Ten Public Works Leaders by APWA in 2001. That same year, he joined Minnesota DOT as an area engineer for the Metro division. He has managed major freeway and interchange projects—including the Triangle Interchange Project in Northern Metro, which was named the Project of the Year by the Minnesota chapter of APWA in 2011. He mentors young engineers in transportation project management and was named a National Public Works Leadership Fellow in 2011.

Kannankutty advises students and new transportation professionals to attend TRB committee meetings and review committees' three-year plans to determine which to join. He muses that his own involvement with TRB began with a "professional awareness that one needs to continuously improve and, if this is done over a sustained period, one would end up being an effective professional while contributing to the growth of one's own profession."

Harold (Skip) Paul

Louisiana Department of Transportation and Development

Harold (Skip) Paul began his 36-year career with the research section of the Louisiana Department of Transportation and Development (DOTD) as an engineer-in-training in the pavements research unit. He soon moved to the bituminous research unit and spent nearly two decades conducting research in the bituminous and materials areas as assistant bituminous research engineer, bituminous research engineer, and materials research manager, and associate director of research. In 1986, the research section became the Louisiana Transportation Research Center (LTRC)—the research, technology transfer, and education and training division of Louisiana DOTD—and in 2006, Paul became director of LTRC.

"There is satisfaction when our solutions are put in practice; I don't want my researchers' work to be bound in a report and put on a shelf."

"I've always wanted to be in research, facing new challenges every day," Paul reflects. "I have had a very fulfilling career solving transportation problems."

Paul graduated from Lehigh University in 1976 with bachelor's degrees in mechanical engineering and English. A licensed engineer in the state of Louisiana, Paul focused his early research on the recycling of asphalt pavements—including early studies on processing reclaimed asphalt pavement, mix design, and specification development, with follow-on projects such as quality assurance and the long-term performance of recycled pavements. In the early 1980s, Paul began investigating polymer-modified asphalt cements (PMAC) and was part of the task force that developed the PMAC specifications still in use today.

At Louisiana DOTD and LTRC, Paul has guided the management and administration of research programs. "The administration of an organization is not as much fun as running experiments in the lab or building a pavement with new materials and designs, but it also has its challenges—marketing our research projects is exciting," he comments. "I wanted to be an engineer, not a business major, yet here I am, selling our products. But there is satisfaction when our solutions are put in practice; I don't want my researchers' work to be bound in a report and put on a shelf."

In addition to his work at LTRC, Paul also served for many years in the U.S. Navy Reserve. Recently retired, Paul served as an enlisted sailor for 12 years and as a Navy Reserve Intelligence Officer for 30 years. "I used management and leadership skills developed in the Navy in my civilian career and I used my engineering and analysis skills in my Navy career," Paul observes. "In reality, research and intelligence are the same process—planning or identifying problems, collecting or gathering raw information, analyzing the information and putting it in a useful format, and finally, disseminating and deploying the product."

Paul first attended the TRB annual meeting in 1982. The next year, he joined the Characteristics of Asphalt–Aggregate Combinations to Meet Surface Requirements Committee, which he chaired from 1989 to 1992. He also was a member of the Flexible Pavement Construction and Rehabilitation Committee, the Characteristics of Asphalt Paving Mixtures to Meet Structural Requirements Committee, and the General Issues in Asphalt Technology Committee, which he currently chairs. He chaired the Asphalt Materials Section from 1992 to 1997, the Design and Construction Group from 1997 to 1999, and the Technical Activities Council from 1999 to 2002. He once again serves on the Technical Activities Council as chair of the State Representatives Advisory Panel and also serves on the Special Task Force on Climate Change and Energy.

For his many years of service, Paul was named a National Associate of the National Academies in 2001. "I was fortunate to follow great leaders as I progressed from position to position within the TRB volunteer organization," Paul affirms. "Today, I strongly encourage my research engineers to participate in TRB. I mentor them to become involved in committee activities."

Paul also is engaged in Cooperative Research Program activities, the second Strategic Highway Research Program, and the Studies and Special Programs division at TRB. He currently chairs two project panels for the National Cooperative Highway Research Program and is a member of the Research and Technology Coordinating Committee, which reviews the highway research, development, and deployment efforts of the Federal Highway Administration (FHWA). He has published more than 45 technical papers with the Transportation Research Board, the Association of Asphalt Paving Technologists, and other journals.

A former board member of the Association of Asphalt Paving Technologists, Paul has participated on many FHWA advisory groups. He recently was appointed chair of the American Association of State Highway and Transportation Officials' Research Advisory Committee and vice chair of its Standing Committee on Research.

Agencies Reaching Customers with New Media

STEPHANIE CAMAY

Camay is Transportation Planner, URS Corporation, New York, New York, and is a member of the TRB Committee Communication Coordinators Council.

Social media provide transportation agencies with an unparalleled opportunity to connect with their customers. Social media networks are valuable public outreach tools—free and instantaneous, they reach large numbers of people and allow for two-way dialogue. An annual survey by the American Association of State Highway and Transportation Officials on social media use by state departments of transportation (DOTs) showed that nearly 90 percent of the agencies use Twitter and more than 75 percent use Facebook.

In follow-up interviews, representatives of Arizona DOT, District of Columbia DOT, New York City DOT, and Washington State DOT provided additional information, summarized below.

When did you start using social media and why?

Arizona DOT: We launched a Twitter page in 2008 to connect with drivers and to share traffic information with a statewide audience, expanding the reach of the 511 Driver Information System. What started as a simple experiment grew quickly; today, we have approximately 16,500 followers on Twitter. The department embraced social media to engage with customers, to provide a new level of service, and to promote traffic data to a new audience. Shortly after launching a Twitter feed, we created a YouTube channel to highlight internally produced videos.

Bertha, the machine that will dig the SR-99 tunnel beneath downtown Seattle, has its own account on Twitter (@BerthaDigsSR99). The project and its outreach are part of Washington State DOT's Alaskan Way Viaduct Replacement Program.

PHOTO: WASHINGTON STATE DOT

District DOT: We started using social media in early 2009. Its value was demonstrated during the historic inauguration of Barack Obama, when some media outlets and many people attending the event used Twitter to exchange information. Our first real foray came in March 2009, with the launch of our Potholepalooza campaign; Twitter was advertised as one more way citizens could report pothole locations. It was good public relations, but adoption was slow. In June 2009, we developed a Facebook page. The following winter, the region was hammered by three blizzards. The DOT found that social media—Twitter in particular—were an effective way to engage customers. In two months, we worked to establish District DOT as a highly responsive agency and added 2,000 new Twitter followers.

New York City DOT: We began using social media in 2009. We started with a Twitter account dedicated to our Urban Art program but soon switched to an agencywide account to promote all of our programs, services, and initiatives. We followed with Facebook and have continued using new social media tools as they are developed. Social media offered a way to reach a population of residents and visitors we had not consistently engaged before, in virtual places where they were already active.

Washington State DOT: We first started using social media in November 2006, when Doug MacDonald, then Transportation Secretary, wanted a way to gain public feedback on our performance after a winter storm. This strategy was intended to allow people to vent and to open conversation about new performance measures and about ways to improve the agency.

What challenges have you encountered in using social media?

Arizona DOT: Time—we have one dedicated blogger who produces approximately three to four blog posts per week and maintains the Facebook page and blog comments. In a perfect world, we would like to include additional guest blogging, greater interaction with stakeholders' social media efforts, and additional social media channels. We would like to engage more with our Pinterest and Flickr accounts and venture more into Storify and similar emerging platforms, but we have focused our efforts to get the most from our resources.

District of Columbia DOT: An active portfolio of social media sites requires time and the work currently is absorbed by staff. We could use a full-time social media manager to provide content and respond to questions or complaints. Another challenge is measuring the impact and reach of our efforts and building a data-driven justification for adding staff.

New York City DOT: One of our biggest challenges has been customer service. New York City has a great 311 system, but it is not foolproof and many prefer submitting service requests via social media. City policy and workflow prevent that, however, frustrating many constituents. We hope to integrate these channels with 311 to make the system seamless and easier to use.

Washington State DOT: From the start, we were fortunate to have the opportunity to be innovative with our social media strategy—to see what works and what does not. Our biggest challenge was convincing our agency colleagues of the value of the endeavor.

What value have social media provided to your organization and public constituents?

Arizona DOT: Although we focus on increasing our numbers of likes, followers, and views, education is our primary goal, and we evaluate our success by the level and quality of participation and engagement—not solely by the numbers.

District of Columbia DOT: By using social media, we have poked a hole in the bureaucracy, giving people on the outside an easy way to communicate with District DOT and to get the information they are looking for without a lot of effort, particularly through the almost instantaneous interaction of Twitter.

New York City DOT: Social media are free for us to use and offer an efficient way to communicate with thousands of people. We have used it to promote public meetings, highlight projects, explain the work we do, and encourage safe behavior. It has also contributed to internal morale—for example, highlighting the great work that roadway repair and maintenance crews are doing elevates their sense of pride, especially when the public comments positively.

Washington State DOT: Through social media we have gained an audience that is receptive to changing travel plans or taking extra time on trips for construction or for inclement weather, without using the standard public service announcement. We now have an audience that considers Washington State DOT a forward-thinking, innovative organization that is willing to be personable and take the time to care about its citizens.

Special thanks to Lloyd Brown, Director of Communications, American Association of State Highway and Transportation Officials, and member, TRB Committee Communication Coordinators Council, for helping to coordinate this article.

PHOTO: MISSOURI DOT

Bus transit trips increased by 8.5 percent in St. Louis, Missouri, over the first three quarters of 2012, compared with the same period in 2011.

Transit Ridership Increases

Transit ridership increased by 2.6 percent—or 201 million trips—in the first three quarters of 2012, compared with the first three quarters of 2011, according to findings from the American Public Transportation Association (APTA). A total of 8 billion trips were made during the 2012 period.

According to APTA, light rail trips increased 4.2 percent from January to September, with the next highest increase (3.6 percent) in heavy rail trips. With 4 billion trips in the first three quarters of 2012, buses had the most passenger trips overall. Bus transportation experienced its biggest increases in cities with populations above 2 million and between 100,000 and 499,999.

Cleveland, Ohio, had the biggest increase in heavy rail transit—nearly 11 percent, compared with the first three quarters of 2011. Light rail transit grew by nearly 34 percent in Memphis, Tennessee. Austin, Texas, experienced the most growth in commuter rail trips (15.6 percent) and St. Louis, Missouri, had the largest increase in bus trips (8.5 percent).

To see the full APTA Transit Ridership Report, visit bit.ly/transitreport.

INTERNATIONAL

Digital Billboards Distract Drivers

Digital billboards, designed to attract attention using static, changing, or moving pictures, are more distracting to drivers than traditional billboards, according to research from the Swedish National Road and Transport Institute and the Karlsruhe Institute of Technology.

Researchers recruited 41 drivers to operate an instrumented vehicle on a route that passed four digital billboards on a four-lane, high-traffic roadway in central Stockholm. Tests were conducted in day and night conditions, and visual behavior data were analyzed. Visual distraction—looking at a billboard continuously for more than 2 seconds or looking away from the road for a high percentage of time—was measured, with dependent variables such as eye-tracking measures and driving performance measures.

According to researchers, drivers passing a digital billboard experienced a significantly longer dwell time, more fixations, and a longer maximum fixation than when passing other signs on the same sections of road. Daytime or nighttime conditions did not make a difference in the data.

To see the full report, visit http://www.scenic.org/storage/PDFs/eebdd.pdf.

(continued on page 59)

Research Databases Add Search Features

The Transportation Research Information Services (TRIS) databases have implemented new interfaces and functionalities. Users of TRID, Practice Ready Papers, PubsIndex, and Research in Progress now can search with author first names—the most frequently requested improvement to TRIS—and can search for author names with wild cards—for example, typing a question mark or an asterisk to represent an unknown character or to find spelling variants—and by applying Boolean logic—using operators such as "AND" or "OR" to combine or exclude search terms.

Users also can select more than one TRB subject area for a search. If more than one term is selected, the default search is "or" for the subject area terms. Subject areas used by International Transport Research Documentation are searchable in the keyword field. To assist users in discovering additional terms in index searches, matching terms are available from a drop-down list in the search field, and multiple terms can be selected.

For more information on the new interfaces, visit www.trid.trb.org.

COOPERATIVE RESEARCH PROGRAMS NEWS

Safety Prediction Models for Arterials

The American Association of State Highway and Transportation Officials' *Highway Safety Manual* (HSM) provides safety analysis tools for highway agencies, including the HSM Part C predictive methods. The first edition of the HSM does not address all facility types of interest to transportation agencies, such as arterials with six or more lanes and one-way arterial streets. Research is needed to develop safety prediction methods for these facility types.

Texas A&M Transportation Institute (TTI) has received a $599,910, 36-month contract [National Cooperative Highway Research Program (NCHRP) Project 17-58, FY 2012] to develop a predictive method for the HSM to address crash frequency and severity for roadway segments and intersections on arterials with six or more lanes and one-way arterial streets. The research also will develop procedures for considering safety in decisions related to these facilities during widening and modification activities, as well as in new facility design.

For more information, contact Mark S. Bush, TRB, 202-334-1646, mbush@nas.edu.

Condition Assessment of Bridge Post-Tensioning and Stay Cable Systems with Nondestructive Evaluation

Nondestructive evaluation (NDE) technology is not available to evaluate the condition of bridge posttensioning and stay cable systems for corrosion, section loss, breakage, grout conditions, voids, water infiltration, and tendon deterioration in anchorage systems. NDE technologies from other industries, however, have potential applications for bridge condition assessments.

TTI has received a $650,000, 30-month contract (NCHRP Project 14-28, FY 2012) to develop inspection guidelines for bridge owners, to assist in selecting an NDE method or combination of methods for assessing the condition of in-service posttensioning and stay cable systems. The guide will consider duct types and will address corrosion, section loss, breakage, grout conditions, voids, water infiltration, and tendon deterioration in anchorage systems, as well as applications to other areas that are difficult to inspect.

For more information, contact Waseem Dekelbab, TRB, 202-334-1409, wdekelbab@nas.edu.

Transit Labor–Management Partnerships

Many organizations in the United States have pursued initiatives to improve labor–management partnerships—often in conjunction with efforts to address specific workplace problems. More information is needed, however, about the challenges faced by transit organizations in building and sustaining these partnerships.

AECOM Technical Services, Inc., has received a $300,000, 24-month contract (Transit Cooperative Resarch Program Project F-20, FY 2012) to develop a practical toolkit for creating, implementing, and supporting positive relationships between labor and management.

For more information, contact Dianne S. Schwager, TRB, 202-334-2969, dschwager@nas.edu.

PHOTO: LARRY LEVINE, WMATA

Washington Metropolitan Area Transit Authority employees work in the bus maintenance shop. TCRP Project F-20 will result in guidance for successful labor–management partnerships at transit agencies.

IN MEMORIAM

William J. Harris, Jr., 1918–2012

William J. Harris, Jr.

A leading transportation researcher and member of the National Academy of Engineering (NAE), William J. Harris, Jr., died December 5, 2012, in East Falmouth, Massachusetts. He was a member of the TRB Executive Committee from 1987 to 1990.

A native of South Bend, Indiana, Harris attended Purdue University, graduating in 1940 with a bachelor's degree in chemical engineering and a master's degree in metallurgy. He served in the U.S. Navy during World War II in charge of the armored aircraft program. In 1948, he received a Ph.D. in metallurgy from Massachusetts Institute of Technology. Harris joined the staff of the Naval Research Laboratory, studying the relationship between metallurgical structure, composition, and steel properties with a focus on ship failure mechanisms.

In the late 1950s, Harris served as executive director of the National Materials Advisory Board at the National Research Council; he later served as chair of the board. Harris also worked for the Battelle Memorial Institute, where he helped establish the Korean Institute of Science and Technology. From 1970 to 1985, he was vice president of research at the Association of American Railroads. In 1976, he was named Railroad Man of the Year by *Modern Railroads* magazine for his role in the development of major rail safety and efficiency improvements. He later served as distinguished professor of transportation engineering at Texas A&M University and associate director of Texas A&M Transportation Institute.

Besides serving as a regular and ex officio member of the Executive Committee, Harris served on many other TRB committees. He was a member of the Executive Committee's Subcommittee on Planning and Policy Review, the Technical Activities Council, the International Activities Committee, the Transportation History Committee, and the Intelligent Transportation Systems Committee, to which he was elected emeritus member in 1999. He also chaired the Group 5 Council, the International Trade and Transportation Committee, and the Committee for the High-Speed Rail IDEA Program.

Harris' service to TRB and accomplishments in transportation research were recognized, respectively, with the W. N. Carey, Jr., Distinguished Service Award in 1977 and the Roy W. Crum Distinguished Service Award in 1989. He was elected to NAE in 1977 for career achievements in research and development, technical planning, and systems analysis for the railroad industry and for his contributions to the materials field. In the late 1990s, Harris was recruited to the President's Commission on Critical Infrastructure Protection. As a consultant, he helped to implement the commission's findings and served as chair of the TRB Task Force on Critical Transportation Infrastructure Security.

NEWS BRIEFS (*continued from page 57*)

Promoting Pedestrian Safety Worldwide

The needs of pedestrians must be integrated into the earliest stages of urban planning project and transportation investments, according to a report from the International Transport Forum. Research from transportation experts and urban planners in 19 countries and the World Health Organization shows that walking trips represent nearly half of all trips in urban areas and that more than 400,000 pedestrians are killed on roads each year.

Photo: Shawn Turner, pedbikeimages.org

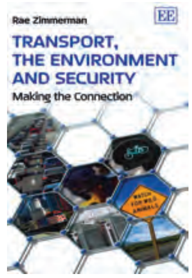
Bicycle, motor vehicle, and foot traffic in Beijing, China.

Lowering the speed limits for motorized traffic from 50 km/h to 30 km/h can achieve an 80 percent reduction in the risk of pedestrian death, according to the report. At any given time, approximately 30 percent of all pedestrians have impaired mobility—from adults supervising young children to pedestrians with physical handicaps. Many pedestrian injuries result from falls related to poor maintenance and design of public spaces.

Recommendations for pedestrian safety include integrating public transportation and pedestrian facilities into urban design; coordinated initiatives to promote walking; a standardized methodology for measuring, reporting, and monitoring pedestrian mobility; national pedestrian observatories; car-free areas and transit-oriented development; national guidance for local jurisdictions on planning for pedestrians; a "safe system" approach for the design of walking environments; traffic-calming zones; high-quality road safety education; and reviews of current traffic codes.

For more information, visit http://internationaltransportforum.org/Pub/pdf/11PedestrianSum.pdf.

Transport, the Environment, and Security: Making the Connection



Rae Zimmerman. Edward Elgar Publishing, 2012; 267 pp.; $120; 978-18-4980-020-4.

This book uses transportation networks as a framework to examine the relationship between transportation and the environment, security, and other infrastructure sectors. Case studies include the impacts of natural hazards, accidents, and transportation security breaches.

The Growth/Stress Generating Phenomenon: Neglected Nemesis of Bridges

Martin P. Burke, Jr. Crown Point Books, 2012; 283 pp.; $95; crownpointbooks@wowway.com.

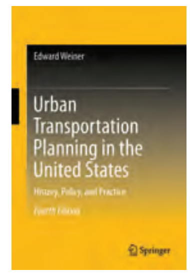
The author, a noted bridge engineer, describes the neglected growth–stress phenomenon and extensively documents its adverse effects on various types of bridges. Also described are the longitudinal forces generated by the phenomenon in contaminated reinforced-concrete bridge decks. The author presents ways to protect new and existing bridges. Long active in TRB, Burke chaired the TRB subcommittee that produced the award-winning *Bridge Aesthetics Around the World.*

Research Universities and the Future of America: Ten Breakthrough Actions Vital to Our Nation's Prosperity and Security

National Research Council. National Academies Press, 2012; 250 pp.; $49; 978-03-0925-639-1.

This report provides a course of action for Congress, the federal government, state governments, research universities, and others to ensure the success of research universities in the United States. Examined are trends in university finance, prospects for improving university operations, opportunities for deploying technology and increasing student diversity, improved regulation of higher education institutions, ways to improve access to graduate education, and more.

Urban Transportation Planning in the United States: History, Policy, and Process, Fourth Edition

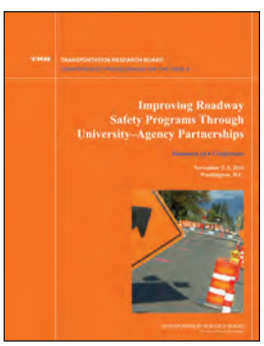


Edward Weiner. Springer Science + Business Media, LLC, 2013; 368 pp.; $179; 978-14-6145-406-9.

This comprehensive text examines the evolution of urban transportation planning, from early developments in the 1930s to today's concerns about sustainable development, security, and pollution control. The fourth edition features new chapters on global climate change and on working with constrained resources. The volume highlights major national events—including the Federal-Aid Highway Act of 1962—and explores the influence of legislation, federal programs, technology advances, and more.

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

TRB PUBLICATIONS

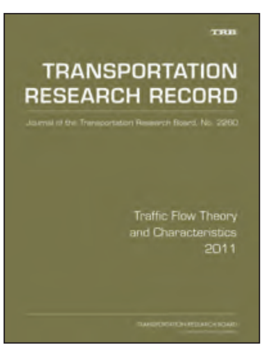


Improving Roadway Safety Programs Through University–Agency Partnerships

Conference Proceedings on the Web 8

This volume comprises presentations from a November 2011 conference on new safety tools and concepts and current successful university–transportation agency partnerships to improve highway safety. Also explored are case studies, research needs, and the challenges to and opportunities in roadway safety.

Available on the web at http://onlinepubs.trb.org/onlinepubs/conf/CPW8.pdf.



Traffic Flow Theory and Characteristics 2011

Transportation Research Record 2260

Papers in this volume examine such topics as travel time variations on urban links, alternative definitions of passing critical gaps, freeway traffic estimation problems, and estimating expressway capacity.

2011; 162 pp.; TRB affiliates, $52.50; nonaffiliates, $70. Subscriber categories: operations and traffic management; planning and forecasting.

Railways 2011, Including 2011 Thomas B. Deen Distinguished Lecture

Transportation Research Record 2261

Authors present research on the economic impacts of high-speed rail and intercity passenger rail service, the influence of value of time on the profitability of railway projects, expanding Alaska–Canada rail, track maintenance of heavy haul railways, and more. The text of the 2011 Thomas B. Deen Lecture, by James W. McClellan, opens the volume.

TRB PUBLICATIONS *(continued)*

2011; 185 pp.; TRB affiliates, $56.25; nonaffiliates, $75. Subscriber categories: railroads; passenger transportation; freight transportation.

Highway Design 2011
Transportation Research Record 2262

Included in this volume are papers examining spacing between freeway ramps; reduced-conflict intersections; low-cost, energy-absorbing bridge rail; a short-radius guardrail system; and utility challenges in project development.

2011; 235 pp.; TRB affiliates, $60; nonaffiliates, $80. Subscriber categories: design; safety and human factors; environment; hydrology, hydraulics, and water quality.

Network Modeling 2011
Transportation Research Record 2263

Measurement of transportation network vulnerability, time-dependent origin–destination demand estimation, reliable shortest paths, and travel speed forecasting are among the topics presented.

2011; 190 pp.; TRB affiliates, $56.25; nonaffiliates, $75. Subscriber category: planning and forecasting.

Pedestrians 2011
Transportation Research Record 2264

Topics such as automatic pedestrian detectors, sign visibility for pedestrians, advance yield markings, phase optimization at intersections, and probability models for pedestrian injury severity are explored in this volume.

2011; 155 pp.; TRB affiliates, $53.25; nonaffiliates, $71. Subscriber categories: pedestrians and bicyclists; safety and human factors.

Highway and Traffic Safety: Vehicles, Behavior, and Roundabouts
Transportation Research Record 2265

Papers in this volume explore injury risk in collisions involving buses, prevention of tractor–semitrailer rollovers, effectiveness of ticketing aggressive drivers, transportation services for seniors, the emissions impacts of roundabouts, and more.

2011; 259 pp.; TRB affiliates, $63.75; nonaffiliates, $85. Subscriber categories: safety and human factors; operations and traffic management; motor carriers.

Public-Sector Aviation: Graduate Research Award Papers, 2010–2011
Transportation Research Record 2266

The graduate research papers in this volume examine high-speed rail and aviation, dynamic airspace configuration, sustainable paving material for airfields, risk assessment of bird–aircraft strikes at commercial airports, analysis of taxiway aircraft traffic, and other topics.

2012; 94 pp.; TRB affiliates, $46.50; nonaffiliates, $62. Subscriber category: aviation.

Geomaterials 2012
Transportation Research Record 2267

The seven papers in this volume investigate topics including aggregate morphology analysis, polish resistance of fine aggregates, aggregate–bitumen bond strengths and asphalt mixture durability, aggregate retention in chip seal, and recycled asphalt pavement content.

2012; 71 pp.; TRB affiliates, $41.25; nonaffiliates, $55. Subscriber categories: geotechnologies; pavements; materials.

Construction 2012
Transportation Research Record 2268

Construction road user costs in rural areas, the value of tablet computers in transportation construction inspection, nondestructive tests of thickness measurements for concrete pavement, intelligent compaction technology, and asphalt mixture beams are explored in this volume.

2012; 129 pp.; TRB affiliates, $49.50; nonaffiliates, $66. Subscriber categories: construction; pavements; bridges and other structures.

Freight Systems 2012: Modeling and Logistics
Transportation Research Record 2269

Authors present research on distribution analysis of freight transportation, parametric and nonparametric trade gravity models, road closures and freight diversion, choice of shipment size in freight transport, simulating sustainable urban gateway development, and more.

2012; 144 pp.; TRB affiliates, $45; nonaffiliates, $60. Subscriber category: freight transportation.

Environment 2012
Transportation Research Record 2270

Examined in this volume are alternative uses of highway rights-of-way, location and design of wildlife crossing structures, air quality at bus stops, in-vehicle exposure to traffic-induced emissions, decomposition analysis for carbon dioxide emissions from car travel, and other topics.

2012; 194 pp.; TRB affiliates, $58.50; nonaffiliates, $78. Subscriber categories: environment; energy.

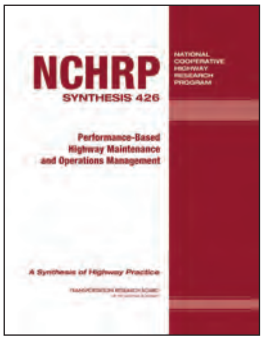
The TRR Journal Online website provides electronic access to the full text of more than 12,800 peer-reviewed papers that have been published as part of the Transportation Research Record: Journal of the Transportation Research Board *(TRR Journal) series since 1996. The site includes the latest in search technologies and is updated as new TRR Journal papers become available. To explore the TRR Online service, visit www.TRB.org/TRROnline.*

TRB PUBLICATIONS *(continued)*

Guidance for the Selection, Use, and Maintenance of Cable Barrier Systems
NCHRP Report 711

This report provides guidance to highway agencies on selecting, using, and maintaining cable barrier systems to reduce serious injuries and fatalities, as well as operational costs.

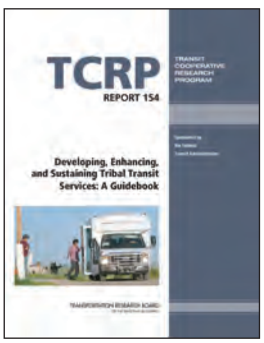
2012; 134 pp.; TRB affiliates, $45; nonaffiliates, $60. Subscriber category: highways.



Optimization of Tack Coat for Hot-Mix Asphalt (HMA) Placement
NCHRP Report 712

New test methods are proposed for measuring the quality and performance characteristics of tack coat in the laboratory and the field. Included is a training manual with proposed construction and testing procedures for tack coat materials.

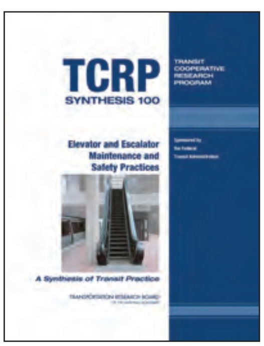
2012; 135 pp.; TRB affiliates, $47.25; nonaffiliates, $63. Subscriber categories: highways; materials; construction.



Estimating Life Expectancies of Highway Assets, Vols. 1 and 2
NCHRP Report 713

Volume 1 of this report is a guidebook for applying a methodology for estimating the life expectancies of major types of highway system assets; Volume 2 describes technical issues and data needs for estimating asset life expectancies and practical field experience.

2012; 370 pp.; TRB affiliates, $65.25; nonaffiliates, $87. Subscriber categories: administration and management; economics; highways.



Performance-Based Highway Maintenance and Operations Management
NCHRP Synthesis 426

Applications of performance-based management practices in highway maintenance and operations by state DOTs are examined in this volume.

2012; 87 pp.; TRB affiliates, $42.75; nonaffiliates, $57. Subscriber categories: administration and management; highways; maintenance and preservation.

Extent of Highway Capacity Manual Use in Planning
NCHRP Synthesis 427

This synthesis assesses how state DOTs, metropolitan planning organizations, and local governments use the *Highway Capacity Manual* for planning analyses, including performance monitoring, identifying problems, prioritizing projects, programming, and decision making.

2012; 49 pp.; TRB affiliates, $34.50; nonaffiliates, $46. Subscriber categories: highways; planning and forecasting.

Developing, Enhancing, and Sustaining Tribal Transit Services: A Guidebook
TCRP Report 154

This report presents an overview of the tribal transit planning process and offers steps for planning a new transit system, enhancing an existing service, or taking action to sustain services.

2012; 224 pp.; TRB affiliates, $57; nonaffiliates, $76. Subscriber categories: public transportation; planning and forecasting; society.

Track Design Handbook for Light Rail Transit, Second Edition
TCRP Report 155

Guidelines and descriptions are presented for the design of common types of light rail transit track—ballasted track, direct fixation track, and embedded track—and considers the characteristics and interfaces of vehicle wheels and rail, tracks and wheel gauges, rail sections, alignments, speeds, and track moduli.

2012; 647 pp.; TRB affiliates, $79.50; nonaffiliates, $106. Subscriber categories: public transportation; railroads.

Elevator and Escalator Maintenance and Safety Practices
TCRP Synthesis 100

Explored in this volume are elevator and escalator maintenance activities, safety practices, and passenger communication efforts at five U.S. transit agencies that together operate more than 1,400 elevators and escalators at 850 rail stations.

2012; 58 pp.; TRB affiliates, $36; nonaffiliates, $48. Subscriber categories: public transportation; safety and human factors; vehicles and equipment.

Implementation and Outcomes of Fare-Free Transit Systems
TCRP Synthesis 101

This synthesis highlights the experiences of public transit agencies that have planned, implemented, and operated fare-free transit systems. The agencies studied are either direct or indirect recipients of federal transit grants.

2012; 96 pp.; TRB affiliates, $42.75; nonaffiliates, $57. Subscriber categories: design; finance; public transportation; security and emergencies.

TRB PUBLICATIONS *(continued)*

Airport Passenger Conveyance Systems Planning Guidebook
ACRP Report 67

Best practices, specific design considerations, and decision-making frameworks are traced for the planning and implementation of passenger conveyance systems at airports—escalators, elevators, moving walkways, and passenger-assist vehicles and carts.

2012; 55 pp.; TRB affiliates, $42; nonaffiliates, $56. Subscriber categories: administration and management; aviation; design.

Guidebook for Evaluating Terminal Renewal Versus Replacement Options
ACRP Report 68

A step-by-step process is described for conducting a business-driven evaluation of options to renew or replace airport terminal facilities. Factors considered include life-cycle cost, obsolescence and condition of facilities, development risk, and more.

2012; 75 pp.; TRB affiliates, $38.25; nonaffiliates, $51. Subscriber categories: aviation; terminals and facilities; finance.

Subsurface Utility Engineering Information for Airports
ACRP Synthesis 34

This synthesis examines how information on subsurface utilities is collected, maintained, and used to increase the safety and effectiveness of airport infrastructure development programs.

2012; 50 pp.; TRB affiliates, $34.50; nonaffiliates, $46. Subscriber categories: aviation; design; geotechnology.

Issues with Use of Airfield LED Light Fixtures
ACRP Synthesis 35

The performance of LED lighting systems for airfields is documented.

2012; 35 pp.; TRB affiliates, $32.25; nonaffiliates, $43. Subscriber categories: aviation; design.

Multimodal Freight Transportation Within the Great Lakes–Saint Lawrence Basin
NCFRP Report 17

This report describes the current multimodal freight transportation system within the binational Great Lakes–Saint Lawrence Basin. The system's performance is explored, as well as opportunities and barriers to performance improvement.

2012; 97 pp.; TRB affiliates, $42.75; nonaffiliates, $57. Subscriber categories: freight transportation; planning and forecasting; economics.

Role of Human Factors in Preventing Cargo Tank Truck Rollovers
HMCRP Report 7

Analyzed in this volume are the causes of major driver factors contributing to cargo tank truck rollovers, with a focus on rollover-specific driver training and safety programs, behavior management techniques, and fitness-for-duty management practices.

2012; 61 pp.; TRB affiliates, $36; nonaffiliates, $48. Subscriber categories: motor carriers; safety and human factors.

Guide to Improving Capability for Systems Operations and Management
Report S2-L06-RR-2

This guide is designed to permit transportation agencies to self-evaluate their current position on systems operations and management related to nonrecurring congestion and provides strategies to help an agency transition to more effective systems management and operations.

2011, 44 pp.; TRB affiliates, $30.75; nonaffiliates, $41. Subscriber categories: administration and management; education and training; highways; law; operations and traffic management; policy. Available as e-book.

Linking Community Visioning and Highway Capacity Planning
Report S2-C08-RR-1

This report assists transportation practitioners in assessing the possibilities of community visioning efforts, identifying practical steps and activities, and establishing links between vision outcomes and transportation planning and project development processes.

2012; 76 pp.; TRB affiliates, $40.50; nonaffiliates, $54. Subscriber categories: highways; planning and forecasting. Available as e-book.

Expedited Planning and Environmental Review of Highway Projects
Report S2-C19-RR-1

Using literature and case studies, this report identifies 16 common constraints on project delivery and offers many strategies—also applicable to design and construction—for addressing or avoiding the constraints.

2012; 120 pp.; TRB affiliates, $45; nonaffiliates, $60. Subscriber categories: environment; highways; planning and forecasting. Available as e-book.

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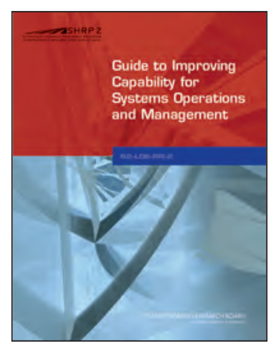

CALENDAR

TRB Meetings 2013

April

15–18 Joint Rail Conference: Next Generation Rail—Meeting Challenges of the Future*
Knoxville, Tennessee

16–18 International Highway Technology Summit: Delivering Innovative Approaches and Best Practices*
Beijing, China

30–May 1 Adapting Freight Models and Traditional Freight Data Programs for Performance Measurement
Washington, D.C.

May

4–5 Integrating Transportation Agency Spatial and Business Data for Improved Management Reporting
Boise, Idaho

5–9 14th TRB National Transportation Planning Applications Conference
Columbus, Ohio

15–17 Road Safety on Four Continents*
Beijing, China

20–22 7th National Seismic Conference on Bridges and Highways*
Oakland, California

June

2–3 10th International Symposium on Cold Regions Development*
Anchorage, Alaska

2–6 30th International Bridge Conference*
Pittsburgh, Pennsylvania

10–12 International RILEM Symposium on Multiscale Modeling and Characterization of Infrastructure Materials*
Stockholm, Sweden

10–12 Meeting State and Metropolitan Planning Organization Information Needs in a Constrained Fiscal Environment: Joint Midyear Meeting for TRB and AASHTO Committees
Washington, D.C.

17–20 7th International Driving Symposium on Human Factors in Driver Assessment Training and Vehicle Design*
Bolton Landing, New York

23–26 Workshop on Freeway Operations and Managed Lanes
Atlanta, Georgia

23–27 International Conference on Ecology and Transportation
Scottsdale, Arizona

July

11–12 8th SHRP 2 Safety Symposium
Washington, D.C.

14–17 8th International Conference on Road and Airfield Pavement Technology*
Taipei, Taiwan

15–18 Workshop on the Future of Road Vehicle Automation
Palo Alto, California

17–19 20th International Symposium on Transportation and Traffic Theory*
Noordwijk, Netherlands

22–25 Transportation: Driving a Sustainable Urban Environment
New Brunswick, New Jersey

30–Aug. 1 Workshop on the Safety Effects of Geometric Design Considerations
Irvine, California

August

4–7 International Symposium of Climatic Effects on Pavements and Geotechnical Infrastructure*
Fairbanks, Alaska

26–27 7th New York City Bridge Conference*
New York, New York

TBD Transportation, Climate Change, Energy Security, and Jobs Conference*
Pacific Grove, California

TBD Roadway Safety Culture Summit
Washington, D.C.

September

23–27 SmartRivers 2013*
Leige, Belgium, and Maastricht, Netherlands

October

16–17 Transit Geographic Information Systems Conference*
Washington, D.C.

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 TRBMeetings@nas.edu. Meetings listed without a TRB staff contact have direct links from the TRB calendar web page.

*TRB is cosponsor of the meeting.

INFORMATION FOR CONTRIBUTORS TO

TR NEWS

TR News welcomes the submission of manuscripts for possible publication in the categories listed below. All manuscripts submitted are subject to review by the Editorial Board and other reviewers to determine suitability for *TR News*; authors will be advised of acceptance of articles with or without revision. All manuscripts accepted for publication are subject to editing for conciseness and appropriate language and style. Authors receive a copy of the edited manuscript for review. Original artwork is returned only on request.

FEATURES are timely articles of interest to transportation professionals, including administrators, planners, researchers, and practitioners in government, academia, and industry. Articles are encouraged on innovations and state-of-the-art practices pertaining to transportation research and development in all modes (highways and bridges, public transit, aviation, rail, marine, and others, such as pipelines, bicycles, pedestrians, etc.) and in all subject areas (planning and administration, design, materials and construction, facility maintenance, traffic control, safety, security, logistics, geology, law, environmental concerns, energy, etc.). Manuscripts should be no longer than 3,000 words (12 double-spaced, typed pages). Authors also should provide charts or tables and high-quality photographic images with corresponding captions (see Submission Requirements). Prospective authors are encouraged to submit a summary or outline of a proposed article for preliminary review.

RESEARCH PAYS OFF highlights research projects, studies, demonstrations, and improved methods or processes that provide innovative, cost-effective solutions to important transportation-related problems in all modes, whether they pertain to improved transport of people and goods or provision of better facilities and equipment that permits such transport. Articles should describe cases in which the application of project findings has resulted in benefits to transportation agencies or to the public, or in which substantial benefits are expected. Articles (approximately 750 to 1,000 words) should delineate the problem, research, and benefits, and be accompanied by one or two illustrations that may improve a reader's understanding of the article.

NEWS BRIEFS are short (100- to 750-word) items of interest and usually are not attributed to an author. They may be either text or photographs or a combination of both. Line drawings, charts, or tables may be used where appropriate. Articles may be related to construction, administration, planning, design, operations, maintenance, research, legal matters, or applications of special interest. Articles involving brand names or names of manufacturers may be determined to be inappropriate; however, no endorsement by TRB is implied when such information appears. Foreign news articles should describe projects or methods that have universal instead of local application.

POINT OF VIEW is an occasional series of authored opinions on current transportation issues. Articles (1,000 to 2,000 words) may be submitted with appropriate, high-quality illustrations, and are subject to review and editing.

BOOKSHELF announces publications in the transportation field. Abstracts (100 to 200 words) should include title, author, publisher, address at which publication may be obtained, number of pages, price, and ISBN. Publishers are invited to submit copies of new publications for announcement.

LETTERS provide readers with the opportunity to comment on the information and views expressed in published articles, TRB activities, or transportation matters in general. All letters must be signed and contain constructive comments. Letters may be edited for style and space considerations.

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◆ All manuscripts should be supplied in 12-point type, double-spaced, in Microsoft Word, on a CD or as an e-mail attachment.

◆ Submit original artwork if possible. Glossy, high-quality black-and-white photographs, color photographs, and slides are acceptable. Digital continuous-tone images must be submitted as TIFF or JPEG files and must be at least 3 in. by 5 in. with a resolution of 300 dpi. A caption should be supplied for each graphic element.

◆ Use the units of measurement from the research described and provide conversions in parentheses, as appropriate. The International System of Units (SI), the updated version of the metric system, is preferred. In the text, the SI units should be followed, when appropriate, by the U.S. customary equivalent units in parentheses. In figures and tables, the base unit conversions should be provided in a footnote.

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