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DETAILS

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COVER: A large-scale crash in a snowstorm closes I-80 in Wyoming. State DOTs play a major role in keeping highways open and interstate freight flowing—Wyoming DOT is developing applications to provide travel advisories, roadside alerts, and more. (Photo: Wyoming DOT/Wyoming Highway Patrol)

TR NEWS

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

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ALSO IN THIS ISSUE:

COMING NEXT ISSUE

A photo essay documents the array of sessions, workshops, events, interactions, exchanges, awards, and more at the 95th Annual Meeting of the Transportation Research Board in January. Feature articles present transportation-related findings from a series of policy studies by the National Academies of Sciences, Engineering, and Medicine on the global connection to changes in the Arctic; plus results from research projects on sustainability as an organizing principle for transportation agencies; incorporating transportation security awareness into state DOT operations and training; design management for projects using design–build and construction manager–general contractor arrangements; and more.

TRB's 95th Annual Meeting drew a record-breaking crowd of students and transportation professionals to Washington, D.C., to share research and to hear from such distinguished speakers as U.S. Transportation Secretary Anthony Foxx, who emphasized the role of transportation in creating opportunity.

PHOTO: ROBERT ASHWORTH, FLICKR

Reducing Carbon Dioxide Emissions from Daily Travel

Insights from Germany

RALPH BUEHLER

The author is Associate Professor, Virginia Tech, Alexandria, Virginia.

(*Photo above:*) Traffic near Portland, Oregon. Per capita carbon dioxide (CO_2) emissions from transportation activities in the United States were several times greater than those in Western European countries such as Germany.

To reduce energy consumption and the related carbon dioxide (CO_2) emissions from daily travel, U.S. policies and regulations have focused on vehicle and fuel technology. The approaches include new vehicle standards for fuel efficiency and CO_2 emissions, tax incentives for the purchase of fuel-efficient vehicles, reduced vehicle registration fees and other incentives for fuel-efficient cars, and support and regulations for alternative fuels (*1, 2*). Despite these efforts, the CO_2 emissions per capita from ground passenger transport—walking, cycling, public transportation, and driving—were three to four times greater in the United States in 2010 than in the wealthy Western European countries of Austria, Denmark, Germany, the Netherlands, or Norway (*3–5*).

The levels of energy consumption and CO_2 emission are related to technological factors, such as the fuel efficiency of vehicles or the fuel type, as well as to the choice of modes and the intensity of mode use. An examination of the differences in CO_2 emissions from daily travel, vehicle fuel efficiency, travel behavior, and transport policy in the United States and Germany offers insights on ways to reduce CO_2 emissions.

Tracking the Trends

Germany is Europe's largest economy and most populous country and shares similarities with the United States. Both are wealthy Western democracies with federal systems of government, have some of the world's highest rates of motorization, boast large lim-

PHOTO: JOS, FLICKR

Many factors—from fuel-efficient technology to travel behavior—are behind Germany's 15-percent reduction in CO_2 emissions between 1990 and 2010.

ited-access highway networks, have a similar share of licensed drivers—70 percent of each population—and are home to significant automobile industries.

In 2010, CO_2 emissions from ground passenger transportation in the United States were higher than those in Germany: 11.7 times greater in terms of total CO_2 emissions, 3.1 times higher per person, 2.1 times larger per passenger kilometer of ground passenger travel, and 2.4 times greater per unit of gross domestic product (GDP) (*4, 6, 7*). Between 1990 and 2010, Germany reduced CO_2 emissions from passenger transportation by 15 percent, but emissions in the United States increased by 12 percent.

Controlling for differences in trends affecting the economy, the population, and travel demand in the two nations during this period, Germany surpassed the United States in reducing CO_2 emissions from ground passenger transportation, with reductions of 36 percent per unit of GDP, compared with 31 percent in the United States; of 17 percent per capita, compared with 9 percent; and of 20 percent per passenger kilometer of travel, compared with 3 percent (*4, 6, 7*).

PHOTO: JULIAN SCHÜNGEL, FLICKR

High gas taxes in Germany in recent years have encouraged demand for fuel-efficient vehicles.

Fuel and Vehicle Technology

In 2010, the German automobile and light truck vehicle fleet was 50 percent more fuel efficient than the U.S. fleet. Between 1990 and 2010, the fuel efficiency of the German vehicle fleet improved at a faster rate than in the United States—from 9.5 to 7.5 liters per 100 kilometers or 27.9 to 33.9 mpg in Germany, compared with 12.1 to 11.2 liters per 100 kilometers or 22.4 to 24.0 mpg in the United States.

Higher and increasing gas taxes in Germany fostered demand for more fuel-efficient vehicles. Although Germany did not impose fuel-efficiency standards on car manufacturers until 2009, the car manufacturers entered into a voluntary agreement with the European Commission (EC) in the late 1990s to reduce the average CO_2 emissions from new vehicles to 140 g CO_2/km over 10 years (*8*).

During this period, most of the improvements in fuel efficiency in Germany were the result of what was termed *dieselization*—an increased share of diesel vehicles in the fleet. Diesel engines are more efficient than gasoline engines, but diesel fuel has higher energy and carbon contents per unit.

Under the voluntary agreement, the improvements reached 160 g CO_2/km in 2006 but were considered insufficient. Since 2009, the EC has required manufacturers to achieve an average of 130 g CO_2/km by 2015 and more recently set the target at 95 g CO_2/km by 2020; this corresponds to 43.7 and 57.0 mpg and assumes a fleet consisting of 75 percent gasoline vehicles and the rest diesel.

The specifics of the European standards were highly contested. For a long time, Germany opposed the goal for 2020—likely representing the interests of its automobile manufacturing industry. As with the corporate average fuel economy (CAFE) standards in the United States, politics significantly influenced and delayed the setting and renewing of European standards.

In both countries, petroleum was the main fuel source for 95 percent of ground passenger transportation in 2010. The share of diesel-powered vehicles in Germany's fleet was higher and has increased at a faster rate than in the United States.

The United States, however, has a longer history of using alternative fuels (*9*). For example, gasoline with a 10 percent component of ethanol is common in the United States. By contrast, the German federal government experienced a public relations disaster and public resistance in 2011 to increasing the ethanol content of gasoline from 5 to 10 percent. Many Germans believed the new fuel would destroy their engines. In the United States, the American Automobile Association has issued a similar warning for new standards raising the ethanol content to 15 percent (*10*).

Travel Behavior

The regulation of vehicle and fuel technology does not fully explain the lower levels of CO_2 emissions from passenger transportation in Germany compared with those in the United States. The differences in travel behavior in the two nations, however, are large. The United States has a higher share of trips by car and more passenger kilometers of car travel, contributing to CO_2 emissions.

The most recent national household travel surveys for 2008–2009 show that driving accounted for a higher share of daily trips in the United States than in Germany—86 percent of trips compared with 58 percent. Germans were more likely to ride public transportation—for 9 percent of trips, compared with 2 percent in the United States; Germans chose cycling for 10 percent of their trips, compared with Americans for 1 percent of their trips; and 24 percent of German trips were by foot, compared with 11 percent in the United States (*11, 12*). Americans drove almost twice as many kilometers per year: 21,700 kilometers or 13,500 miles, compared with 11,000 kilometers or 6,800 miles driven by Germans.

Dissimilarities in trip distances, land use, or socioeconomics, however, do not fully explain the differences in travel behavior in the two countries. Average U.S. trip distances were 15.7 kilometers or 9.8 miles, compared with German trip distances averaging 11.2 kilometers or 7.0 miles. Nevertheless, both countries have a similar share of trips shorter than 1.6 kilometers, or 1 mile—32 percent in Germany and 27 percent in the United States; and the share of trips shorter than 400 meters or one-quarter mile in both countries was comparable—8 percent versus 6 percent. Yet Americans traveled by car for 65 percent of the trips shorter than 1.6 kilometers and for 38 percent of trips shorter than 400 meters, compared with Germans for 28 percent and 7 percent of the respective trip distances (*11, 12*).

The average population densities are higher in Germany, but controlling for population density shows that Germans were more likely to walk, cycle, and ride public transport. Americans who live in dense, mixed-use areas, close to public transportation, were more likely to drive than Germans living in lower-density areas with a more limited mix of land uses and farther from public transport (*13*).

Lessons

Germany's experience shows that public policies can help increase the demand for more fuel-efficient vehicles and can limit car travel, while improving the attractiveness of walking, cycling, and public transportation as alternatives to driving.

Photo: Scott Lowe, Flickr

The United States has a long history with alternative fuels. Compressed natural gas fuel was introduced more than 30 years ago, although use is mostly confined to public transportation fleets.

1. Gasoline Taxes

In 2010, 1 liter of unleaded gasoline cost $1.96 in Germany, equivalent to $7.41 per gallon, but $0.80 in the United States, equivalent to $3.01 per gallon (*14*). Most of the difference reflects German gas taxes, which are eight times higher than the U.S. rates. In 1986, the gap in gasoline retail prices between the countries was approximately 80 percent; in 2010, the gap had increased to 140 percent. Some of this gap resulted from Germany's environmental tax—designed to curb energy use—which increased the taxes on gasoline by 0.15 per liter, or approximately $0.75 per gallon, between 1999 and 2003.

By contrast, the U.S. federal government has not increased the gasoline tax for two decades. In 2009 and 2010, revenue from gasoline taxes and other highway user taxes and fees in Germany was approximately two times higher than roadway spending by all levels of government. In the United States, roadway user revenue collected by federal, state, and local governments covered approximately 60 percent of

Most Americans use personal vehicles to conduct their daily business—86 percent of daily trips in 2008 and 2009 were by car, according to the National Household Travel Survey.

Photo: Dennis S. Hurd, Flickr

Many Germans use buses or rail to run errands; public transportation demand is seven times greater in Germany than in the United States.

Photo: Sascha Kohlmann, Flickr

spending on roadway construction and maintenance (*15*, Table VM 202; *16*).

2. Parking and Traffic Calming

On the local level, most German cities have increased the cost of car parking and have reduced the availability of parking in city centers and neighborhoods (*17*). Moreover, limited-access highways in Germany rarely penetrate cities and city centers. Traffic calming measures on up to 85 percent of urban road network—mainly in residential neighborhoods—with speed limits of 7 to 30 km/h also discourage automobile travel.

3. Promoting Public Transportation

All levels of government in Germany have implemented policies that help make walking, cycling, and public transportation attractive alternatives to driving. Contributing to the greater attractiveness of public transportation in Germany are the regional integration of public transportation services, the coordination with other modes, the regionwide fare integration across operators, the steeply discounted monthly and annual tickets, the unified user information systems, and real-time information for travelers; moreover, buses and light rail receive traffic priority (*18*).

Public transportation vehicle load factors are critical in expanding public transportation service to reduce CO_2 emissions. The greater number of passengers per transit vehicle partly explains the lower CO_2 emissions from transportation in Germany. In 2010, public transportation in Germany logged 59 vehicle kilometers per capita—three times the U.S. rate of 20 vehicle kilometers per capita; in addition, demand in Germany was approximately 7 times greater—140 linked public transportation trips per capita per year compared with 20 in the United States (*18–20*).

4. Local Initiatives to Promote Walking and Cycling

Most of the innovations that have promoted walking and cycling—such as car-free pedestrian zones, areawide traffic calming, integrated citywide bicycling networks, bicycling training courses for schoolchildren, and pedestrian-activated traffic signals—were pioneered and implemented at the local and state levels (*21*). The German federal government has provided technical guidance and flexible funding mechanisms for nonmotorized modes.

Although some U.S. cities have made progress, the localities remain less bike and pedestrian friendly than those in Germany. For example, in 2010, cyclist and pedestrian fatality rates per kilometer cycled or walked were 4 to 5 times greater in the United States than in Germany (*21*).

5. Flexibility in Land Use Planning

Land use planning in Germany fosters shorter trip distances and higher population densities. Municipal governments develop the land use plans and decide where various land uses are permitted. The regional and state plans are developed with the involvement of lower levels of government and can restrict local plans (*22*). Moreover, the federal government mandates the coordination of land use plans with other sectors—such as transportation—and with neighboring jurisdictions.

Lack of parking in many German city centers has discouraged downtown driving.

Photo: onnola, Flickr

In Germany, residential zones allow for doctors' offices, small shops, and restaurants—the land use planning is more flexible than in the United States. Moreover, German zoning typically applies to small areas of one or two blocks; this ensures shorter trip distances (23).

Applying the Lessons

The greater CO_2 emissions from ground passenger transportation in the United States compared with those in Germany are the result of a combination of technological, fiscal, and behavioral factors. The German example shows that policies can help shape technology and travel behavior.

Germany's experience demonstrates that a vibrant, populous, wealthy country can thrive despite lower levels of petroleum consumption and can reduce the CO_2 emissions from daily travel. Adopting this approach may help reduce CO_2 emissions from ground passenger transportation in the United States as well.

References

1. *Circular E-C164: Climate Change and Transportation*. Transportation Research Board of the National Academies, Washington, D.C., 2012. www.trb.org/Publications/Blurbs/167508.aspx.
2. Buehler, R. Daily Travel and Carbon Dioxide Emissions from Passenger Transport: A Comparison of Germany and the United States. In *Transportation Research Record: Journal of the Transportation Research Board, No. 2454*, Transportation Research Board of the National Academies, Washington, D.C., 2014, pp. 36–44.
3. Buehler, R. and J. Pucher. Sustainable Transport in Freiburg: Lessons from Germany's Environmental Capital. *International Journal of Sustainable Transportation*, Vol. 5, No. 1, 2011, pp. 43–70.
4. *CO_2 Emissions from Fossil Fuel Combustion in Transportation End-Use Sector*. Environmental Protection Agency, Washington, D.C., 2012.
5. *CO_2 Emissions from Fuel Combustion: 1971–2009*. International Energy Agency, Paris, 2012.
6. *OECD Factbook*. Organisation for Economic Co-Operation and Development, Paris, 2012.
7. *CO_2 Emissions from Passenger Transport*. Umweltbundesamt, Dessau, Germany, 2012.
8. *CO_2 Emission Standards*. European Commission, Brussels, Belgium, 2012.
9. *Alternative Fuels and Incentives*. U.S. Department of Energy, Washington, D.C., 2012.
10. *AAA Urges Regulators to Put Consumers First When Examining the Renewable Fuels Standard*. AAA, Washington, D.C., 2013.
11. *National Household Travel Survey*. U.S. Department of Transportation, Washington, D.C., 2009.
12. *Mobilitaet in Deutschland 2008/2009*. Federal Ministry of Transportation, Bonn and Berlin, Germany, 2010.
13. Buehler, R. Determinants of Transport Mode Choice: A Comparison of Germany and the USA. *Transport Geography*, 2011.
14. *Energy Prices and Taxes*. International Energy Agency, New York, 2012.
15. *Highway Statistics 2010*. Federal Highway Administration, Washington, D.C., 2012.
16. Buehler, R. Transport Policies, Automobile Use, and Sustainable Transport: A Comparison of Germany and the United States. *Journal of Planning Education and Research*, Vol. 30, September 2010, pp. 76–93.
17. Hass-Klau, C. *The Pedestrian and City Traffic*. Belhaven Press, New York, 1993.
18. Buehler, R., and J. Pucher. Demand for Public Transport: A Comparison of Germany and the USA. *Transport Reviews*, 2012.
19. *VDV Statistik 2010*. Verband Deutscher Verkehrsunternehmen, Berlin, Germany, 2011.
20. *Transportation Factbook 2010*. American Public Transportation Association, Washington, D.C., 2011.
21. Pucher, J., and R. Buehler, eds. *City Cycling*. MIT Press, Cambridge, Mass., 2012.
22. Kunzmann, K. State Planning: A German Success Story? *International Planning Studies*, Vol. 6, No. 2, 2001, pp. 153–166.
23. Hirt, S. Mixed Use by Default: How the Europeans (Don't) Zone. *Journal of Planning Literature*, Vol. 27, No. 4, 2012.

Photo: Katherine Kortum

German cities like Leipzig have a robust bicycling culture, encouraged by local pedestrian and cycling initiatives.

Steering the Way Through Disruptions and Transformations

Findings from the Transportation Research Board's 2015 State Partnership Visits Program

Developments and activities in state agencies in 2015 underscored the dual title of one of TRB's emphasis areas for the year—transformative or disruptive technologies. Technological and social developments are generating greater than ordinary uncertainty, for better or worse—or possibly both.

PHOTO: STEVE FECHT FOR CHEVROLET

An automated Chevrolet research vehicle (*right*) demonstrates collision avoidance on a city street. New technologies such as connected–automated vehicles constitute a growing area of focus for state departments of transportation (DOTs) and for TRB.

In every mode and in nearly every area of expertise, states are experiencing technological disruptions and transformations. Nevertheless agencies must continue planning, designing, constructing, maintaining, and operating transportation facilities, and other public- and private-sector organizations must continue developing and delivering transportation products and services.

The Internet of things and the big data it generates promise improved reliability and efficiency and the development of entirely new transportation experiences, including fully automated vehicles, but also pose new problems of privacy, safety, and security. Climate change threatens the viability of some infrastructure yet is opening previously impassable marine routes. New energy sources may reduce greenhouse gas emissions but may pose other environmental, safety, and transportation capacity issues.

Will automated cars reduce vehicle miles traveled (VMT), or will VMT increase as "zero occupancy" vehicles cruise on streets that no longer have parking spaces while the vehicle owners are busy with work or at play? Or will shared transportation services mean that most people will not own vehicles? What social impacts will these new technologies and approaches have? How will laws and regulations change? What will be the impacts for transportation agencies?

State departments of transportation (DOTs) not only are asking these questions but are actively seeking answers. Transportation agencies are using new technologies to conduct traditional activities; agencies are engaged with the federal government and with automobile manufacturers in testing and deploying automated vehicle and intelligent infrastructure technologies. State DOTs are planning for increased goods movement across transportation modes and are harnessing data to improve operations and customer services.

Specialists in the Transportation Research Board's (TRB's) Technical Activities Division identify current issues, collect and generate information on the issues, and disseminate the information throughout the transportation community. The TRB Annual Meeting, TRB-sponsored conferences and workshops, webinars, 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 on all modes of transportation.

A major source of this information is the TRB annual state partnership visits program. Transportation professionals on the TRB staff meet on site with representatives of state 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, webinars, and meetings. This report summarizes what the TRB staff learned from visits and activities during the past year.

Image: North Carolina DOT

A rendering of the I-77 Express Lanes in North Carolina. Supported by a public–private partnership, the project will help relieve increased traffic congestion in the Charlotte area.

Institutional Issues

Policy, Management, and Leadership

To address the decline in gasoline tax revenues, Oregon DOT piloted a mileage-based user fee program, OReGo. The up to 5,000 voluntary participants will pay a fee of 1.5 cents per mile instead of the historic fuel tax and will receive a tax credit for used fuel. The Oregon legislature will evaluate the results of OReGO in 2017 and decide on expanding or modifying the program.

North Carolina DOT launched a public–private partnership to develop the I-77 Express Lanes in the Charlotte area; the 26 miles on the Interstate are among the most congested in the state. North Carolina DOT is evaluating two other public–private partnerships for upcoming projects.

Planning

Transportation planners and modelers have struggled against uncertainties since the profession emerged. Planners must deal with many complex issues: climate change, the travel behavior and location choices of the millennials and immigrants, new vehicle and infrastructure technologies, communications and information technologies, and more. Each of these challenges could dramatically change land development patterns, travel demand, and the types of transportation infrastructure to serve the demand. In combination, these factors can amplify the uncertainties and could redirect transportation planning on an entirely new trajectory.

Improvements and developments in sophisticated analytical tools are providing the specificity to explore the environmental requirements and the behavioral and operational effects of these trends. The models have helped in understanding and forecasting the impacts of changes.

Decision makers, agency leaders, and planners are exploring scenario-planning or sketch-planning tools and approaches. The National Cooperative Highway Research Program (NCHRP) Report 750 Foresight series, *Strategic Issues Facing Transportation*,[1] provides a strong foundation for states interested in scenario planning. Several states are piloting the tools and approaches developed in the NCHRP projects.

Legal Issues

State DOT attorneys are dealing with an array of issues associated with technology and innovation. The safety product litigation related to guardrail design and installation was a main focus. Although these issues are primarily legal, the controversies are political as well. At the summer meeting of the Legal Resources Group, attorneys from state DOTs looked into innovative techniques for settling eminent domain cases and examined issues related to pipelines in Texas.

Addressing the issues associated with connected and autonomous vehicles requires cooperation among a variety of legal disciplines. The legal studies projects of TRB's Cooperative Research Programs are addressing autonomous vehicles, with a Legal Research Digest slated for release;[2] another study is examining liability issues related to shared ride services.[3]

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[1] www.trb.org/Main/Blurbs/171856.aspx.
[2] http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_lrd_069.pdf.
[3] www.trb.org/Publications/Blurbs/154565.aspx.

The National Cooperative Highway Research Program Report 750 Foresight series, *Strategic Issues Facing Transportation*, addresses topics from shifts in demographics to future energy scenarios.

Photo: ellenm1, Flickr

Wind turbine blades often need oversize load permits for transport. Agencies are working to mitigate the impacts of domestic energy production on roads and freight systems.

Several topics loom large for environmental attorneys:

◆ In completing National Environmental Protection Act (NEPA) documents, how should agencies analyze the greenhouse gas emissions from proposed projects?

◆ What administrative records should agencies compile for responses to NEPA or other Administrative Procedure Act challenges?

◆ What effects will the proposed definition of "waters of the United States" in the final rule from the U.S. Environmental Protection Agency and the U.S. Army Corps of Engineers have on project permitting?

◆ What legal issues will arise as more states take advantage of the NEPA assignment provision in the Moving Ahead for Progress in the 21st Century Act (MAP-21)?

◆ How will the streamlining provisions in MAP-21 and proposed highway reauthorization legislation affect the project development process?

Environment, Energy, and Climate Change

Several state DOTs began developing and updating agreements with the Federal Highway Administration (FHWA) for administering categorical exclusions under NEPA. The agreements must be established or revised by 2019, according to the most recent regulatory update. Agencies also are working to comply with changes in the air quality model guidance and to improve understanding of roadside ecological habitats, as well as mitigation strategies for threatened species.

The transport of oil, natural gas, coal, and other energy resources is a focus as states address the requirements and implications of the various modes of delivery—for example, by road, rail, marine vessel, or pipeline. With increases in freight movement and construction, agencies are working to reduce the environmental and climate change effects of heavy-duty vehicles and from the manufacture of transportation-related construction materials.

Resilience

Providing "a safe and resilient transportation system in an environmentally responsible manner" is a strategic goal of the Vermont Agency of Transportation, which is developing methods and tools for resilience planning. The final product will identify vulnerabilities in the road networks in several watersheds and project their impacts.

Transportation agencies in several states, including Alaska, Arizona, California, Connecticut, Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, New York State, Tennessee, and Washington State, participated in Climate Change Resilience Pilots sponsored by FHWA. A series of webinars disseminated the results and lessons learned. The pilots focused on assessing the vulnerability of transportation infrastructure to extreme weather events and on analyzing options for enhancing the resilience of vulnerable locations.

Bridge 19 in Rochester, Vermont, after Tropical Storm Irene. The Vermont Agency of Transportation is developing strategic resilience plans.

Photo: VTrans

Photo: University of Missouri Kansas City

Researchers use an unmanned aircraft system (UAS) to conduct a bridge inspection in Missouri. New technologies present both opportunities and challenges to state DOTs and other agencies.

Data

With the increased demand for transportation data, states are integrating and deploying data assets and tools to meet customer needs and to inform key decisions. This often requires communicating the data in easily understandable formats. Many states have taken a storytelling approach to present data from geographic information systems (GIS) applications.

- Maryland generates an annual mobility report integrating traffic count, signal system, vehicle probe, and construction project data to assess network mobility and to identify and resolve bottlenecks.
- Washington State DOT has integrated roadway inventory and highway operations activities with crash, collision, and ticketing information to provide information to law enforcement and local agencies and to the public.
- Illinois and Montana have used their roadway inventory information assets to develop a web-enabled permitting process, including route generation, mapping, and instructions, for overdimensioned and overweight vehicles.

Effective governance, management, and business planning processes are key to data programs. Alaska, California, Colorado, Idaho, Maryland, Minnesota, Ohio, Oregon, Texas, Utah, Virginia, and Washington are leading initiatives in safety data governance. NCHRP Report 814, *Data to Support Transportation Agency Business Needs: A Self-Assessment Guide*, describes approaches for evaluating data programs agencywide and at the program-specific level.[4]

States are obtaining key data through new technologies. Florida and Ohio have used unmanned aerial vehicles to collect data on traffic patterns, and Michigan and Minnesota have used the technology for inspecting assets, such as unpaved roads.

Probe-based data have provided states with a valuable tool for measuring performance; as the coverage and quality improve, the results can help meet the data requirements associated with FHWA's Highway Performance Monitoring System.

Lidar technologies have proved valuable in assembling asset inventories. Utah and Florida have effective statewide programs.

Aviation

Regulation of unmanned aircraft systems (UAS) continues as a dominant topic in the industry. The Federal Aviation Administration (FAA) has worked with commercial UAS operators, but more needs to be done as UAS use by the general public becomes more common.

Security remains a major focus. Cybersecurity gained emphasis this year, particularly in relation to the deployment of new airspace management technologies under the NextGen initiative to change air traffic control from radar to satellite-based GPS.

Other issues include the pros and cons of transitioning the U.S. air traffic control system to private or quasi-private management; the effects of airline industry consolidation on regional transportation options; and the results of updated research on the community impacts of aviation-related noise.

[4] www.trb.org/Main/Blurbs/173470.aspx.

Photo: John Perry, Flickr

San Diego International Airport is close to many residential neighborhoods. Recent research in the aviation industry has examined the community impacts of aircraft noise.

Photo: Southeast Missouri Regional Port Authority

Through the Missouri River Freight Corridor Development program, Missouri DOT is investing in the river as a major freight passage.

Freight

TRB highlighted the importance of the U.S. inland waterways freight system in 2015 with the release of Special Report 315, *Funding and Managing the U.S. Inland Waterways System: What Policy Makers Need to Know.* Agencies are supporting economic development and multimodal connectivity projects to stimulate commerce in states that rely on river traffic to convey products for overseas markets.

The Missouri River Freight Corridor Development effort serves as a premier example. The Missouri DOT program is "redeveloping the river as a freight corridor with logical market nodes and reliable service that supports a sustainable market and logistics system." Focus areas include expanding freight markets, identifying the port infrastructure and equipment requirements to initiate and support river freight services, evaluating potential markets and strategies for expansion, and identifying river management techniques to optimize freight movement.

State DOTs play an important role in the fluidity of the national freight system. Interstate 80, one of the busiest U.S. truck corridors, crosses the continental divide in Wyoming, and the state DOT concentrates resources to keep the Interstate open throughout the winter; nevertheless, closures are sometimes necessary, with a cost of hundreds of thousands of dollars per day to the national economy. With support from U.S. DOT's Connected Vehicle Pilot Deployment Program, Wyoming DOT is developing applications that will use vehicle-to-vehicle and vehicle-to-infrastructure connectivity to provide travel advisories, roadside alerts, and parking information to minimize the costs.

Highways

Design

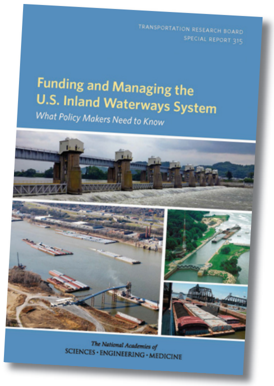
Many state DOTs are working to update their design manuals and practices to produce more sustainable transportation products; the Washington State DOT *Design Manual* and the New York State DOT Green-LITES initiative are examples. These approaches provide functionality for the present without depleting the resources available to future generations. The goals are to protect the environment, manage finances responsibly, and address other societal needs, such as livable communities.

The approach affects the design of stormwater facilities, pavements, bridges, and other structures. The designs consider the materials, the emissions generated, and the life-cycle costs. In addition to the impact on available resources, considerations include the project's fit in the context of a corridor or community and the safe accommodation of bicycles and pedestrians.

Performance-based seismic design (PBSD) of bridges is an emerging area of research. Developed to determine the reliability of buildings in earthquakes, PBSD can provide a probabilistic, quantifiable method to determine the exceedance of varied and multiple performance objectives. Research is under way to develop the bases for the codes and specifications for applying PBSD to bridge design.

Construction and Materials

State transportation agencies continue to explore alternative contracting for project delivery, after gaining experience with the processes of preaward procurement and project delivery decision making. States are seeking guidance in administering alternative contracts.



More information on Special Report 315, *Funding and Managing the U.S. Inland Waterways System: What Policy Makers Need to Know*, is available at www.trb.org/Publications/Blurbs/172741.aspx.

Photo: Wyoming DOT/Wyoming Highway Patrol

A crash involving many freight vehicles in Wyoming closes I-80, one of the nation's busiest truck corridors. Wyoming DOT is focusing efforts on developing technology and connected infrastructure to enhance freight fluidity.

Some states have tried alternate design–alternate bid for pavement construction projects, allowing contractor input into the selection of pavement type. An NCHRP synthesis project is under way to document the state of the practice.

Most state agencies lack staff for construction program oversight. In-house staff reductions, coupled with the requirements for documentation beyond construction inspection, have forced agencies to outsource some of the work and to look to new technologies in meeting the responsibilities.

State agencies continue to specify the use of reclaimed asphalt pavement (RAP). Some states are trying to optimize the quantity of RAP as a cost-saving measure while maintaining performance. A few states have allowed reclaimed asphalt shingles as a partial replacement for asphalt binder.

Concern about the age properties of reclaimed materials has led to the development and testing of rejuvenators. An NCHRP synthesis on the use of RAP and recycled asphalt shingles in asphalt mixtures will provide guidance to agencies,[5] and efforts are under way to refine the American Association of State Highway and Transportation Officials specifications for the use of reclaimed materials in asphalt mixes.

Slide-in bridge construction is gaining popularity, to save construction time, reduce the impacts on traffic, and provide a safer work environment. The second Strategic Highway Research Program Project R04, Innovative Bridge Designs for Rapid Renewal, produced an accelerated bridge construction toolkit[6] that included standard concepts for lateral slide technology, in use by several states.

Photo: Wikimedia Commons

A transportation agency conducts a bridge inspection. Performance-based seismic design is an emerging area of research.

Geotechnical Engineering

In 2015, increased precipitation created safety problems along transportation corridors in several states. In Oklahoma pavements were flooded, rockfalls and landslides occurred, and erosion damaged bridge abutments and piers; California experienced a mudflow and a debris flow; and a rockfall blocked railroad tracks in Vermont.

The frequency of microearthquakes has increased in some states that allow the use of fracking technology to tap energy resources; a direct link between fracking and the increase in earthquakes, however, has not been found. Oklahoma DOT is developing a protocol, response plan, and postearthquake inspection manual on the seismic stability of bridge foundations.

Approximately 50 percent of all construction claims relate to geotechnical issues. NCHRP has published a synthesis on the influence of geotechnical investigation and subsurface conditions on claims, change orders, and cost overruns.[7]

A few state DOTs have explored geotechnical asset management to complement transportation asset management (TAM) initiatives; several states have developed a variety of management practices for geotechnical assets. A new NCHRP project is developing an implementation plan to assist transportation agencies in incorporating geotechnical asset management into TAM.[8]

Interest in techniques that improve data gathering has prompted some state DOTs to test thermal integrity profiling as a tool for the quality assurance and quality control of drilled shafts. The early results have been encouraging.

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[5] http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3794.

[6] www.trb.org/Main/Blurbs/168046.aspx.

[7] NCHRP Synthesis 484, www.trb.org/Main/Blurbs/173907.aspx.

[8] http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4065.

Maintenance and Preservation

State DOTs continue to develop maintenance-related performance measures, not only for pavements and bridges but for many auxiliary assets, with a focus on linking maintenance and preservation activities with asset management systems. The link is essential for determining the return on investment from preservation and maintenance activities both in cost savings and in extending the service life of assets.

Agencies are expanding the use of automated data collection to measure the condition of roadside assets such as signs, guardrails, and striping. Advances in technology allow agencies to equip maintenance field personnel with handheld devices for planning work based on location-specific asset condition and treatment.

Many maintenance departments face challenges in recruiting and retaining a well-trained workforce. Utah DOT has developed a transportation technician qualification program to address workforce training and development. The program combined the construction and maintenance technicians into a single pool and defined a process for linking training requirements and levels of pay.

Highway Operations

Connected–automated vehicle technologies and issues are emerging quickly and have the potential to spur revolutionary change, not only for highways but across all modes. The impacts affect transportation operations, land use, safety, roadway geometric design, pavements, bridge design, transit and transit operations, freight and goods movements, and more.

The next generation of vehicle automation is arriving soon, as automobile manufacturers and suppliers are advancing and testing the ability of vehicles to drive themselves under certain conditions—for example, in stop-and-go congestion, on freeways, and on low-speed local roads. Because of this technology shift, consumer technology companies, such as Apple, are considering entry into the transportation market.

Vehicle automation is expected to advance the sharing economy, perhaps to offer new travel alternatives, such as automated rideshare and carshare options. Some forecasts project declines in private car ownership and in per capita driving.

Public agencies are exploring the possible impacts of the multiplying technologies related to automated vehicles. Some state DOTs are developing strategies to prepare for implementation.

Other developments in the operations area include applications of real-time data on traffic signal phase and timing—referred to as SPaT data—that can be broadcast at signalized intersections and received by vehicles, enhancing mobility and safety. Integrated corridor management allows operational coordination between networks along a corridor, so that transportation agencies can manage the total capacity of a corridor to reduce congestion and increase travel time reliability.

Safety

After a steady decline in the number of roadway fatalities and serious injuries for more than a decade, the United States recently experienced a troubling increase. Although evidence suggests that the improved economy is contributing to the increase, with more cars on the roadways, states continue to seek out the most effective ways of reducing the number of serious crashes, drawing on a variety of infrastructure and behavior-related countermeasures. Many states are employing new methods for identi-

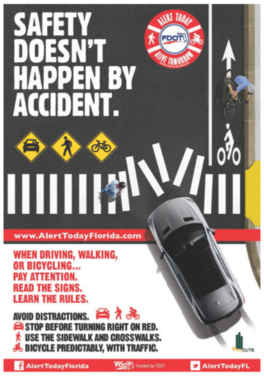
PHOTO: CHRISTOPHER KOEPKE/CALTRANS

A 1.5-mi mudslide on SR-58 near Bishop, California, in October 2015 stranded more than 200 vehicles. Mud flowed over the median barrier onto a railroad right-of-way below; Caltrans employees and emergency contractors cleared and reopened the highway less than one week later.

PHOTO: STEVE FECHT/CHEVROLET

A Chevrolet vehicle demonstrates pedestrian crash-avoidance technology.

Photo: Florida DOT



Florida DOT's "Alert Today, Alive Tomorrow" is part of a comprehensive effort to improve safety for vulnerable road users.

fying solutions with the greatest potential to reduce fatalities and serious injuries.

The Idaho Transportation Department (ITD) uses an innovative, data-driven program for the safety analysis of highway corridors to set priorities for funding safety improvement projects that can greatly reduce fatalities and injuries. Improvements include narrowing lane widths to widen shoulders, signal timing adjusted to weather conditions, and variable speed limits. ITD recently launched a program to reduce impaired driving by influencing community norms. Idaho is exploring options to apply this approach to deter other risky driving behaviors.

Florida DOT received two National Roadway Safety Awards in 2015, one for the innovative Advanced Lighting Measurement System, which addresses the significant number of nighttime crashes, and the other for the Safe Mobility for Life Coalition, which addresses the increase in crashes involving aging drivers.

To improve safety for vulnerable roadway users, Florida has taken a holistic approach to reduce pedestrian and bicycle fatalities and injuries. The initiative includes a comprehensive complete streets policy, increased enforcement, and the "Alert Today, Alive Tomorrow" educational campaign.

Ports and Waterways

With the expanded Panama Canal locks slated to open in early 2016, East and Gulf Coast seaports and state DOTs have been preparing their infrastructure for the prospect of increased capacity demands on freight transportation networks. The expansion project creates an additional lane for larger vessels through the Panama Canal, effectively doubling the waterway's capacity.

Many ports, such as the Port of Miami, have updated their infrastructure to accommodate post-Panamax vessels.

Photo: Port of Miami Crane Management, Inc.

Previously the locks served vessels with a capacity of up to 5,000 twenty-foot equivalent units (TEUs) of cargo. With the expansion, larger vessel classes carrying up to 13,000 TEUs will be able to call on U.S. ports in the Gulf and along the Eastern Seaboard.

Several major U.S. projects are under way at port cities to accommodate the larger vessels and the expected surges in landside cargo. The Port of Miami has invested in new cranes, a direct rail link, a tunnel for highway access, and a harbor dredging project to increase capacity. A project to raise the deck of the Bayonne Bridge in the Port of New York and New Jersey will allow larger ships to access modernized, rail-connected terminal facilities and is due for completion in 2017.

Seaports from Houston to Boston are making investments in terminals and pressing for federal dredging projects to increase the channel dimensions to accommodate larger ships. States have leveraged U.S. DOT's Transportation Investments Generating Economic Recovery—or TIGER—grant program to bolster intermodal highway connections and rail access to seaports.

Rail

Passenger Rail

Increases in state support of medium-distance rail corridors—less than 750 miles long—continued in 2015. The legislation mandating the additional support allows state DOTs to contract for services from vendors besides Amtrak. Indiana DOT exercised that option this year in contracting part of the operation of the Hoosier State service between Indianapolis and Chicago. Other states are looking for alternative providers to improve service and save money.

Construction of the long-awaited California high-speed rail system has begun in Central Valley. The service will connect San Francisco and Los Angeles with a 520-mile system that is to be completed in 2028. This is the first new dedicated high-speed rail system to start construction in the United States; others are planned for Texas and Florida.

Freight Rail

Amid continued concerns about the safety of shipping significant quantities of hazardous fuels by rail, state DOTs concentrated on fostering cooperation between rail carriers and emergency responders. Efforts include sharing shipment data with local authorities to help in planning for potential emergencies.

State DOTs also are participating in programs to reduce pedestrian and trespasser fatalities on rail lines. Collision fatalities at highway–rail grade crossings have declined dramatically in the past two decades, but pedestrian and trespasser fatalities have not. Railroads and states are trying to reduce these accidents through education and enforcement, but the popularity of using digital cell phone cameras on and around railroad tracks is making the effort difficult.

Public Transportation

The effect of connected and automated vehicles on transit use and the role of public transportation in health and wellness are emerging as issues. Many transit professionals believe that automated cars could solve the problem of last-mile travel from station to destination. For example, a commuter could drive to a station, send the car home to park, and summon it later for pickup.

Medical and health organizations are opening up to partnerships with transportation providers to reduce health care costs. Missed screenings, missed appointments, and lack of access to pharmacies and grocery stores can affect wellness, and the medical community is recognizing public transportation's role in health care delivery.

Public transportation agencies are continuing to make capital investments. For instance, Houston, Texas, opened two new light rail transit (LRT) lines in May 2015, linking to the University of Houston and adding significantly to the LRT network. Hartford, Connecticut, opened a new bus rapid transit facility in spring 2015. One rider thanked the management for the improved connectivity, which allowed her to travel to medical appointments.

In November, the TRB Standing Committee on Light Rail Transit cosponsored the 13th International LRT and Streetcar Conference with the American Public Transportation Association. Themes included new vehicle designs, off-wire operation, improved battery storage, and the resurgence of trolleys. On the technology front, new public transportation applications of information technology, social media, and GPS-based information systems are continually gaining introduction.


PHOTO: REAPEREXPRESS, WIKIMEDIA COMMONS

Houston MetroRail's new Purple Line conducts test runs along Rusk Street in the downtown area.

A Time for Discoveries

As these reports show, the challenges and opportunities facing transportation require a multimodal and interdisciplinary approach. Freight movement may be the most obvious area in which multimodal impacts call for multimodal solutions; in passenger movement, the distinctions between private automobile use and public transportation are being blurred.

Information technology companies and health care providers are clearly stakeholders for transportation agencies—and vice versa. New relationships are being developed and new institutional arrangements are emerging. This is a time for discoveries in transportation.

Did You Know?

- Ohio has the second largest number of bridges of any state in the nation, with 42,412 more than 10 feet long, and enough roadways to go around the Equator 10 times—258,773 lane miles.


PHOTO: WIKIMEDIA COMMONS

A barge on the Ohio River.

- The Ohio River carries 63 million tons of annual commodities—more cargo tonnage than the Panama Canal (*see photo, left*).
- The Massachusetts Bay Transportation Authority has launched an online survey that will allow customers to vote for their favorite mass transit apps.[a]
- In 2000, Massachusetts DOT held its first two conferences on pedestrian and bicycle travel. The programs have continued, and attendance has grown from 50 at the first conference to more than 700 at the 2015 Moving Together Conference. The conference brings together leaders in planning, public health, safety, and other fields to discuss biking and walking in Massachusetts.[b]

[a] http://blog.mass.gov/transportation/mbta/mbta-survey-choose-your-favorite-app/.
[b] www.movingtogetherma.org/index.html.

NCHRP REPORT

Productivity

The Connection Between Transportation Performance and the Economy

GLEN WEISBROD

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PHOTO © KADMY/SHUTTERSTOCK.COM

From the warehouse to shipping routes, efficient infrastructure and transportation systems can enhance productivity.

Productivity is not a new buzzword but is now in vogue. Productivity is important for transportation operators and is a primary driver of regional and national economic development. An increasing number of state departments of transportation (DOTs) want to consider productivity impacts in prioritizing programs and projects.

Productivity can be defined as the ratio of output produced per unit of input. For instance, freight operators consider fleet productivity in terms of ton-miles moved per truck, or daily deliveries made per driver. Transit operators consider passenger miles served per vehicle. Transportation systems that are faster, safer, and more reliable—and pickup and delivery systems that are more efficient—can increase productivity ratios. These systems can make better use of available resources and spur greater competitiveness and profitability for transportation service operators.

The same concepts apply to the nation's economy, for which productivity can mean more output per worker or more value added per dollar of business investment. By expanding access to labor markets, supplier markets, and customer markets, transportation infrastructure enables greater productivity for producers of goods and services, as well as for transportation providers.

Transportation's Effects

National Cooperative Highway Research Program (NCHRP) Report 786, *Assessing Productivity Impacts of Transportation Investments,* examines the sources of productivity and notes that transportation can have several effects that include the following (*1*):

- Increasing the scale of customer markets that can be served from a single location, enabling fixed costs to be spread over a larger revenue base;

Photo: Allen Skyy, Flickr

Crowds of commuters and travelers pass through Penn Station in New York daily. Transportation expands access to labor markets, specialized materials and services, and more.

◆ Expanding labor markets and the ability of businesses to access workers with diverse and specialized skills, enabling a better matching of worker skills to business needs;

◆ Expanding access to suppliers of highly specialized input materials and services;

◆ Enabling new and more efficient manufacturing, distribution, and business operation technologies; and

◆ Enabling clusters of businesses that can gain from the shared use of common resources.

Supply Chain Clusters

Supply chain technology has advanced with improvements in transportation. Fast and reliable truck freight movement via Interstate highways has allowed producers in a range of industries to adopt just-in-time delivery and lean manufacturing processes, which increase productivity by reducing or eliminating the costly warehousing of parts and materials.

This has led to the development of supply chain clusters along highway corridors. For example, the automotive cluster in the Southern United States brings together car assembly plants and parts suppliers along 150-mile lengths of four highway corridors: I-65, I-75, I-81, and I-85.

The geographic span of these clusters reflects the area from which a same-day, round-trip truck pickup and delivery can be made along uncongested highway routes. The dispersion of assembly plants and suppliers within these areas reflects the cost advantages of spreading out in more rural areas with reduced costs for land and labor.

Improved highway access also has enabled large-scale, centralized logistics and distribution technologies. The completion of I-81, for example, allowed long-distance, north–south truck movements to avoid the congested I-95 corridor. That, in turn, enabled the emergence of centralized warehouses in Eastern Pennsylvania to serve the Greater New York City region, as well as other nearby metropolitan areas.

Technology-Led Industries

Effective road and transit systems for passenger transportation in urban areas also have increased labor productivity by expanding the scale of labor markets. This particularly benefits the research and development (R&D), professional services, and high-tech industries, which seek larger labor markets with a greater choice of workers who have diverse and specialized skill sets.

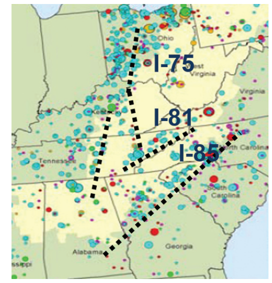
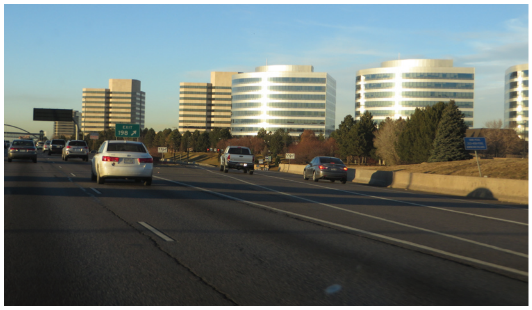


Image: EDR Group/Appalachian Regional Commission, Sources of Regional Growth in Non-Metropolitan Appalachia

Auto supply chain corridors in the Southeastern United States.

Photo: Virginia DOT

Running from New York to Tennessee, I-81 provides an alternative north–south freight route to I-95.



The Denver Tech Center along the I-25 corridor in Colorado is home to several major businesses and corporations.

Photo: Ken Lund, Flickr

High-tech clusters associated with computer equipment, for instance, have tended to develop in metropolitan areas with a leading R&D university and a relatively large, educated labor market accessible by a highway. Several notable computer technology clusters started as highway-oriented developments—such as the 128 Technology Corridor along Route 128–I-95 in Massachusetts, Silicon Valley along US-101 in California, and Research Triangle Park along NC-147 at I-40 in North Carolina. More recent centers, such as the Denver Tech Center along I-25 in Colorado and the I-270 Corridor in Maryland, have continued the pattern.

Transit's Roles

A recent American Public Transportation Association study of the relationship between transportation and high-tech clusters found two emerging trends that involve transit services (2). One is the operation of bus services sponsored by private industry, supplementing public transit plans for services to relieve congestion in the highway-oriented clusters of technology businesses.

The other trend is the emergence of a new generation of inner-city technology clusters for creative software, social media, and biotechnology R&D companies. The inner-city areas offer transit service, which appeals to many young technology workers who prefer nonautomobile environments.

Kendall Square in Cambridge, Massachusetts, is an emerging transit-friendly, urban technology cluster.

Photo: EDR Group/APTA, *The Role of Transit in Support of High-Growth Business Clusters*

Kendall Square in Cambridge, Massachusetts; Midtown–SoMa (or South of Market) in San Francisco, California; and Midtown South in New York City are examples of emerging urban technology clusters. In these transit-friendly environments, software and Internet media firms can maximize their productivity by expanding their scale of operation, their access to qualified workers, and their access to R&D centers.

Intermodal Connectivity

Intermodal connectivity is another source of increased productivity. Rail, air, and marine terminals provide ways for businesses to reach beyond the regional supplier and customer markets served by road-based modes to access national and international markets. This can encourage operations at a larger scale, reducing the unit costs of production and increasing the efficiency of centralized distribution systems.

At the regional level, new logistics parks have emerged across the country near air and rail intermodal centers. At the national level, a recent project report from the Airport Cooperative Research Program documented the contributions of air system connectivity to national economic growth in North America (*3*).

Multiple modal terminal facilities also can be linked for greater productivity. In British Columbia, Canada, for example, the multimodal Greater Vancouver Gateway Transportation Plan has linked road, rail, air, and marine facilities. According to Bob Wilds, Director of the Greater Vancouver Gateway Council, the plan "brought together industry and public agencies [that] understood the need to maintain the region's competitiveness as a global gateway."

Slowdowns and Bottlenecks

Infrastructure that once enabled productivity growth, however, may not automatically maintain the same levels of performance over time. Aging facilities and increasing congestion can undermine transportation performance with slowdowns and bottleneck delays. These problems can occur on roads, transit stops, rail terminals, airports, and seaports and apply equally to freight and passenger transportation services. Slowdowns and bottleneck delays reduce the productivity of commuters, transportation workers, vehicles, and equipment.

The effects of slowdowns and bottlenecks can be more extensive. Besides adding cost for transportation service operators and inconvenience for individual travelers, delays also can lead to greater impacts on the economy. For instance, reliability drops as congestion grows, so that freight shippers and receivers incur more overtime costs as workers wait at loading docks for delayed pickups and deliveries.

Photo: WMATA

A busy Metro platform in downtown Washington, D.C. Efficient transit flows prevent highway bottlenecks, which can reduce the effective size of the labor market for businesses, as well as the range of suppliers and customers.

When delivery reliability falls, manufacturers increase warehouse stocks for parts and materials to avoid shortages, shutdowns, and added operating costs. Wholesalers and retailers respond in a similar manner to avoid a loss of sales because of delays in product arrivals. To allow more time for drivers to reach destinations, trucking companies may pad the delivery schedules, moving the pickup times earlier, hiring more drivers, and acquiring more vehicles to make the same number of deliveries in a day.

Slowdowns and bottlenecks also can reduce the effective size of the labor markets from which businesses can draw workers and can reduce the range of suppliers and customers for businesses. When this happens, some businesses move from centralized distribution facilities to establish satellite centers. Consequently, the unit costs of products go up, and the competitiveness of operating in these locations goes down, with negative effects on jobs and pay rates.

Transportation Agencies' Role

Recognition is growing that transportation facilities can have impacts on accessibility, reliability, and intermodal connectivity, and that these lead to economic impacts far greater than the costs to vehicle operators. Some transportation facilities may play a more critical role than others in supporting regional economic productivity and competitiveness.

A growing number of state DOTs and some metropolitan planning organizations now are adopting prioritization criteria and planning methods that recognize productivity effects. Some have adopted rating systems that give weight to factors supporting economic productivity—such as enhancing truck routes, intermodal facilities, access to global gateways, or connectivity to markets and key economic corridors. Others have incorporated economic impact models such as REMI or TREDIS that assess the productivity impacts of projects.

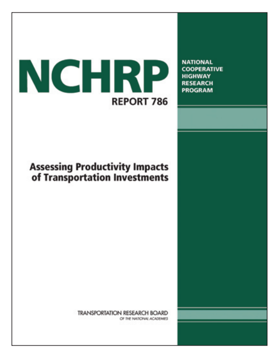
NCHRP Report 786 describes a variety of tools that agencies can use to calculate productivity impacts directly. Better and more effective transportation investment decisions can be made when the wider impacts are considered; the economy—including businesses and consumers—is likely to be better off as a consequence.

Photo: Wikimedia Commons

The new Port Mann Bridge in British Columbia, Canada, was part of the Greater Vancouver Gateway Transportation Plan.

References

1. *NCHRP Report 786: Assessing Productivity Impacts of Transportation Investments*. Transportation Research Board of the National Academies, Washington, D.C., 2014. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_786.pdf.
2. *The Role of Transit in Support of High Growth Business Clusters*. American Public Transportation Association, 2014. https://www.apta.com/resources/reportsandpublications/Documents/TransitHighGrowthClustersUS-Final2013-1124.pdf.
3. *ACRP Report 132: The Role of U.S. Airports in the National Economy*. Transportation Research Board of the National Academies, Washington, D.C., 2015. http://onlinepubs.trb.org/Onlinepubs/acrp/acrp_rpt_132.pdf.



NCHRP Report 786, *Assessing Productivity Impacts of Transportation Investments*, is available from the TRB online bookstore, https://www.mytrb.org/Store/Product.aspx?ID=7322; to view the book online, go to http://www.trb.org/Publications/Blurbs/171356.aspx.

NCHRP SYNTHESIS REPORT

Responses to Extreme Weather Impacts

Practices in the U.S. Transportation Sector

CHRIS BAGLIN

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Before, during, and after an extreme weather event, a state department of transportation (DOT) fulfills many duties and manages resources and activities that vary in scope and scale. Key actions may include the following:

- Inspecting bridges, roads, railways, and airfields;
- Establishing detours;
- Clearing debris from highways and runways;
- Assisting with traffic control and flow; and
- Working with local authorities to rebuild infrastructure.

PHOTO: MICHAEL RIEGER/FEDERAL EMERGENCY MANAGEMENT AGENCY

Colorado DOT road crews construct a temporary culvert to ensure residential access in preparation for a severe weather event.

National Cooperative Highway Research Program (NCHRP) Synthesis 454, *Response to Extreme Weather Impacts on Transportation Systems*, identifies lessons learned from eight state-level responses to extreme weather events that affected transportation operations and infrastructure. The report examines related practices and outlines ways to share knowledge and to collect and analyze data for decision support.

The synthesis reviews the impacts of extreme weather and state DOT actions involving operations, maintenance, design, construction, planning, com-

PHOTO: RICHARD SCOTT/U.S. ARMY CORPS OF ENGINEERS NASHVILLE DISTRICT

A road sign at Chickamauga Lock in Chattanooga, Tennessee, was damaged when a tornado touched down in October 2010.

munications, interagency coordination, and data and knowledge management. The report lists more than 200 actions that states can use or adapt to circumstances.

The cost impacts of extreme weather events are a major concern; the report presents key practices to mitigate costs. These include early attention to Federal Highway Administration (FHWA) and Federal Emergency Management Administration (FEMA) requirements, reliance on an incident command system during the response and recovery, and leveraging data and knowledge management.

Addressing Costs

In the past decade, flooding, wildfires, extreme heat, unusual precipitation, and other weather events have temporarily incapacitated several transportation systems. The eight extreme weather events described in NCHRP Synthesis 454 had statewide financial impacts and overwhelmed the budgets of small towns.

◆ **Intense rains and floods in Washington State, 2007.** Snowmelt, rains, and a windstorm led to widespread flooding; 10 feet of water covered a segment of the main Interstate between Portland and Seattle. The Interstate shutdown lasted four days and resulted in $47 million in lost economic output. Damage to transportation infrastructure statewide cost $23 million for state and Interstate highways and $39 million for city and county roads.

◆ **Intense rains, floods, and tornadoes in Tennessee, 2010.** Two days of intense rain caused a once-in-a-thousand-years flood in Central and Western Tennessee, submerging an Interstate and killing several people. The cost of the transportation impacts was $45 million.

◆ **River flooding in Iowa, 2011.** To avoid risks to population centers, authorities released spring melt and rainwater that had collected at flood control dams into a river system within rural areas. The release caused more than $50 million in damage to bridges and roads and inundated an Interstate for three months.

◆ **Tropical Storm Irene in Vermont, 2011.** When Tropical Storm Irene reached Vermont, the ground was already saturated with rain, leading to record floods. The two to three days of flash floods damaged 500 miles of highway and 200 bridges and stranded 11 communities. Recovery of the transportation system is expected to cost between $175 and $200 million.

◆ **Drought and wildfires in Texas, 2011.** The most severe drought on record led to pavement damage and more than 30,000 wildfires. Pavement damage under high heat conditions totaled $26 million, and the wildfire control efforts cost $5 million.

◆ **Severe snowstorms in Alaska, 2011–2012.** An unusual cycle of snow and rain led to 18 feet of snow in the coastal town of Cordova, Alaska. Plowing costs ran nearly 25 times the town's annual snow-removal budget.

◆ **Prolonged heat event in Wisconsin, 2012.** As temperatures soared in summer 2012, heat buckling on roads occurred 30 to 40 times a day. Repairs totaled $800,000 to $1 million.

◆ **Hurricane Sandy in New Jersey, 2012.** The storm passed through the state in less than one day but drove ocean water far inland, killing many people. The destruction of roads, bridges, and other transportation infrastructure totaled $2.9 billion.

PHOTO: PATSY LYNCH/FEMA

A worker installs a replacement highway guard rail that was destroyed by wildfires in Texas in 2011.

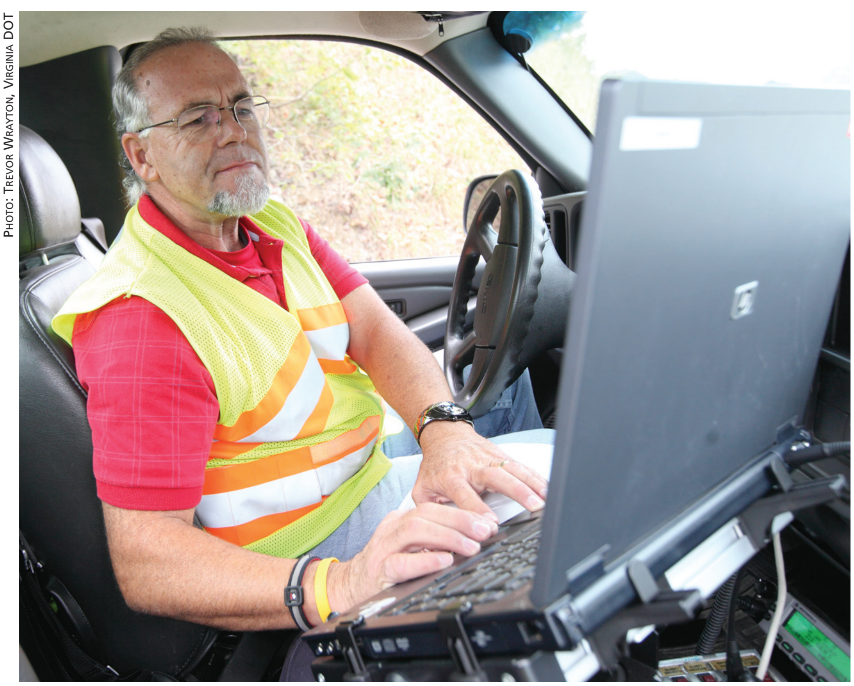


PHOTO: TREVOR WRAYTON, VIRGINIA DOT

A Virginia DOT regional incident management coordinator checks in from the field. Many DOTs have established incident command systems to deal with extreme weather events.

Flooding on Interstate 5, Chehalis, Washington, in 2007.

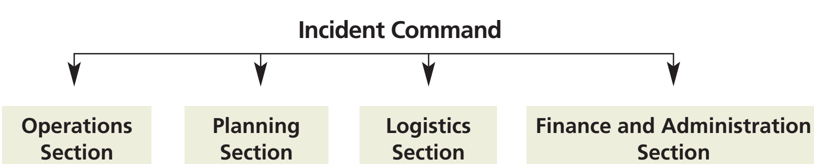
PHOTO: WASHINGTON STATE DOT

Securing Reimbursement

Governments, businesses, charities, and the public share in the impacts and in the associated costs from extreme weather events. Two major federal programs reimburse states for documented damage: FHWA's Emergency Relief and FEMA's Public Assistance. States therefore are establishing effective processes for obtaining reimbursement, including staff training and in-house streamlining of applications. Examples include the following:

- ◆ New Jersey and Alaska developed staff training materials in preparation for the effects of severe weather events.
- ◆ After a major flood in 2008 and before the 2011 flood, Iowa DOT trained its staff in federal reimbursement procedures.
- ◆ During the state's post-Irene recovery, the Vermont Agency of Transportation requested that a state attorney focus on reimbursement issues and hired technical experts to assist communities in applying for federal programs.
- ◆ Texas DOT has established web-based platforms for collaborating on the paperwork required by FHWA and FEMA.
- ◆ Iowa DOT has developed an "electronic DDIR" system named after an FHWA form; the in-house system saved many hours of staff time before, during, and after the 2011 flood.

FIGURE 1 Essential components of an incident command system.



Incident Command System

Extreme weather events require state DOT staff to work with offices and agencies with which they may not have routine interactions. An incident command system (ICS) has become a standard method for coordinating resources and establishing interagency controls in an emergency response. An ICS effectively avoids unclear chains of command, poor communication—for example, because of conflicting technologies or unfamiliar terminologies—and a lack of systematic planning.

An ICS provides responders with a shared organizational structure without jurisdictional boundaries; personnel assigned to an ICS report to an ICS supervisor, not to their day-to-day supervisor. The ICS fills the core management function with support from four areas: operations, planning, logistics, and finance and administration (see Figure 1, below left).

An incident commander is stationed at the scene—for example, near the site of a flooded highway segment—and establishes the incident objectives, strategies, and priorities. The incident commander oversees response to the incident or event, including the incident plan.

The impacts of extreme weather events may have few precedents in scope or severity; the ICS approach reduces activities to the four easily understood functions, without regard to offices or personnel titles. Table 1 (below) lists practices that have emerged from DOTs adopting ICS to manage extreme weather events.

Data and Knowledge Management

NCHRP Synthesis 454 identifies data and knowledge management as a distinct function in state DOT responses to extreme weather. The collection of and access to relevant data at the right scale is important for the efficient and cost-effective use of resources.

For example, during Vermont's response to Tropical Storm Irene, routine bridge inspection information was not readily available to contractors before site visits. In other cases, useful information collected by agency staff during an event was not always saved for future reference and use.

Practical Approaches

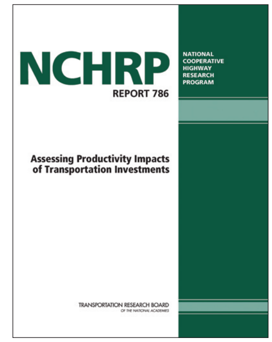
Knowledge management tools and concepts can help state DOTs preserve, find, and reuse information in addressing a similar event. Implementing knowledge management for an extreme weather event is challenging, but transportation agencies have successfully used both high- and low-tech approaches. Table 2 (page 26) lists knowledge management practices that state DOTs have found useful.

According to NCHRP Synthesis 454, investing in the data sets and data collection technologies—especially geospatial data—in support of preparedness for extreme weather and response offers economic benefits. Nevertheless, extreme weather events are so-called because they are rare; as a result, collection of the data most suitable for decision support may not be routine or may not be fully understood or defined.

NCHRP Synthesis 454 outlines the data practices relevant to extreme weather events. Wisconsin DOT, for example, collected a new data set of all the 2012 heat-buckling sites, including the age and depth of the pavements and the type and orientation of the joints, to consider the next steps and to support the pilot of a basic tool to forecast heat buckling.

Establishing a Framework

A data collection framework is critical. Key steps include setting the specific objectives for the data collection and agreeing on data analysis methods and tools. Information governance is important for databases that contain multiple kinds of content, such as lessons learned, observed practices, and key decisions.

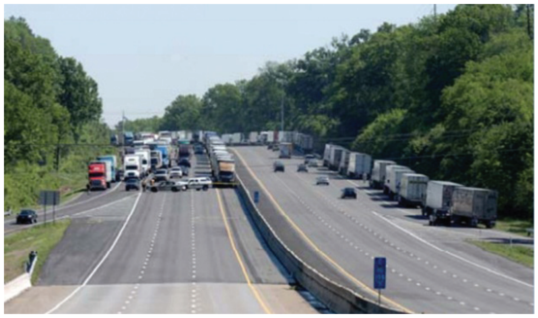


NCHRP Synthesis 454, *Response to Extreme Weather Impacts on Transportation Systems*, is available from the TRB online bookstore, https://www.mytrb.org/Store/Product.aspx?ID=7185; to view the book online, go to www.trb.org/Main/Blurbs/170765.aspx.

TABLE 1 Transportation Agency Practices: Incident Command Systems

Timing in Relation to Extreme Weather Event	Activity
Before	Preassign roles aligned with the ICS structure.
Before	Know the experience of staff in-depth when assigning roles.
Before	Develop training on effective use of the ICS, through basic training at all levels.
Before	Familiarize staff with mobile information technology and other equipment used in the field.
Before	Prepare standard operating procedures for ICS.
Before	Prepare checklists and pocket manuals for the ICS section leaders with key information on each role.
Before	Practice deployment of the ICS in response to minor events.
Before	Provide training in technical details of a likely event, such as riverine flooding.
Before	Address administration of contracts under the ICS—have contractors register and standardize the process for paying contractors.
Before and during	Design the workflow under the ICS, including a process to track equipment on loan to contractors and materials supplied by contractors.
Before and during	Develop processes for communications under the ICS and ensure that proper equipment will be on hand—such as portable cell towers; inspect radios and cellphones; and develop alternatives in case of outages of power or of cell reception.
During	Create a short list of transportation mission-oriented objectives to help the agency and others prioritize their work and avoid diverting resources to other needs.
During and after	Ensure that the ICS demobilization process is defined, communicated, and implemented—for example, have the incident command staff review and discuss experiences before returning to their assignments, or plan brown-bag lunches for staff to discuss the event.

Flash floods cause a major backup on I-40 in Tennessee in 2012.



Data sets also may serve multiple purposes—for example, a review of extreme weather events in a region also can support climate change planning. Similarly, the data sets may provide insight into vulnerabilities—for example, data on margins of safety and structural failures also can inform a climate risk analysis.

A strategy to classify types of content and to categorize topics is key to the creation of a successful database. Data in a fixed or tabular form, as well as unstructured data—such as the text of a report—can be captured with a variety of software, including open-source tools. State DOTs then can use data analytics—including simple tools available for most applications—for decision support.

Responses and Resiliency

State DOT responses to the impacts of extreme weather events continue well beyond immediate management. Each state contacted for NCHRP Synthesis 454 is conducting reviews and assessments; seeking out new sources of data, information, and expertise; and adapting personnel skill sets, programs, and processes for successful responses to extreme weather risks.

TABLE 2 Transportation Agency Knowledge Management Practices Related to Extreme Weather Events

Timing in Relation to Extreme Weather Event	Activity
Before	Develop a way to locate and contact agency experts easily.
Before	Develop succession planning to maintain continuity and a knowledge base.
Before	Collect and report on emerging maintenance practices related to more severe and unpredictable weather.
During	In the absence of preassigned staff, leverage the knowledge base of personnel with experience from a previous disaster.
Before, during, and after	Ensure information sharing through SharePoint or other collaboration software and conference calls.
Before, during, and after	Identify the data sets (e.g., bridge information or plan drawings) that benefit decision making; identify ways to improve data collection and access to the data.
Before, during, and after	Capture images of locations or of the critical infrastructure likely to be affected.
After	Develop an After Action Report that records effective practices, lessons learned, and new approaches.
After	Include in any After Action Report contributions from all regions, not only from those affected.
After	Conduct postevent workshops and other activities to share and record knowledge and lessons learned.
After	Provide a forum for the public to tell stories about transportation issues from the event—for example, through a web-based personal account project.
After	Store applications for financial assistance in paper or scanned form, with a defined retention schedule; make projects searchable by event code.
After	Use in-house staff resources to collect and analyze data on extreme weather event impacts to support decision making.
After	Use in-house and academic resources to research information on key issues relating to impacts from extreme weather events of concern—such as flooding—and develop a synthesis of the body of knowledge.
After	Distinguish emergency management processes from day-to-day processes in postevent assessments of the state DOT response to the event.
After	Provide a structured forum and process for developing lessons learned from extreme weather events to capture practices and ideas for improvement; if necessary, hire an external facilitator.

NCHRP REPORT

Evolutions in the Geometric Design of Highways and Streets

Integrating Performance-Based Analysis

BRIAN L. RAY

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Highway and street geometric design has evolved significantly in the past century, and the movement toward performance-based approaches is reaching practitioners. Transportation design has incorporated performance-based approaches for many years, primarily in relation to materials such as pavement or steel. Results from projects sponsored by the National Cooperative Highway Research Program (NCHRP) are bringing these approaches to highway and street geometric design.

Performance-based analysis allows professionals to consider and recommend solutions that are more effective and adaptable to the context of a project than those based on compliance with a nominal dimensional value from a design standard or specification. Geometric design solutions, for example, can be developed, assessed, and advanced based on their support of the desired outcomes for the project. This can lead to customized solutions and can help guide project decision making. Advances in performance-based methodologies support context-sensitive and practical solutions to meet project needs and to maximize investments.

Sources of Standards

Early roadway design focused on the quality of travel and on adapting to weather. Early in the history of automobiles, low traffic volumes and relatively low speeds made the quality of travel and year-round use the priorities. As traffic volume grew, and motorized vehicles became a dominant transportation mode between 1920 and 1940, vehicle designs advanced,

Photo: Pimpinellus, Wikimedia Commons

The eastern span of the San Francisco–Oakland Bay Bridge was replaced in 2013 by a self-anchored suspension bridge that can withstand the largest earthquake expected in a 1,500-year period. Agencies are incorporating more performance-based approaches such as seismic design into highway infrastructure.

The "modern highway" of the early 20th century adapted quickly to automobile use; most transportation policies focused on design uniformity across jurisdictions.

PHOTO: NEW YORK PUBLIC LIBRARY

speeds increased, and highway and street design practices evolved to react and to adapt.

Transportation policies emphasized design uniformity and consistency on similar roadway types between the states. This allowed consistent construction practices, materials, and a uniform experience for roadway users. The design of facilities was uniform and consistent, regardless of jurisdictions, but the standards did not necessarily imply or consider a level of safety performance.

Standards evolved beyond consistency in dimensions and began to signify quality of performance in operation or safety. In the late 1960s and 1970s, groups such as the Highway Research Board—predecessor to the Transportation Research Board—moved beyond materials testing to assess user needs and human factors and to establish design values focused on operational outcomes and safety performance. Eventually, the Federal Highway Administration (FHWA) established 13 roadway design criteria to provide operational uniformity and design consistency, with the intent to attain desired safety performance.

Need for Flexibility

The evolution in roadway design has produced high-quality roadways serving a range of users and vehicle types. Applied research results have helped to quantify design criteria based on observed operations and safety performance. Nevertheless, despite advances in experience and software, the highway and street design process has remained centered on nominal design values or standards. Yet designers need to apply engineering judgment in their design activities, as well as the flexibility inherent in published design guidance.

Roadway agencies have limited financial resources and often develop projects within physical constraints—such as a limited right-of-way in an urban area or an area with specific environmental sensitivities. Constructing roadways categorically to meet design standards, therefore, is not always fiscally possible or reasonable.

Through initiatives such as context-sensitive solutions and performance-based practical design,

NCHRP Publishes Performance-Based Framework for Roadway Design

NCHRP Report 785, *Performance-Based Analysis of Geometric Design of Highways and Streets*, documents a process framework for conducting performance-based analyses of highway geometric design. The methodology is based on understanding intended project outcomes and then considering and selecting the geometric design elements or features that best meet a project's unique context.

The performance-based analysis framework in NCHRP Report 785 helps practitioners develop solutions that

- Facilitate walking, biking, and transit, in addition to serving passenger cars and goods movement;

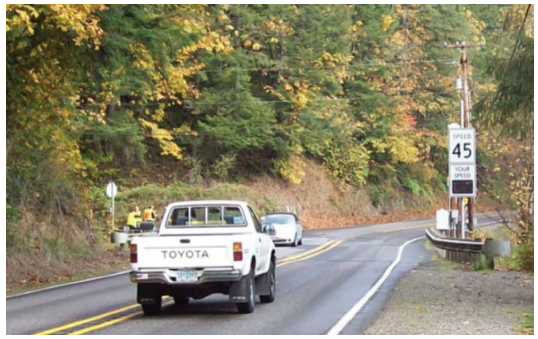
Clear delineation of curves is another low-cost safety improvement.

professionals are able to apply flexible design approaches to construct roadways adapted to the unique needs of each contextual environment. New approaches were needed to support contemporary planning and design decision making. A performance-based approach could support project documentation needs and inform and guide project decision making.

Performance-Based Design

Other technical areas have adopted performance-based approaches since the 1970s. For example, fire safety design shifted from a code-compliance approach to a systems approach—the focus was not on how thick a wall must be but on how much protection the wall could provide and for how long before burning through.

Similar changes in the evolution of seismic design led to changes in engineering practice and research in structural engineering. Engineers recognized that code-based strength and ductility requirements for designing new buildings were not always suitable for evaluating and upgrading existing structures. Applying performance-based engineering methods in seismic structural design meant that a building must withstand a seismic event and minimize the loss of lives even if the structure becomes an economic loss. With this emphasis on making rational



Example low-cost safety treatments along a crash-prone stretch of roadway may include guardrails and speed feedback signs.

business- and safety-related decisions, seismic engineering moved toward predictive methods for assessing potential seismic performance.

Varying from Standards

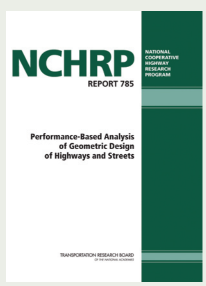
Designers often must consider geometric solutions with dimensions that differ from published values. Historically, engineers have considered design standards or other published nominal values as the measures for comparing and assessing design choices. With this approach, comparing design dimensions to nominally accepted values often becomes a surrogate for relative safety performance.

These decision-making approaches, however, cannot be used to document or support design choices that require variances or to evaluate design exceptions. In some cases, a variant design choice

- ◆ Reduce crash frequency and severity;
- ◆ Enhance a community's livability;
- ◆ Support economic development; and
- ◆ Support other context-sensitive and practical design considerations and approaches.

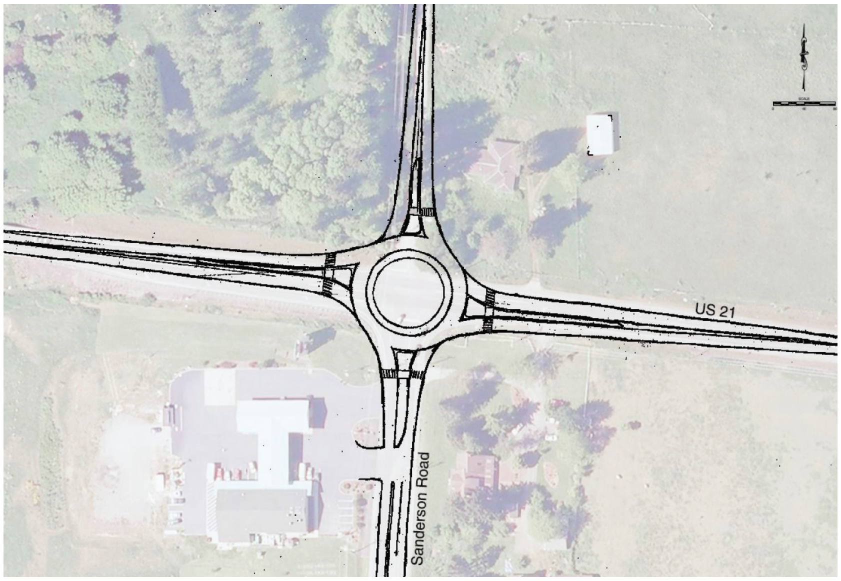
The performance-based approach supports project documentation needs and can inform and guide project decision making while supporting risk management. As NCHRP and AASHTO explore changes and approaches to improve the processes of highway geometric design, performance-based analysis will play a central role.

A performance-based process framework considers the performance factors for particular geometric design elements. Designers can consider and select design values or features based on the impact that the resulting geometric design performance has on the intended project outcomes. NCHRP Report 785 documents ways to consider and apply published design criteria for roadways and to assess a design's performance in terms of accessibility, mobility, quality of service, reliability, and safety.



NCHRP Report 785, *Performance-Based Analysis of Geometric Design of Highways and Streets*, is available from the TRB online bookstore, https://www.mytrb.org/Store/Product.aspx?ID=7394; to view the book online, go to http://www.trb.org/Main/ Blurbs/171431.aspx.

Transportation agencies have limited resources with many competing demands. Performance-based analysis provides designers with new methods and principles for customizing design recommendations from a range of solutions appropriate to any design context or environment. The NCHRP Report 785 framework supports a range of initiatives, including context-sensitive design and solutions, performance-based practical design, flexibility in design, complete streets, and multimodal design. This framework represents a fundamental, positive advance in the evolution of highway and street geometric design.



A roundabout alternative for an intersection project, designed to prevent turning and angle crashes.

may have been accepted depending on its closeness to a published standard or value, assuming acceptable safety risk.

Performance-based analysis is a natural step forward from historical, nominal dimension-based approaches to highway and street geometric design and project development. Practitioners can make informed decisions about the performance trade-offs often encountered in fiscally and physically constrained environments.

The approach is applicable when upgrading or refurbishing a facility and can inform decision making when evaluating and implementing new facilities. NCHRP Report 785, *Performance-Based Analysis of Geometric Design of Highways and Streets* (see sidebar, page 28), advances the principles and methods of roadway design, allowing users to augment standards as the measure of an appropriate design.

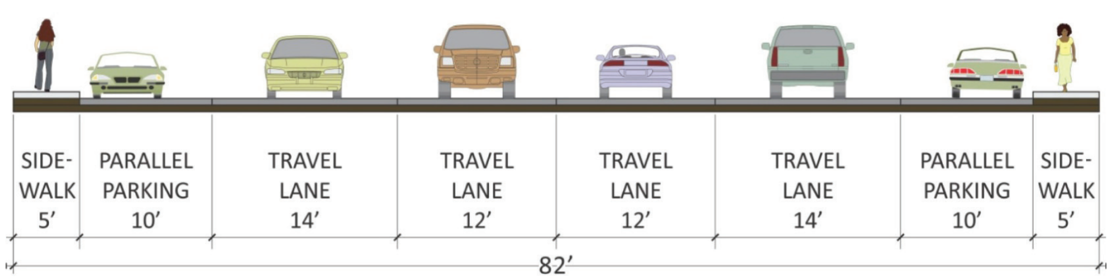
Performance-Based Analysis

Geometric design always has considered a project's context in establishing three-dimensional values for roadway segments and intersections. Engineering judgment and experience, combined with geometric policies—such those established by the American Association of State Highway and Transportation Officials (AASHTO)—have provided a sound basis for effective designs.

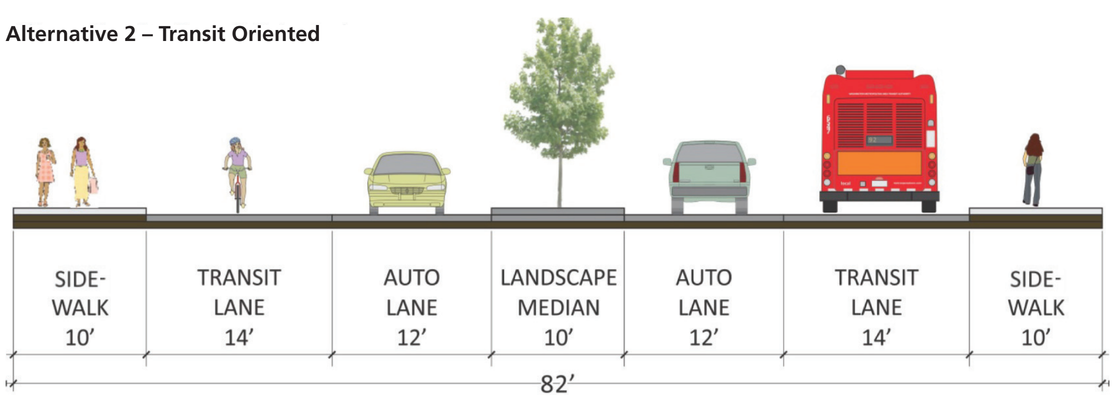
Adapting geometrics to specific conditions has remained a concern, because of the perceived risk of deviating from published values. But attaining full standards can increase project costs and generate other issues; FHWA therefore has emphasized flexibility in highway design. AASHTO has supported design flexibility and a context-sensitive approach but recognizes that more substantial methods for quantitatively assessing alternative options for geometric design were needed.

Practical design focuses on applying design

Alternative 1 – Existing Conditions



Alternative 2 – Transit Oriented



Alternative designs for a roadway alignment (*top*) include a transit-oriented design (*bottom*).

(*continued*)

elements to meet identified project needs in the best way at the greatest value. This differs from a focus on how far a design varies from a published nominal value. Many agencies struggling to manage and operate roadway facilities with limited funding have embraced the concept of flexible geometric design solutions to meet documented project needs—often identified through public and stakeholder outreach—and intended project outcomes.

Practical design and solutions became the means of meeting project needs in a cost-effective and value-oriented way. FHWA is exploring performance-based practical design approaches to quantify and support project design decisions.

Diverse Users and Contexts

Whether an approach is practical design, flexible design, or "3R"—resurfacing, restoration, and rehabilitation—the intent is the same. New initiatives recognize that design choices must consider various users and must balance needs and performance for each unique context.

Complete streets legislation at the state level recognizes the importance of serving each type of road user. Whether a facility serves freight, transit, or pedestrian and bicycle needs, designers must allocate three-dimensional design values to meet a variety of user needs.

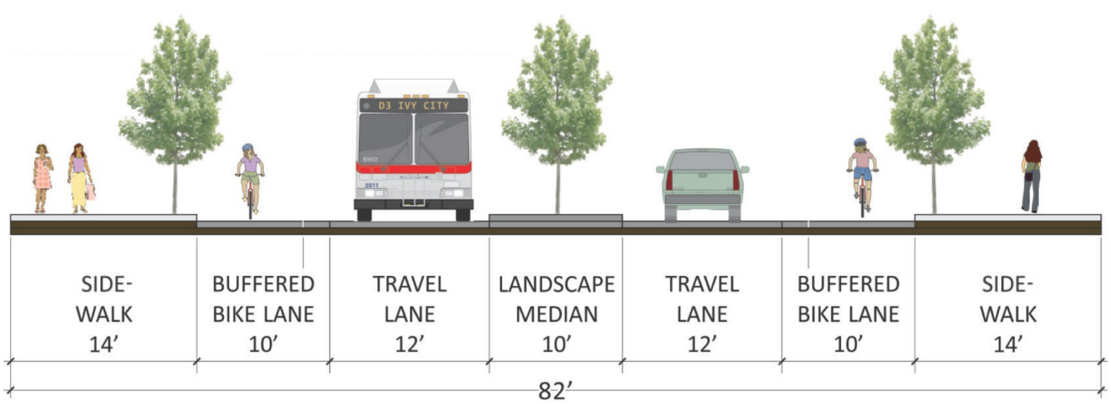
PHOTO: SEATTLE DOT

Bicycle lanes, refuge islands, and on-street parking accommodate all users of this Seattle, Washington, street.

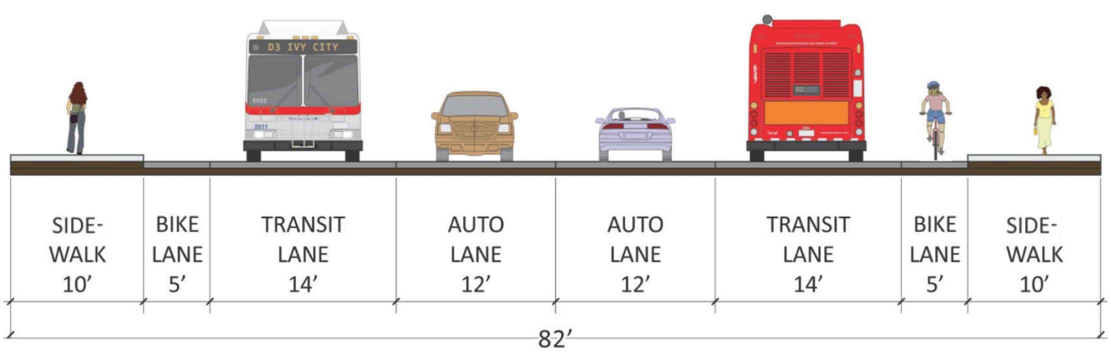
Increasingly, nominal-based, published dimensions have proved inadequate for assessing and recommending design elements and values. Performance-based analysis is a more comprehensive means of supporting geometric design decisions.

Street and highway geometric design is an evolving practice. The emerging methods, philosophies, and approaches integrating performance-based analysis to guide and inform project decisions will lead to community supported, practical, and cost-effective geometric design solutions. Performance-based approaches, integrated into many areas of engineering practice, are becoming available to designers for highway and street design and construction.

Alternative 3 – Bicycle and Pedestrian Oriented



Alternative 4 – Hybrid of Transit, Pedestrian, and Bicycle



Alternative designs for a roadway alignment (*continued*): a bicycle- and pedestrian-oriented design (*top*), and a hybrid design (*bottom*).

Rail Corridor Capacity

Unraveling the Mysteries of Shared Corridor Management

DAVID P. SIMPSON, ALAN BING, AND JUSTIN FOX

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What is rail corridor capacity? Why is it difficult to measure? Why does it so often cause proposals for shared use to founder? How can public- and private-sector stakeholders work together to build a transparent, objective, and publicly defensible foundation for shared rail investment and high levels of rail service integrity?

National Cooperative Highway Research Program (NCHRP) Report 773, *Capacity Modeling Guidebook for Shared-Use Passenger and Freight Rail Operations*, offers straightforward, user-friendly guidance to educate transportation planners, public officials, rail service operators, and corridor owners about a critical element in successful corridor partnerships.

The guidebook assists state department of transportation (DOT) officials in understanding the issues when rail corridor owners demand new public investment as a condition for providing access for passenger service operators. Sponsored by the Standing Committee on Rail Transportation of the American Association of State Highway and Transportation Officials, NCHRP Report 773 addresses the key role of states in sponsoring and funding new passenger rail operations. The report builds on the more general practical information in NCHRP Report 657, *Guidebook for Implementing Passenger Rail Service on Shared Passenger and Freight Corridors,* published in 2010.

Structured Approach

The goal of NCHRP Report 773 is to broaden understanding of rail capacity, so that corridor partners can address service proposals and related infrastructure needs in an objective manner. Public agency sponsors of passenger operations are frequently frus-

PHOTO: LEE CANNON, FLICKR

The Northeast Corridor is the busiest passenger rail corridor in the country and moves approximately 350,000 carloads of freight per year.

trated by the challenges of developing an operation that must simultaneously address public benefits and legitimate private-sector concerns. A transparent modeling structure to assess rail capacity can confirm the design and scale of proposed changes and can inform decision makers who may be unfamiliar with the complexity of the rail environment.

Unlike highways, most rail corridors are privately owned. Public sponsors, including U.S. DOT, want assurances that public benefits are realized from investments of taxpayer funds. Rail capacity modeling is a tool for determining the appropriate shares of investment by each of the corridor partners. Rail capacity modeling also may establish the baseline for ongoing contributions for upkeep and maintenance.

Work Program

The guidebook assembles information from three main sources:

- ◆ Stakeholder approaches to analyzing line capacity for new or expanded passenger rail services;
- ◆ Descriptions of the analytical approaches that rail planners use for capacity analysis, including manual methods and computer-based operations simulations; and
- ◆ Four case studies demonstrating the application of these methodologies to identify capacity constraints and the improvements that could facilitate fluid freight and passenger train operations.

Stakeholder Outreach

Researchers interviewed representatives from state DOTs, Amtrak, the Federal Railroad Administration (FRA), each of the four largest U.S. Class I railroads that host passenger services, and several large commuter operators to gain perspectives on what is working, what is not, and what needs to be addressed for effective joint capacity planning on the U.S. rail network. Following are the key themes that emerged from each stakeholder group.

Freight Carriers

Freight carriers recommended that passenger rail sponsors take the long-term view of service goals and capacity needs—a minimum 20 years—instead of focusing on the agreements and the start-up investments to support the earliest phase of service. Some railroad representatives also suggested that long-term infrastructure planning would contribute to corridor preservation and to establishing dedicated passenger alignments in urban regions.

Freight carriers also noted the limitations of formal capacity and operations modeling tools in

Photo: Paul Sullivan, Flickr

Freight cars pass an Amtrak California train traveling the Capitol Corridor.

defining infrastructure needs. The scale and configuration of the physical plant set the upper bounds for service delivery. Within those bounds, however, a variety of elements—management, operations, and support systems—determine the service delivery in a corridor. Other factors to consider in assessing rail capacity include the following:

- ◆ Dispatch performance, which involves the support systems provided to dispatchers in delivering movement instructions, as well as a dispatcher's willingness to use all available routes within a corridor to expedite traffic;
- ◆ Train length and horsepower-to-ton ratios for different classes of train service;
- ◆ Communications protocols and support systems;
- ◆ The reliability of train operations beyond the physical boundaries of the shared-use corridor;
- ◆ Recovery resources to move operations back to normal after unplanned events, such as equipment failures, derailments, severe weather, and grade-crossing incidents;
- ◆ Track maintenance and capital renewal strategies; and

Photo: Unsplash

Rail capacity is determined by a variety of factors, from train length and recovery recourses to infrastructure and systems redundancy.

Photo: Patrick Cashin, Metropolitan Transportation Authority

Metro-North Railroad crews repair a damaged section of track after a derailment near the Spuyten–Duyvil station in New York. Regular and special track maintenance and renewal activities affect rail capacity.

◆ The level of infrastructure or systems redundancy to mitigate the risk of unplanned events—a point that is a source of many conflicts over corridor investments.

Public Agency Service Sponsors

Nearly all public agency service sponsors advocated more transparency in capacity modeling. Carriers want to protect the confidentiality of commercial relationships and data; some do not document the volume assumptions in their capacity modeling, while others share these data with their public agency partners.

Federal Railroad Administration

FRA, host freight carriers, and many state DOTs emphasized the need to define the long-term service scenario for a new passenger operation, as well as the steps for investment and the service speeds and frequencies. This approach would offer the following advantages:

◆ Consideration of discrete project investments for long-term operations and infrastructure configuration, avoiding fixes that do not allow for growth;

◆ Early identification of the limits of shared use and the establishment of benchmarks for segregated infrastructure;

◆ Preservation of abandoned or lightly used rail alignments as needed to protect the long-term service vision; and

◆ Creation of a more stable planning environment for public agencies and private carriers.

Moreover, a detailed, long-term improvement plan could lead to quicker implementation of capacity-enhancing projects—for example, through task-order contracts.

Elements of Capacity

Capacity is a function of three primary elements:

◆ The physical characteristics of the segment, such as single or double track, the distance between passing sidings, the signal systems, the permitted speeds for different types of trains, the curvature, and the gradients;

◆ The characteristics of train operations, such as the number and types of trains on the line during a specific period of time, speeds, the train length and weight, the locomotive power of each train, and stops for passenger stations or to drop off and pick up freight cars from industry sidings; and

◆ Management practices and protocol, including dispatch procedures, safety regulations, and treatment of train movements through passenger terminal areas.

As a general principle, the capacity of a line decreases with the heterogeneity of train operations. Capacity may be considered adequate when each user is able to meet service quality goals. For a passenger service operator, the goal may be to achieve a certain percentage of on-time arrivals or to ensure that individual train and aggregate delays do not exceed a certain level.

In contrast, the service goals of a freight operator depend on the type of service—for example, an intermodal train may be required to meet punctuality goals, reflecting commitments to customers, but for other train types, the objectives may be to minimize delays and unnecessary stops and starts that increase fuel, employee, and other costs.

Capacity Analysis

The two main approaches to capacity analysis consider these factors to varying degrees in assessing a rail line segment's ability to carry a given volume and mix of traffic and to meet service quality goals.

Scoping Approaches and Tools

Scoping analyses usually compare alternatives for routes or for a transportation corridor—for example, minor upgrades to a line, a major upgrade providing higher speeds and more frequent service, or construction of a new right-of-way. Scoping tools include the following:

◆ **Train performance calculators,** used to calculate the unconstrained journey time for a single train on a rail segment. The inputs are train weight, locomotive power, speed, tractive effort, resistance from rolling friction and aerodynamic drag, and brake performance. Infrastructure and operations data include gradients, curvature, speed limits, location, and dwell time at station stops.

◆ **String line analysis**, a time–distance plot of all trains operating on a line segment during a certain period, most often 24 hours. Usually distance in miles is shown on the vertical axis, which also shows stations, passing siding, or crossover locations. The horizontal axis shows time in hours and minutes. Train movements are shown as forward- or backward-sloping lines depending on the direction of travel; steeper slopes indicate a faster train.

◆ **Grid time analysis**, used to test the upper limit for the number of daily trains that a corridor can handle, without regard to train service commitments. The theoretical capacity is dictated by the time it takes a train to travel the distance between two sidings and clear the way for an opposing train.

◆ **Other planning and scoping approaches**, which can include a parametric capacity estimate for calculating capacity from a formula with the inputs including the number of tracks, the signal block lengths, the train speeds, the siding and crossover spacings, and the mix of train speeds.

Operations Simulation Analysis

Computer-driven simulation analysis has become the principal method for resolving line capacity issues. The models provide a step-by-step simulation of all trains operating on a line segment, to create a complete and accurate picture of operations.

The models incorporate schedule data, the arrival of trains at both ends of the line segment, and a train performance calculator to simulate train movement over the line between signals, sidings, crossovers along the segment, and a dispatching algorithm that mimics the meet-and-pass and similar decisions by a dispatcher. Model outputs include string line charts, journey time and delay statistics, and animations.

The guidebook identifies four simulation models:

◆ The **Freight–Passenger Rail Corridor Project Screening Tool**, developed under a National Cooperative Freight Research Program (NCFRP) contract, is a web-based tool for initial planning analysis, easily accessible by all parties.

◆ **Berkeley Simulation Software's Rail Traffic Controller (RTC)**, used by Class I railroads, government agencies, commuter and passenger operators, and consultants, simulates dispatch behavior on a North American freight railroad coping with high variability in the timing and volume of train movements.

◆ **Systra's RAILSIM program**, used by commuter and passenger agencies, Class I railroads, and consultants, simulates complex schedules of passenger operations and includes planning features for equipment and staff resources related to passenger service.

◆ **RAILS2000 program** is used primarily by the consulting units within CANAC Railway Services; the program's use in the industry has declined.

Typical Applications

Typical applications for scoping models are for feasibility studies, conceptual planning studies, and alternative screening. The more time-consuming and expensive operations simulations, however, are typically reserved for highly detailed operations analyses, planning for specific infrastructure investments, and agreements on shared-use contract terms between a host railroad and a public agency service sponsor.

Case Studies

The guidebook includes four case studies:

◆ **A grid time analysis of the LOSSAN Corridor** along the California coast between San Luis Obispo, Santa Barbara, Los Angeles, and San Diego. Amtrak intercity trains, a California-sponsored intercity corridor passenger train, two Class I railroads, a short line railroad, and two commuter railroads share the corridor segments.

◆ **An RTC operations simulation of Amtrak's New Haven–Hartford–Springfield line**, shared by Amtrak intercity services, a Class I railroad, and two short line railroads, soon to be joined by a new passenger service sponsored by Connecticut. The start-up of the new service, slated for 2016, triggered the simulation.

◆ **Capacity planning for high-speed, intercity passenger trains between Chicago, Illinois, and St. Louis, Missouri**. The trains are expected to achieve speeds of 110 mph on a Union Pacific Railroad main line in 2016.

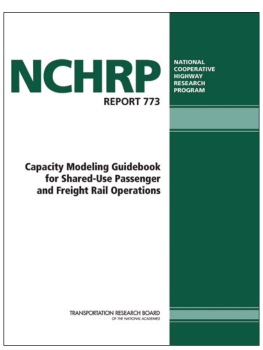
Photo: Steve Boland, Flickr

The Amtrak Pacific Surfliner travels past the San Clemente Pier in California. NCHRP Report 773 features a grid-time analysis of the Los Angeles–San Diego corridor.

TABLE 1 Summary of Analysis Methodologies for North Sound Case Study, Washington State

Approach	Labor Hours	Data Needs	Comment
Grid time analysis	40	Track charts, employee timetable, and train counts for Everett to Blaine	Quick for spotting potential trouble areas. Difficult to apply to complex networks.
NCFRP web-based simulator	120	Track charts, train operating patterns, and equipment detail for Bellingham Subdivision	Good scoping-level tool. Lacks tools to visualize train simulation. Not user friendly for testing network robustness—for example, for running multiple scenarios. Model utility in complex network situations was not tested. Data saved on web servers. Free tool.
Rail Traffic Controller	400	Track charts, employee timetable, train operating patterns, and equipment detail for Scenic and Bellingham Subdivisions	Proven operations simulation methodology. Good tools for visualization of train simulation. Easily calibrated to reflect actual dispatcher practices. Runs on a local computer. RTC licenses must be purchased.

◆ **A capacity analysis of a shared-use corridor in the North Puget Sound area**, between Everett and Bellingham, Washington. A new regional passenger rail service, sponsored by Washington and Oregon, would share the corridor with BNSF Railway freight trains, Amtrak intercity trains, Everett–Seattle commuter trains, and passenger trains on the *Cascades* corridor serving Eugene and Portland, Oregon; Tacoma and Seattle, Washington; and Vancouver, British Columbia, Canada. The analysis used three methodologies: a grid time analysis, the web-based operations simulation, and an RTC simulation (Table 1, above).



NCHRP Report 773, *Capacity Modeling Guidebook for Shared-Use Passenger and Freight Rail Operations*, is available from the TRB online bookstore, https://www.mytrb.org/Store/Product.aspx?ID=7441; to view the book online, go to http://www.trb.org/Main/Blurbs/171662.aspx.

Building Lasting Partnerships

The most successful passenger rail corridor franchises involve service sponsors, passenger service operators, and corridor owners working together to develop a robust planning, communications, and service monitoring structure. Adequate physical plant capacity is critical to support high levels of service integrity for all users—freight, commuter, and intercity passenger operators.

Building trust and understanding to bridge the cultural chasm between public agencies and private rail freight operations is possible, but a commitment of resources—time and people—is required from both sides. The parties also need to understand that the partnership is ongoing, requiring regular, disciplined interaction, beyond the purchase of service capacity.

Each corridor and service opportunity is unique, but some common themes underlie the approach to planning and capacity management for well-run operations:

◆ Obtain up-front, transparent agreement on the technical definitions for service performance by all classes of trains, including on-time performance, transit times, service reliability, and the ability for service to recover from unplanned events.

◆ Obtain up-front agreement on the long-term, 20-year total volume of trains that each class of users intends to move through the corridor. Assess the corridor for that 20-year scenario, and then determine the logical breakpoints for service frequency, speed, and investment.

◆ Appreciate the limits of the railway physical plant and the need to extend an analysis to points beyond the physical boundaries of the proposed new passenger operations.

◆ Formal modeling of service should extend to the geographic limits of the freight crew district territories affected by the new passenger service.

◆ Protect the integrity of freight service by incorporating infrastructure improvements well removed from the area slated for new passenger operations. This approach is effective when the area of new passenger service is in a congested urban environment or the topography is challenging, severe, and costly to address.

◆ Explore all of the drivers of service capacity instead of focusing on the fixed physical plant. Dispatch systems and protocol, capital maintenance and renewal practices, and rail terminal fluidity have major impacts on service delivery but are not automatically captured in a modeling and simulation exercise. Perform stress tests to prepare for unplanned events, such as extreme weather or other natural disturbances.

P O I N T   O F   V I E W

Estimating Preconstruction Costs

Who Cares? Why Bother?

DOUGLAS D. GRANSBERG

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In 2013, the National Cooperative Highway Research Program (NCHRP) awarded the research team at Iowa State University a project to develop a framework for estimating preconstruction costs for highway projects. NCHRP Project 15-51 received broad support from state departments of transportation (DOTs) across the nation. The team gathered five years of data on preconstruction costs from five states: California, Georgia, Iowa, New York, and Utah, as well as detailed case study data from projects in five other states: Colorado, Maryland, Montana, Oklahoma, and Rhode Island. The NCHRP project findings will be released soon.

PHOTO: NORTH CAROLINA DOT

A North Carolina DOT engineer oversees a road project in Guilford County. Transportation agencies estimate preconstruction costs in different ways.

Two Surprises

The research team and the NCHRP project panel encountered two surprises as the agencies furnished data. First, each of the state DOTs that provided preconstruction cost data added a caveat: the agency could not confirm the accuracy of the information, although the data came directly from the financial database. In each case, a data quality control process was lacking to verify that in-house personnel working on multiple active projects were charging their time properly.

PHOTO: GEORGIA DOT

Georgia DOT's Northwest Corridor Express Lanes Project along I-75 and I-575. NCHRP Project 15-51 studied preconstruction data from Georgia and other states.

The second surprise was more challenging. During the in-depth case study interviews, agency personnel expressed the opinion that a tool for estimating preconstruction costs early in the process of project development would not be of great value to their agency. Two reasons were advanced to substantiate this opinion:

1. Preconstruction costs are a small percentage of the total construction costs; a more certain estimate would not appreciably change the budget for preconstruction.
2. The accountability for controlling preconstruction costs was minimal, if any, and no penalties were imposed for overrunning the preconstruction budget.

One person who was interviewed articulated the issue eloquently: "If 4 percent of the estimated construction cost is the preconstruction budget, then overrunning it by 10 percent is 0.4 percent, a tiny number. Why waste time collecting, processing, and maintaining a preconstruction database when the improved estimates and budgets result in a trivial savings?"

Countering the Argument

Although pragmatic, this analysis ignores several facts that effectively counter the argument. First, preconstruction budgets are in dollars, but the unit of effort is the person-hour. If the budget established by a fixed

PHOTO: AL COVEY, VIRGINIA DOT

A Virginia DOT inspector tests soil compaction on the east side of Route 106 roundabout near Petersburg.

percentage translates into 20,000 hours of preconstruction planning, design, and administration, a 10 percent overrun equals 2,000 hours. A typical year encompasses 2,080 working hours; therefore the overrun equates to nearly one person-year of additional effort. At the typical cost for agency or consulting engineer time, including associated benefits, the overrun would equate to more than $100,000.

Second, the claim ignores the value of the planning and design documents, which "define the level of required construction quality and, as such, are extremely important to a transportation project's ultimate success" (*1*). Failing to provide a sufficient budget for developing those documents could result in rushing the work to completion or could reduce the amount of time spent on the final construction documents. Although this may not apply fully to documents developed by in-house planning and design staff, the effect would occur when the DOT decides to outsource a majority of the preconstruction efforts (*2*).

The literature identifies a third issue. Previous research has shown that inadequately funding the preconstruction process creates an unintentional cap on the amount of design work that can be applied to a project, and this may have a negative impact on the quality of the construction documents (*3–5*). Research by Morgen (*6*) and Kirby et al. (*7*) found that design deficiencies were the primary drivers of changes in construction contracts and that "56 percent of all modifications are aimed at correcting design deficiencies." Another study, by Burati et al. (*8*), found that changes resulting from design errors that were identified after the award of a construction contract accounted for 79 percent of all costs for change orders and for an average of 9.5 percent of the total project cost.

TABLE 1 Conceptual Savings Possible for a Hypothetical Project

Expense	Assumed Percentage	Cost
Construction cost	—	$10,000,000
Design cost	4% of construction cost	$400,000
Design contingency	10% of design cost	$40,000
Change orders due to design errors	9.5% of construction cost	$950,000
Savings (assuming contingency will eliminate design errors)	—	$910,000

Rational Contingency

Therefore, accurately estimating and fully funding preconstruction services and assuring that resources are sufficient by developing a rational preconstruction contingency should substantially diminish the changes to correct design errors during construction. Burati et al. estimated an average savings of 9.5 percent. Adding a 10 percent contingency to the design contract should allow the designer sufficient hours to detect and correct design errors. Table 1 (below) shows the potential savings from this admittedly optimistic assumption.

The data in Table 1 show a benefit-to-cost ratio of roughly 24 to 1. If the additional hours furnished by the contingency decrease the design errors by only 50 percent, the increased spending to reduce postaward construction changes related to planning or design errors still would yield a huge return on investment.

This leads to the conclusion that estimating the cost of preconstruction services on a project-by-project basis, instead of applying a semiarbitrary percentage of construction cost, could yield savings in both cost and time during construction. If the savings shown in Table 1 are realized on 11 projects, each budgeted at $10 million, the state DOT would avoid enough cost growth during construction to let a twelfth project at $10 million.

This hypothetical discussion is intended to motivate investment of the time, effort, and resources for estimating preconstruction costs with the same rigor applied to estimating construction costs. Ensuring that projects in need of additional resources to produce high-quality construction documents have those funds from the outset could increase the number of projects a state DOT can finance each fiscal year. A side benefit would be the release of planning and design funding from projects that require less than the customary percentage of construction costs to complete the preconstruction process.

Building the Database

Nothing in the transportation infrastructure construction industry is free. Before the potential savings can be realized, an agency must implement a comprehensive program to track the time applied during preconstruction. This includes investing to ensure confidence that the input data represent actual costs, and that the output is both reasonable and realistic. The guidelines developed in NCHRP Project 15-51 describe a process for achieving a level of confidence in both the database of preconstruction service costs and in the estimated preconstruction costs.

The major barrier to implementing the process proposed by NCHRP Project 15-51 is the notion that accurate estimation of preconstruction costs does not matter, and even if it did, the resources to implement a project-specific preconstruction service estimate will never be available. Nevertheless, no one would deny that the goal of reducing design errors that generate construction cost growth is a worthy endeavor. Past research has shown conclusively that appropriately increasing the funding allocated to preconstruction will increase an agency's control over the final cost of construction by ensuring certainty in costs and scheduling. The industry has lacked a reliable methodology for estimating preconstruction costs, but NCHRP Project 15-51 has developed a process that can be implemented with standard commercial spreadsheet support on standard commercial database software.

Choosing the Smarter Way

In answer to the questions posed in the subtitle of this article,

- *Who cares?* Taxpayers deserve as much capacity and service as government budgets can provide.
- *Why bother?* Efficient use of available capital entails letting as many projects as practicable; if an agency shifts its goal from cost savings to cost certainty, investing in the preconstruction process can enhance construction cost certainty.

An agency's upper management must take the next step to allocate the resources necessary to implement a program for estimating preconstruction and to hold project managers as accountable for preconstruction budgets as for construction budgets. Past FHWA Administrator Victor Mendez has stated that "it is imperative we pursue better, faster, and smarter ways of doing business" (*9*); he replaced the word "cheaper" in the old mantra with "smarter."

Rationally estimating the cost of preconstruction services is a smarter way of doing business, because investing in the preconstruction efforts will increase the cost certainty (*1, 10*). Now that state DOTs have been released from the obligation to find the cheapest solutions for transportation projects, they can adopt the preconstruction estimating process developed under NCHRP Project 15-51 to establish a program to let as many projects as practicable with the confidence derived from enhanced project cost certainty.

PHOTO: FHWA

Advocate of "better, faster, and smarter ways of doing business," Victor Mendez, then Federal Highway Administrator, speaks with reporters at the groundbreaking of the Downtown Crossing project in Louisville, Kentucky, in 2013.

References

1. Gransberg, D. D., C. Lopez del Puerto, and D. Humphrey. Relating Cost Growth from the Initial Estimate to Design Fee for Transportation Projects. *Journal of Construction Engineering and Management*, Vol. 133, No. 6, 2007, pp. 404–408.
2. Hunter, K. D., and D. D. Gransberg. Comparative Analysis of Two Models for Estimating Highway Project Design Costs. Presented at Transportation Research Board 93rd Annual Meeting, Washington, D.C., January 2014.
3. Williams, T. P., N. Parker, and J. Klotz. Development of an Estimating Tool for Transportation Project Design Effort. Presented at Transportation Research Board 92nd Annual Meeting, Washington, D.C., January 2013.
4. Carr, P. G., and P. S. Beyor. Design Fees, the State of the Profession, and a Time for Corrective Action. *Journal of Management in Engineering*. Vol. 21, No. 3, 2005. pp. 110–117.
5. McSkimming, J., B. Peck, B. Hoy, and S. Carr. The Quality of Design Documents: What Can the CM Do? CMAA Forum on Quality of Design Documents, 2005. http://cmaanet.org/user_images/forum.quality_of_design_documents_-_mcskimming.pdf.
6. Morgen, E. T. Claims by the Federal Government Against Its A/E: Guidelines for Improving Practice. Office for Professional Liability Research, Victor O. Schinner and Co., Washington, D.C., 1986.
7. Kirby, J. G., D. A. Furry, and D. K. Hiks. Improvements in Design Review Management. *Journal of Construction Engineering and Management*, Vol. 114, No. 1, 1988, pp. 69–82.
8. Burati, J. L., J. J. Farrington, and W. B. Ledbetter. Causes of Quality Deviations in Design and Construction. *Journal of Construction Engineering and Management*, Vol. 118, No. 1, 1992. pp. 34–36.
9. Mendez, V. *Every Day Counts: Innovation Initiative*. Federal Highway Administration, Washington, DC, 2010, pp. 1–2.
10. Beemer, J. *The Cost of Perfection in Public Works Projects: A Design Professional's Perspective*. American Council of Engineering Companies, 2005. www.acec.org/advocacy/pdf/tcop_2006-04-20.pdf.

POINT OF VIEW presents opinions of contributing authors on transportation issues. Readers are encouraged to comment in a letter to the editor on the issues and opinions presented.

Improving the Reliability and Resiliency of Traffic Signals in an Urban Environment

Cost–Benefits in Washington, D.C.

SOUMYA S. DEY, BENITO O. PÉREZ, AND RAHUL JAIN

The authors are with the District Department of Transportation, Washington, D.C. Dey is Director of Research and Technology Transfer, Pérez is Parking Management and Operations Planner, and Jain is Transportation Engineer.

The roadway network of Washington, D.C., consists almost exclusively of arterials; freeways account for less than 1 percent of the city's roadway mileage. Consequently, the efficiency of the District of Columbia transportation system depends on the reliability and resiliency of the signal system.

Signal disruptions challenge the operation, mobility, and safety of the system's customers and strain the District's resources. A variety of events can disrupt signal operations—for example, dark signals during power outages, flashing signals caused by sudden fluctuations in line voltage or by internal malfunctions in the control cabinet, twisted signal heads, outages of signal light-emitting diodes, and signal pole or cabinet knockdowns by vehicles.

PHOTO: ANDREW BOSSI, FLICKR

A major blizzard in 2010 caused power outages throughout the D.C. metropolitan area.

Identifying Major Causes

An analysis of signal data from 2008 to 2013 revealed that power-related signal outages accounted for only 5 percent of disruptions but 87 percent of the outage time. These outages therefore had a disproportionately negative impact on the transportation system.

The Washington, D.C., signal system experiences an average of 330 outages each year, lasting for a total of 3,850 hours. Extreme weather events account for a large proportion of the outages; the derecho* of 2012, for example, caused two-thirds of the total duration of outages for the year.

PHOTO: DISTRICT DOT

The intersection at 4th Street and Pennsylvania Avenue NW in Washington, D.C., is a complex mix of arterial roads, bicycle lanes, and pedestrian thoroughfares.

Two-Pronged Strategy

To mitigate the impacts of signal outages, the District Department of Transportation (DOT) adopted a two-pronged strategy:

1. **Back-up generators.** In 2005, the agency procured 200 emergency backup generators with a competitive grant from the U.S. Department of Homeland Security. Each gasoline-powered generator can operate a typical intersection for up to six hours. An automatic transfer switch isolates the traffic cabinet outfitted with a generator port from the power grid

* A derecho is a widespread, long-lived wind storm. According to the National Oceanic and Atmospheric Administration, derechos are associated with bands of rapidly moving showers or thunderstorms variously known as bow echoes, squall lines, or quasilinear convective systems.

With American Recovery and Reinvesment Act funds, District DOT installed uninterruptible power supplies along major corridors, such as Massachusetts Avenue, NW.

when the generator is running and automatically reconnects the intersection to the grid when the power is restored.

2. **Battery backups.** Since 2010, District DOT has invested in uninterruptible power supply (UPS) battery backups, installed at approximately 300 signalized intersections—20 percent of the system. American Recovery and Reinvestment Act funds kick-started the program. A UPS battery can power a typical intersection for approximately six hours. District DOT has allocated funds annually to increase the UPS coverage. In addition, UPS battery backups are now part of the agency's signal specifications—new signals or signal modifications include UPS in the construction cost.

Deploying the Strategy

Between 2008 and 2013, District DOT deployed the generators approximately 900 times with a total run time exceeding 10,000 hours. In 2014, for example, the system deployed UPS back-ups approximately 1,400 times for a total of 500 hours.

An analysis showed that 69 percent of the UPS usage was for less than 1 minute, and 12 percent was for 1 to 5 minutes (Figure 1, right). This indicated that UPS usage was triggered predominantly by brownouts or by a lack of clean electricity. Without the UPS, the affected signals would have lapsed into the flash mode.

A graphic visualization of the data revealed that the current UPS and generator-ready signals are covering high-outage areas. A few obvious gaps in the visualization indicated locations that would benefit from UPS installations or from retrofitting the cabinet to connect to a generator.

Benefits

The deployment of generators and UPS units provides several benefits that outweigh the associated costs. Tangible benefits include savings in personnel and in user costs. Intangible benefits include increased safety for city personnel—for example, for police and traffic control officers—and for motorists, plus savings in vehicle emissions and in fuel consumption through improved traffic flow.

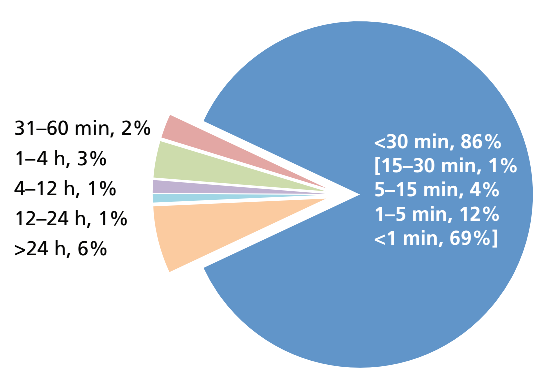

FIGURE 1 Deployment of UPS battery backup for traffic signals, by duration (min = minutes, h = hours).

PHOTO: DISTRICT DOT

A traffic control officer directs drivers at 7th and T Streets, NW.

Personnel Cost Savings

The impact of a signal outage depends on the location, time, and duration of the outage and on the traffic demand. Washington, D.C., laws require motorists to treat a dark signal as a four-way stop. The District dispatches a police officer or two traffic control officers to direct traffic at critical dark-signal intersections during periods of high demand.

Powering a signal with a generator avoids the cost of deploying a police officer or traffic control officers. The deployment of these personnel at the intersections that were powered by generators or UPS would have cost $830,000 between 2008 and 2013. In 2014, the personnel cost savings for intersections powered by UPS during outages longer than one hour would have been approximately $37,000.

User Cost Savings

The difference in the vehicle delays with regular signal operation powered by a generator or UPS compared against the delays with a four-way stop when a signal is dark can be used to estimate the user costs. The agency used the SYNCHRO program to model the delays under the two scenarios.

All of the intersections that were powered by generators were categorized according to their functional classes (*1*). Then the average traffic volume of the intersecting roadways, plus a random sample of the intersections, was modeled. Adding the delay savings from each generator deployment, according to its intersection category, yielded the total savings in delay. The Federal Highway Administration methodology (2) and the median income data for the Washington, D.C., metropolitan area then were used to monetize the delay savings.

The user cost savings from signals operating with a generator was an estimated $28 million for the six-year period. The user cost savings with UPS in 2014 came to approximately $1.4 million.

Intangible Benefits

Safety is the primary intangible benefit of maintaining signal operation. In addition, generators and UPS units yielded operational efficiencies and environmental benefits from reduced fuel consumption and lower vehicular emissions.

References

1. *Highway Functional Classification Concepts, Criteria, and Procedures*. Federal Highway Administration, 2013. www.fhwa.dot.gov/planning/processes/statewide/related/highway_functional_classifications.
2. *Work Zone Road User Costs: Concepts and Applications*. Federal Highway Administration, 2011. http://ops.fhwa.dot.gov/wz/resources/publications/fhwahop12005/index.htm#toc.

Drivers wait for the signal at the exit for I-395 in Washington, D.C. Signal outages are costly, from personnel deployment to the user costs of time lost and fuel consumed.

Low-Cost Approach to Reducing Crashes on Multilane Undivided Highways in Louisiana

KIRK ZERINGUE AND XIAODUAN SUN

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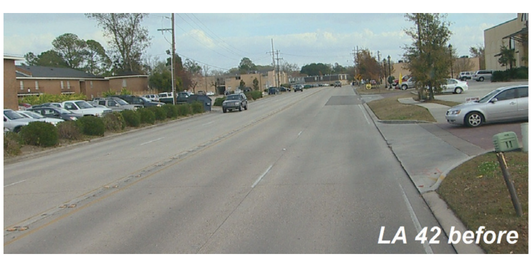
Undivided highways consistently perform at low levels of safety, particularly in urban and suburban areas with relatively high densities of driveways. Federal Highway Administration (FHWA) statistics show that rural two-lane highways have the highest traffic fatality rate but undivided highways have the highest crash rate and highest crash injury rate in the United States. A large proportion of the crashes on undivided roadways involve rear-end collisions.

Problem

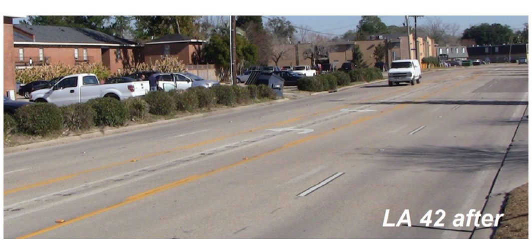
Louisiana has approximately 1,200 miles of undivided multilane roadways; most of these are four-lane highways in the state's Department of Transportation and Development (DOTD) system. Ninety-three percent of these roadways are in urban and suburban areas.

Installing a physical separation—either a barrier or a green space—is the crash countermeasure most often recommended. If the roadway width is sufficient, however, a four-lane undivided highway can be changed easily into a five-lane roadway with the center lane available for left-turns; this configuration reduces rear-end collisions.

Nevertheless, this conversion option introduces access control problems and therefore is not considered a good design alternative, although it may be the least expensive. Louisiana already had policies that discouraged the use of five-lane roadway designs in the construction of new roads; the state seldom had considered this option for reducing crashes on undivided roadways. Tight budgets, however, precluded expensive solutions.



(a)



(b)

LA-42 (*a*) before and (*b*) after conversion from four to five lanes.

Solution

Between 1999 and 2007, several Louisiana DOTD district offices identified the reduction of rear-end crashes on four-lane undivided highways as an urgent need. To meet this need within the available budgets, the district offices received permission to convert several segments of undivided four-lane roadways into five-lane roadways; the center lane served as a two-way left turn lane. The conversion required restriping the pavement markings without increasing the pavement width.

Researchers from the University of Louisiana at Lafayette evaluated the effectiveness of this approach as part of a study funded by the DOTD's Louisiana Transportation Research Center (*1*). The main objective of the study was to identify and develop crash modification factors (CMFs) unique to Louisiana.

CMFs are a tool for evaluating benefit–cost relationships through estimates of the effectiveness of roadway improvements in reducing crashes or reducing crash severity. The study developed a Louisiana-specific CMF for converting a four-lane urban undivided roadway to a five-lane roadway. The researchers examined the sites converted by the Louisiana DOTD districts between 1999 and 2007.

The statistical analysis included six years of crash data—three years before the restriping projects and three years after, excluding the project implementation year. The CMFs for all roadways were estimated at less than 0.6, with a standard deviation of less than 0.07. This finding indicated that the implementation of the conversion strategy would reduce the expected number of crashes by 40 percent. Table 1 (page 44) summarizes the crash reductions for each segment.

A major concern was whether the conversion had increased other types of crashes despite reducing the number of rear-end collisions. An analysis of the data by crash type on all four segments showed decreases

TABLE 1 Crash Reduction Summary

Route	Before		After		Change	
	Crashes	*Average Crash Rate (per million VMT)*	*Crashes*	*Average Crash Rate (per million VMT)*	*Crashes*	*Average Crash Rate (per million VMT)*
LA-3025	358	10.05	147	4.59	-59	-54.3
LA-182	178	8.12	85	3.53	-52	-56.5
LA-28	206	7.38	99	4.09	-52	-44.6
LA-1138	260	16.01	167	10.63	-36	-33.6

Note: VMT = vehicle miles traveled.

of 44 percent to 82 percent in rear-end collisions.

On LA-3025, reductions in all major types of crashes also were evident, particularly in sideswipe crashes in both directions and in right-angle crashes. LA-1138 registered a significant decrease of 89 percent in head-on collisions and a 75 percent decrease in same-direction sideswipe crashes.

On LA-28, however, head-on crashes and same-direction sideswipe crashes increased, although other types of crashes showed a decreasing trend. On LA-182, right-angle, left-turn, and same-direction-sideswipe crashes increased slightly—but a lack of information on the type of collision for several crashes from the time before the conversion affected the comparison.

Application

Although Louisiana no longer allows five-lane roadway designs for new construction, the crash reductions associated with the lane conversion approach were impressive and clearly demonstrated that this solution was feasible under financial constraints. The benefit–cost ratio of lane conversion by restriping is huge—more than 160. Louisiana DOTD therefore plans to continue using this crash countermeasure on a case-by-case basis on urban and suburban undivided roadways.

In one case, the Louisiana DOTD Traffic Section identified LA-42, Burbank Drive, as a candidate for conversion in 2013. The four-lane undivided highway with two travel lanes in each direction is near the Louisiana State University campus in Baton Rouge. This section of LA-42 has a high traffic volume—an average daily traffic of approximately 17,400 vehicles—with heavy congestion during peak periods.

TABLE 2 Estimated Benefit–Cost Ratios for Lane Conversions

Segment	Total Benefits ($)	Total Cost ($)	Benefit–Cost Ratio
LA-3025	2,754,000	14,100	195
LA-182	1,914,000	11,500	166
LA-28	2,110,000	10,600	199
LA-1138	2,317,000	12,300	188

During the peaks, a large number of vehicles attempt left turns into the many businesses, apartment complexes, and side roads. No turn lanes support these movements, however; as a result, left-turning vehicles have to wait within the travel lane for an opening, delaying traffic and increasing the risk of rear-end collisions on a busy road.

The conversion project removed the four-lane striping and the raised pavement markers (RPMs) in November 2013 and installed new striping and RPMs for five lanes. The new pavement marking added a two-way left-turn lane through the length of the project, with dedicated left-turn lanes at the traffic signals. Removing the turning vehicles from the through lanes is expected to ease congestion and to reduce some types of crashes within the project area. Figure 1 (below) presents a typical section of the conversion, showing the lane widths.

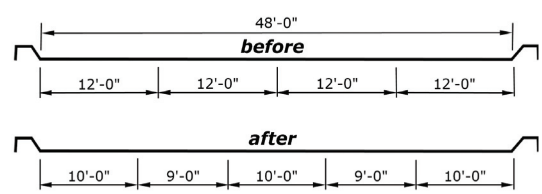


FIGURE 1 LA-42 lane width and configuration, before and after conversion from four to five lanes.

Benefits

The benefit–cost ratio for each segment was determined by comparing FHWA's average costs for injury crashes and property-damage-only crashes with Louisiana DOTD's average costs for the restriping. Table 2 (below left) shows the estimated benefit–cost ratios.

The LA-42 project expects a reduction in congestion, along with a reduction in certain types of crashes, such as rear-end collisions. Researchers will continue to monitor the crash data from this site and will analyze the effectiveness of the conversion after three years of crash data are collected.

Reference

1. Sun, X., and S. Das. *Developing Louisiana Crash Reduction Factors*. Project No 08-3SS, Louisiana Transportation Research Center, Baton Rouge, 2013.

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

Suggestions for Research Pays Off topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, Keck 488, 500 Fifth Street, NW, Washington, DC 20001 (202-334-2956; gjayaprakash@nas.edu).

CALENDAR

TRB Meetings

April

3–5 **Lifesavers National Conference on Highway Safety Priorities**
Long Beach, California

13–16 **World Steel Bridge Symposium***
Orlando, Florida

22–28 **World Tunnel Congress**
San Francisco, California

25–27 **International Conference on Winter Maintenance and Surface Transportation Weather**
Fort Collins, Colorado

May

1–4 **6th Conference on Innovations in Travel Modeling**
Denver, Colorado

1–4 **North American Travel Monitoring Exposition and Conference (NATMEC): Improving Traffic Data Collection, Analysis, and Use**
Miami, Florida

4–6 **15th International Conference on Managed Lanes**
Miami, Florida

17–19 **Road Safety on Five Continents***
Rio de Janeiro, Brazil

June

2–3 **Ferry Safety and Technology Conference**
New York, New York

12–14 **2nd International Symposium on Disaster Prevention and Mitigation of Highway Infrastructure**
Xi'an, China

14–16 **International Symposia on Enhancing Highway Performance: 7th International Symposium on Highway Capacity and Quality of Service and 3rd International Symposium on Freeway and Tollway Operations***
Berlin, Germany

21–23 **From Sail to Satellite: Delivering Solutions for Tomorrow's Marine Transportation Systems**
Washington, D.C.

26–29 **American Society of Civil Engineers International Conference on Transportation and Development***
Houston, Texas

26–30 **8th International Conference on Bridge Maintenance, Safety and Management***
Foz do Iguaçu, Brazil

27–30 **National Equipment Fleet Management Conference***
Columbus, Ohio

July

6–7 **3rd International Conference on Access Management***
Pretoria, South Africa

10–12 **11th National Conference on Transportation Asset Management**
Minneapolis, Minnesota

11 **Geological Modeling: Methods and Methodologies**
Colorado Springs, Colorado

16–18 **International Conference on Transportation Infrastructure and Materials**
Xi'an, China

19–21 **Automated Vehicles Symposium 2016***
San Francisco, California

24–27 **Transportation-Related Noise and Vibration Committee Summer Conference**
Missoula, Montana

25–27 **GeoChina 2016 International Conference***
Shandong, China

26–29 **Resource Conservation and Recovery Summer Conference**
Asheville, North Carolina

TBD **Transportation-Related Environmental Analysis, Ecology, and Historic and Archeological Preservation Summer Conference**
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*TRB is cosponsor of the meeting.

Stuart D. Anderson

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Stuart D. Anderson has taught construction project management and planning at Texas A&M University for more than 25 years. After receiving a Ph.D. in civil engineering in 1989 from the University of Texas at Austin, Anderson joined the faculty at Texas A&M as an assistant professor. He served as professor and as A. P. and Florence Wiley Chair at the Zachry Department of Civil Engineering. He now is Zachry Chair in Construction Integration and serves as research engineer and program manager at the Texas A&M Transportation Institute (TTI) Constructed Facilities Division.

As a researcher, Anderson models processes for project management; topics of his studies include early estimating and cost management, leading indicators for project outcomes, innovative project delivery and contracting systems, and improving project process through constructability and accelerated construction strategies and techniques. "Research brings innovation to the transportation industry," Anderson comments. "Innovation can improve current practice by enhancing project processes—both technical and management—through new ideas and concepts that can be applied in practice."

"Innovation can improve current practice by enhancing project processes—both technical and management—through new ideas and concepts that can be applied in practice."

Anderson recently was appointed assistant vice chancellor for facilities planning and management for the Texas A&M System, overseeing the planning and management—as well as renovation and new building construction—of all the facilities of the College of Engineering.

In 2005, he took a one-year development sabbatical from Texas A&M and worked for the Washington State Department of Transportation (DOT) as a cost risk engineer. He developed cost-estimating guidelines and a cost-estimating training course. This involved interviewing Washington State DOT staff, as well as analyzing interview data, reviewing procedure manuals, and participating in training courses. Anderson reviewed cost estimates for four projects ranging in cost from $11 million to more than $100 million.

Notable research projects include his first project with the National Cooperative Highway Research Program (NCHRP), on the constructability review process. He met with an industry advisory team four times during the research, which produced practical guidelines for constructability reviews. For a recent NCHRP project on effective scoping practices, the research required a variety of experts—in design, traffic management, right-of-way, utilities, the environment, and construction—and developed guidelines that will be published as NCHRP Report 821. "Success in preparing a quality scoping process in other industries drove the research, although the front end scoping process was modified to fit the transportation industry," Anderson notes.

"Lots of transportation research focuses on technical areas; more research is needed on how to apply project management processes in transportation," Anderson observes. "This is often overlooked, in my opinion, particularly in terms of project management from inception to completion." A project management approach, he notes, can foster an environment of integrated teamwork and can avoid "silos" that allow groups to pass off work to the next in line.

Anderson joined the Standing Committee on Construction Management in 1996. He served on the committee for 15 years, chairing it from 2003 to 2009. He also served on the Task Force on Accelerating Innovation in the Highway Industry, the Task Force on Design–Build, and the Standing Committee on Project Delivery Methods. He chaired the Construction Section from 2009 to 2015 and, at the same time, served on the Design and Construction Group Executive Committee.

"Build a network of contacts in the state DOTs, Federal Highway Administration, American Association of State Highway and Transportation Officials, consultants, contractors, academics, and TRB staff—this is a great way to obtain help with research projects, to learn about the transportation industry, and to develop lasting friendships," Anderson comments. "Start early in your career and volunteer—building a network of contacts takes time."

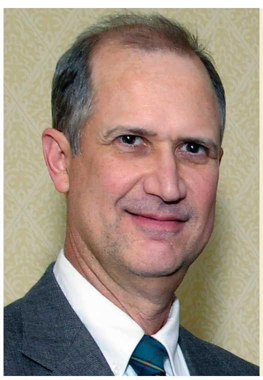
Anderson received the Zachry Teaching Excellence Award in 1993 and the Outstanding Researcher award from the Construction Industry Institute in 1997. In 2010 he was inducted into the National Academy of Construction and in 2015 was inducted into the Pan-American Academy of Engineering.

D. Stephen Lane

Virginia Transportation Research Council

As a research associate at what is now the National Institute for Standards and Technology, D. Stephen Lane began his professional career inspecting laboratories that tested construction materials. The job was an introduction to the significant role of standard specifications and test methods in the construction industry and their importance in assuring the quality and durability of construction. At the time, his only inklings of a future career in transportation were the many miles that the former Johns Hopkins University geology major had logged, traversing the roads of the continental United States and Canada.

After receiving a master's degree in geology from Old Dominion University, Lane joined the engineering staff of the National Aggregates Association and the National Ready Mixed Concrete Association. He planned and oversaw laboratory research projects on concrete and concrete-making materials, analyzed data, and served as an instructor for the associations' short courses. His educational background in the geological sciences provided a different perspective on the materials used in construction. "I discovered the important role of geologists in concrete and aggregate research and was able to apply the practice with civil engineers at the associations' joint research laboratory," Lane comments.



"Active participation in professional organizations is an excellent tool for an individual's career development, but it also provides equal benefits to the individual's employer."

He joined two professional organizations, ASTM and the American Concrete Institute; both organizations rely on member volunteers to develop standards and other guidance, and both foster research to develop and sustain a large knowledge base. "Active participation in professional organizations is an excellent tool for an individual's career development, but it also provides equal benefits to the individual's employer," Lane observes. "Participation expands the individual's knowledge and broadens his or her awareness—and use of the organization's products can help the employer's business."

In 1990, Lane went to work for the Virginia Transportation Research Council (VTRC) and joined teams that comprised engineers and scientists with diverse backgrounds. The Virginia Department of Transportation had recognized that some concrete pavements and structures were being damaged by the alkali–silica reaction then under study by the first Strategic Highway Research Program; this was a major topic for the teams. At the same time, he continued to focus his research on construction materials, principally aggregates, hydraulic cement concretes, and material durability.

During this period, Lane was introduced to the Transportation Research Board (TRB). He joined the Standing Committee on Basic Research and Emerging Technologies Related to Concrete in 1993. He started what became a longtime membership in the Standing Committee on Mineral Aggregates, which he served as chair from 1999 to 2005. Lane was appointed to three National Cooperative Highway Research Program project panels, chairing panels on on Aggregate Shape Characterization and the Relationship of Portland Cement Characteristics to Concrete Durability. He also chaired the Geology and Properties of Earth Materials Section and in 2015 joined the Technical Activities Council as Design and Construction Group chair. He also serves as a member of the Standing Committee on Physicochemical and Biological Processes in Soils.

As his involvement in TRB increased, Lane realized the benefits and opportunities offered by the Board's broad and diverse platform. "Career paths and organization structures can often lead to a narrow-focused niche perspective where important context can easily be missed—or, worse, disregarded," Lane comments. "Participation in TRB provides both the big picture and fine detail needed to solve our transportation problems."

At VTRC, Lane studies the engineering properties and durability of cementitious materials, concretes, and aggregates for use in the construction and maintenance of transportation structures and pavements. As a researcher, he disseminates findings to local, regional, and national audiences via a range of publications, from the *Transportation Research Record: Journal of the Transportation Research Board* to *Concrete International* to VTRC publications. He also provides consulting services, conducts petrographic examinations, manages the petrographic laboratory, and guides the testing of concrete and aggregates to assess their quality and performance.

"Recently, agencies have been emphasizing the implementation of research findings; this is important as it is the primary mechanism for extracting value from the effort," Lane notes. "Overemphasizing implementation from the start, however, can be an undesirable impediment to working on issues that have a longer-term path to a solution or that have the unfortunate effect of leading to predetermined results."

Horses pasturing near railroad tracks. Research on the effects of rail noise on equine populations has been scarce.

PHOTO: KARTA OEHLER, FLICKR

Research on Noise Effects of Rail Routes on Equines

Research on the potential effects of noise from high-speed rail (HSR) on horses has been minimal, yet the planned HSR routes in California pass through areas with equine populations on ranches and in recreational areas. Researchers at the Mineta Transportation Institute, San Jose State University, conducted a literature review and contacted individuals with experience in HSR projects or horses to help corroborate findings; they also mapped equestrian trails, trail access points, and boarding facilities to show the density and locations of California's equine populations and activities.

Theoretically, researchers stated, noise levels of 100 dBA sound exposure level can harm horses; Federal Railway Administration guidelines already screen for conflicts at that decibel level and all existing HSR lines operate below it. Loud noises are known to startle horses, which can lead to negative effects for horses and riders, but the specific amount of noise needed to startle a horse has not been measured.

Researchers noted that the few studies that explicitly addressed conflicts between noise and equines uniformly concluded that horses tend to habituate to noises that are regularly repeated; however, this response pattern has not been tested with train noise.

To read the full report, visit http://transweb.sjsu.edu/PDFs/research/1427-high-speed-rail-and-equine-issues. pdf.

Adjusting Signals to Prevent Red-Light Running Crashes

Red-light running (RLR) crashes that occur during signal phase transitions can be mitigated with red clearance extension—that is, extending the all-red clearance interval if an RLR vehicle is detected. Using a literature review, large-scale field study, and VISSIM hardware-in-the-loop (HIL) simulation, researchers at the Oregon Department of Transportation evaluated three extension system alternatives.

The field study took place at five Oregon intersections that had high rates of RLR vehicles. Researchers recorded nearly 150 hours of video footage to understand driver behavior in response to the onset of the yellow change interval on major approaches and the green indication on minor approaches. The video data, along with signal timings, geometries, peak volumes, and operating speeds, were used to calibrate an HIL simulation of one intersection. The simulation then was used to code and evaluate the performances of three alternative red light extension systems: the downstream detection (DD) alternative, which Oregon DOT currently uses; the smart upstream speed-conditional detection (SUSCD) alternative, set at 215 ft from the intersection; and the SUSCD at 475 ft.

The DD system successfully detected 67 percent of vehicles with a high risk of collision; its utility in triggering a correct red-light extension—that is, one that allowed the vehicle to clear the intersection—was 38.6 percent, with an average vehicle delay of 13.08 seconds. At 215 feet, the SUSCD system successfully detected 23.1 percent of high-risk vehicles, with correct red-light extensions only 18 percent of the time and an average vehicle delay of 13.1 seconds. The SUSCD system at 475 feet successfully detected 49.3 percent of RLR vehicles, with 8.5 percent of them correct RLE events.

Although the DD alternative was more accurate than the SUSCD systems, the SUSCD systems—which had to predict RLR vehicles rather than simply detect them—were more efficient. The rate of highly effective correct extensions for the DD system was approximately 18 percent but was almost 100 percent for the SUSCD systems.

To read the full report, visit www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/2016/SPR773_Smart_Red_Clearance.pdf.

ACADEMIES HONOR BARBER-GRAY AND BRACH—At a National Academies of Sciences, Engineering, and Medicine awards ceremony on December 15, 2015, Phyllis Barber-Gray—(*at left*) with Clayton Daniel Mote, Jr., President, National Academy of Engineering, and Ralph Cicerone, President, National Academy of Sciences—was recognized for her more than 50 years of service to TRB. Ann Brach (*at right, with Cicerone*) received the Best in a Leading Role award for her guidance of the second Strategic Highway Research Program.

COOPERATIVE RESEARCH PROGRAMS NEWS

Supporting Transitions to New Technologies

The following active Cooperative Research Programs projects address vehicle and machine automation and intelligent transportation systems (ITS) issues:

◆ **Automated Machine Guidance in the Transportation Industry**

Automated machine guidance (AMG) links sophisticated design software with construction equipment to operate machinery with high levels of precision, improving speed and accuracy in transportation construction and eliminating guesswork, manual control, and labor involved in traditional methods.

Iowa State University received a $350,000 contract [National Cooperative Highway Research Program (NCHRP) Project 10-77] to develop guidelines for the use of AMG technology for state transportation agency construction projects. The final report currently is under review.

For more information, contact David A. Reynaud at 202-334-1695 or dreynaud@nas.edu.

◆ **Impacts of Connected and Automated Vehicles on Transportation Agencies**

Connected vehicles and automated vehicles are different technologies—particularly as private-sector developments progress—but some of the challenges they present to transportation agencies are similar. NCHRP Project 20-24(98), "A Connected–Automated Vehicle Research Roadmap for AASHTO," produced a draft research plan for addressing connected vehicle–automated vehicle (CV-AV) issues.

Booz Allen Hamilton, Kimley-Horn and Associates, Texas A&M Transportation Institute, and Virginia Tech Transportation Institute have received a $2 million contract (NCHRP Project 20-102, FY 2015 and FY 2016) to identify critical issues in CV-AV that state and local transportation agencies and AASHTO will face, conduct research to address those issues, and carry out activities related to technology transfer and information exchange.

For more information, contact B. Ray Derr at 202-334-3231 or rderr@nas.edu.

◆ **Transportation Agency Infrastructure Technology and Connected Vehicles**

Many transportation agencies have invested in ITS technologies to support advanced management and operation strategies; the deciding factors were the identification of safety and mobility benefits and the ease of integration with existing technologies. Tools developed by the second Strategic Highway Research Program, the U.S. Department of Transportation, and state agencies can estimate system performance and assess the impacts of advanced technologies and strategies on performance.

Florida International University has received a $99,000 contract (NCHRP Project NCHRP 20-07, Task 376) to develop a framework supporting transportation agency decisions on ITS infrastructure—particularly on legacy systems—considering the deployment of vehicle-to-infrastructure systems.

For more information, contact B. Ray Derr at 202-334-3231 or rderr@nas.edu.

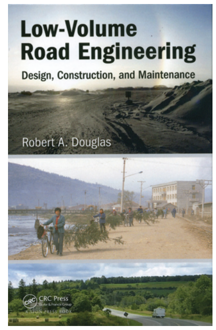
◆ **Developing an ITS Technology Web Portal for Transit System Leaders**

In many transit agencies, individual business units procure and use ITS in stand-alone mode, limiting the ability to benefit a range of business areas. Internal procedures can help integrate available ITS technologies into legacy systems, open data sources, and transparent structures—leading the creative, effective, and efficient distribution of information.

To assist transit leaders in understanding ITS technologies, the American Public Transportation Association (APTA) plans to host a resource for transit system leaders on the APTA website. The Tech Portal would help transit system leaders understand current and emerging technology and communicate about deployment. ConSysTec has received $100,000 (Transit Cooperative Research Program Project G-13) to develop content and structure for this web-based knowledge portal.

For more information, contact Lawrence D. Goldstein at 202-334-1866 or lgoldstein@nas.edu.

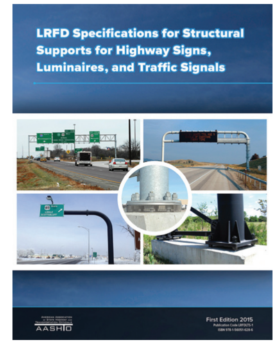
BOOK SHELF



Low-Volume Road Engineering

Robert A. Douglas. CRC Press, 2016; 326 pp.; hardback, $118.96; e-book, $97.97; 978-1-48221-263-1.

This volume offers an international perspective on the engineering design of low-volume roads and their construction and maintenance. Topics addressed include road location and geometric design, pavement design, slope stability and erosion control, construction, maintenance, and geosynthetics. Also examined are low-volume road standards and practices in the United States, Canada, the United Kingdom, South Africa, Australia, and New Zealand. The author, a senior geotechnical engineer in Ontario, served on the TRB Standing Committee on Low-Volume Roads from 2004 to 2014.



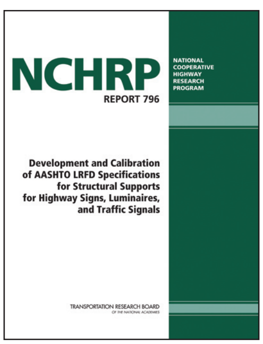
Load and Resistance Factor Design (LRFD) Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, 1st Edition

American Association of State Highway and Transportation Officials (AASHTO), 2015; 436 pp.; AASHTO members, $240; nonmembers, $312; 978-1-56051-628-6.

This first edition supersedes the *Sixth Edition of Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*, incorporating and expanding the design specifications. Included are new sections on fabrication, construction, and more; current research on LRFD calibration, loads, and resistances; and relevant specifications from other AASHTO documents.

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

TRB PUBLICATIONS



Development and Calibration of AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals
NCHRP Report 796

This report provides specifications for structural supports of highway signs, luminaires, and traffic signals for inclusion in the AASHTO LRFD methodology.

2014; 123 pp.; TRB affiliates, $45.75; nonaffiliates, $61. Subscriber category: bridges and other structures.

Guidebook on Pedestrian and Bicycle Volume Data Collection
NCHRP Report 797

Presented are methods and technologies for counting pedestrians and bicyclists, guidance on developing a nonmotorized count program, and examples of how organizations have used nonmotorized count data.

2014; 159 pp.; TRB affiliates, $53.25; nonaffiliates, $71. Subscriber categories: operations and traffic management, pedestrians and bicyclists, planning and forecasting.

The Role of Planning in a 21st Century State Department of Transportation: Supporting Strategic Decision Making
NCHRP Report 798

This report examines how the planning function in state departments of transportation (DOTs) can more effectively support strategic decision making.

2015; 119 pp.; TRB affiliates, $48; nonaffiliates, $64. Subscriber categories: administration and management, planning and forecasting.

Management Guide to Intellectual Property for State Departments of Transportation
NCHRP Report 799

Guidance is presented for the management of copyrights, patents, and other intellectual property that may be used or produced as part of a DOT's usual business activities.

2015; 151 pp.; TRB affiliates, $53.25; nonaffiliates, $71. Subscriber categories: administration and management, law, research.

Successful Practices in GIS-Based Asset Management
NCHRP Report 800

This report provides guidance for state transportation agencies on using geographic information system (GIS) technologies in transportation asset management.

2015; 157 pp.; TRB affiliates, $50.25; nonaffiliates, $67. Subscriber categories: administration and management, data and information technology, policy.

TRB PUBLICATIONS *(continued)*

Proposed Practice for Alternative Bidding of Highway Drainage Systems
NCHRP Report 801

This report explores the application of a performance-based process for selecting drainage pipe systems. The selection process is based on performance criteria for the drainage system and on consideration of the full range of suitable pipe materials.

2015; 145 pp.; TRB affiliates, $50.25; nonaffiliates, $67. Subscriber categories: construction, hydraulics and hydrology, materials.

Volume Reduction of Highway Runoff in Urban Areas: Guidance Manual
NCHRP Report 802

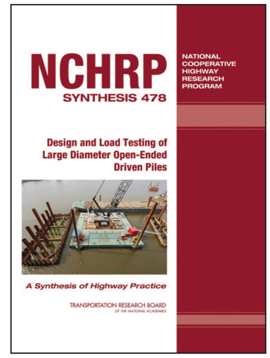
This report explores practices for the reduction of stormwater volumes in urban highway environments, presenting a five-step process for identifying, evaluating, and designing solutions to reduce runoff volume to meet site-specific conditions. An accompanying CD-ROM includes a tool to estimate the performance of volume reduction.

2015; 226 pp.; TRB affiliates, $60.75; nonaffiliates, $81. Subscriber categories: design, environment, hydraulics and hydrology.

Design and Load Testing of Large Diameter Open-Ended Driven Piles
NCHRP Synthesis 478

Documented in this volume are the selection, use, design, construction, and quality control of large-diameter, open-ended driven piles for transportation structures.

2015; 138 pp.; TRB affiliates, $48; nonaffiliates, $64. Subscriber categories: design, highways, materials.



Forecasting Transportation Revenue Sources: Survey of State Practices
NCHRP Synthesis 479

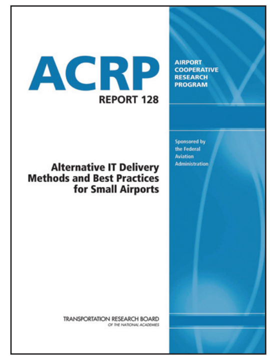
This synthesis documents current and proposed forecasting methodologies, as well as information about the types of revenue being forecasted and DOTs' satisfaction with the accuracy of the projections.

2015; 51 pp.; TRB affiliates, $34.50; nonaffiliates, $46. Subscriber categories: administration and management, economics, finance, highways.

Alternative IT Delivery Methods and Best Practices for Small Airports
ACRP Report 128

Offered in this volume are guidance and templates to help airport staff understand the appropriate IT delivery methods and best practices based on strategic goals and requirements.

2015; 122 pp.; TRB affiliates, $48; nonaffiliates, $64. Subscriber categories: aviation, data and information technology.



Evaluating Methods for Counting Aircraft Operations at Nontowered Airports
ACRP Report 129

This report reviews techniques and technologies applied at airports without air traffic control towers to estimate aircraft operations.

2015; 165 pp.; TRB affiliates, $53.25; nonaffiliates, $71. Subscriber categories: aviation, planning and forecasting.

Guidebook for Airport Terminal Restroom Planning and Design
ACRP Report 130

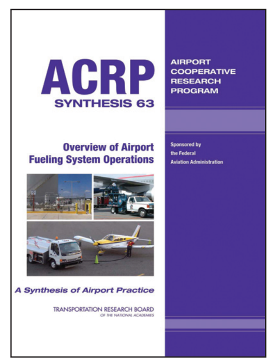
This report explores a process to help airport practitioners plan, design, and implement terminal restroom projects. Appendixes—including a discussion of the restroom of the future—are available online and on the CD-ROM that accompanies the print version of the report.

2015; 85 pp.; TRB affiliates, $51; nonaffiliates, $68. Subscriber categories: aviation, terminals and facilities.

Overview of Airport Fueling Operations
ACRP Synthesis 63

This synthesis addresses fueling standards and regulations as well as common operations and components, and serves as a reference for several fueling processes and procedures.

2015; 119 pp.; TRB affiliates, $45.75; nonaffiliates, $61. Subscriber categories: aviation, operations and traffic management.



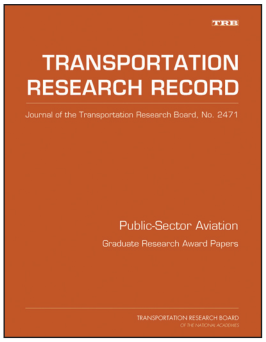
Issues Related to Accommodating Animals Traveling Through Airports
ACRP Synthesis 64

Presented in this volume are ways for airports to develop a coordinated approach to animal transportation that accommodates the well-being of animals traveling through airports.

2015; 85 pp.; TRB affiliates, $41.25; nonaffiliates, $55. Subscriber categories: aviation, operations and traffic management.

To order TRB titles described in Bookshelf, visit the TRB online Bookstore at www.TRB. org/bookstore/ or contact the Business Office at 202-334-3213.

TRB PUBLICATIONS *(continued)*



Public-Sector Aviation
Transportation Research Record 2471

The papers in this volume, winners of a nationwide competition for graduate research in aviation, address U.S. civil air show crashes, airport infrastructure investment, airport traffic and metropolitan economies, and more.

2015; 81 pp.; TRB affiliates, $42.75; nonaffiliates, $57. Subscriber category: aviation.

Low-Volume Roads 2015, Volumes 1–3
Transportation Research Record 2472, 2473, and 2474

Subjects related to low-volume roads all over the world are examined in these volumes, from safety treatment of trees to dust control on unpaved roads to implementing a strain-based policy for managing weight restrictions.

2015; Vol. 1, 242 pp.; TRB affiliates, $66.75; nonaffiliates, $89. Vol. 2, 249 pp.; TRB affiliates, $63; nonaffiliates, $84. Vol. 3, 224 pp.; TRB affiliates, $60.75; nonaffiliates, $81. Subscriber categories: Vol. 1; safety and human factors, design, environment; Vol. 2; geotechnology, maintenance and preservation, materials; Vol. 3; pavements, materials, construction.

Railroads; Freight and Passenger Systems, Volumes 1–2
Transportation Research Record 2475 and 2476

Dynamic demand forecasting and ticket assignment for high-speed rail, light rail crossing safety performance functions, and maintenance and replacement of railroad timbers and concrete crossties are among the topics explored in these volumes.

2015; Vol. 1, 112 pp.; TRB affiliates, $48; nonaffiliates, $64. Vol. 2, 144 pp.; TRB affiliates, $50.25; nonaffiliates, $67. Subscriber categories: Vol. 1; rail, freight transportation, passenger transportation; Vol. 2; rail, design, safety and human factors.

Freight Systems, Volumes 1–2
Transportation Research Record 2477 and 2478

Authors present research on estimation of seasonal daily traffic flow of agricultural products and implications, budgeting fuel consumption of container ships, a case study of logging trucks, and more.

2015; Vol. 1, 116 pp.; TRB affiliates, $48; nonaffiliates, $64. Vol. 2, 140 pp.; TRB affiliates, $50.25; nonaffiliates, $67. Subscriber categories: Vol. 1; freight transportation, economics, planning and forecasting; Vol. 2; freight transportation, motor carriers, planning and forecasting.

Marine Transportation, Port Operations, and Intermodal Freight
Transportation Research Record 2479

Topics covered in this volume include the adoption of liquefied natural gas as a fuel for shipping on the Great Lakes, vessel route choice theory and modeling, and the environmental balance of shipping emissions reduction strategies.

2015; 100 pp.; TRB affiliates, $45.75; nonaffiliates, $61. Subscriber categories: marine transportation, freight transportation, terminals and facilities.

Research and Education
Transportation Research Record 2480

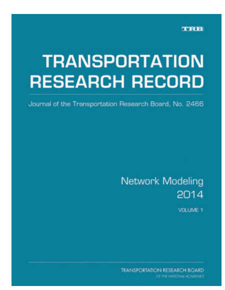
Opportunities for enhancing construction education and student internships with multimedia tools, the inverted classroom and its influence on student attitudes, and a multiagent route choice game for transportation engineering are presented in this volume.

2015; 72 pp.; TRB affiliates, $41.25; nonaffiliates, $55. Subscriber categories: research, education and training.

The TRR Journal Online website provides electronic access to the full text of approximately 15,000 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.*

In the interests of space, the summaries of *Transportation Research Record: Journal of the Transportation Research Board* volumes have restarted with titles published in 2015. For summaries and pricing of the 2014 volumes listed below, see www.trb.org/Publications/PubsTRRJournalPrint.aspx:

- Transportation Research Record 2466: *Network Modeling, Vol. 1*;
- Transportation Research Record 2467: *Network Modeling, Vol. 2*;
- Transportation Research Record 2468: *Bicycles and Motorcycles;*
- Transportation Research Record 2469: *Demand Management, Parking, Taxis, and Accessible Transportation and Mobility;* and
- Transportation Research Record 2470: *Freeway Operations*.



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.

SUBMISSION REQUIREMENTS: Manuscripts submitted for possible publication in *TR News* and any correspondence on editorial matters should be sent to the Director, Publications Office, Transportation Research Board, 500 Fifth Street, NW, Washington, DC 20001, telephone 202-334-2972, or e-mail jawan@nas.edu.

◆ 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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