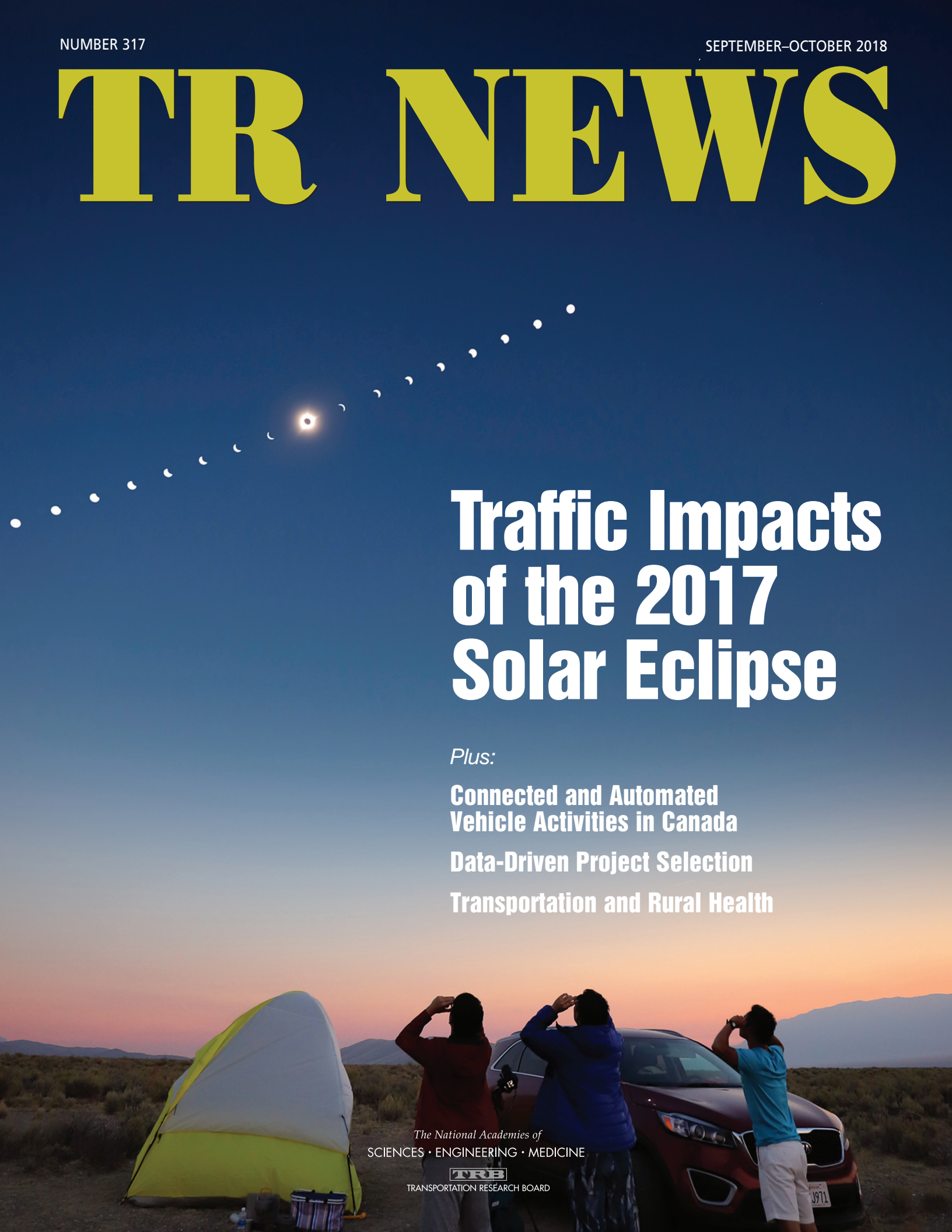
NUMBER 317

SEPTEMBER–OCTOBER 2018

TR NEWS



Traffic Impacts of the 2017 Solar Eclipse

Plus:

Connected and Automated Vehicle Activities in Canada

Data-Driven Project Selection

Transportation and Rural Health

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The National Academies of
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COVER: Without clouds to obscure the eclipse and deter potential travelers, August 21, 2017, saw large crowds gathering at many viewing sites. (Photo: Eddie Yip, Flickr)

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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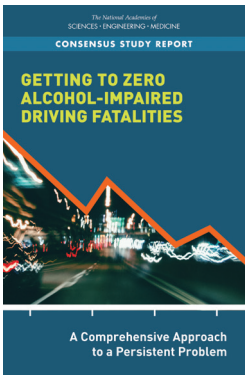


Image: National Academies Press

To combat the deadliest, costliest danger on U.S. roads—alcohol-impaired driving—a study committee of the Health and Medicine Division of the National Academies of Sciences, Engineering, and Medicine identified evidence-based, promising interventions to reduce fatalities caused by alcohol-impaired driving in the United States. The November–December 2018 issue of *TR News* will feature an article on the study, particularly its findings on alcohol-impaired driving interventions. Other articles will present information on TRB forums and international events highlighting automated vehicles, the U.S. Department of Transportation's Disadvantaged Business Enterprise Program, and transportation-related noise research.

The report *Getting to Zero: Alcohol-Impaired Driving Fatalities* examines the programs, systems, and policies that have the most promise in preventing injuries and death from alcohol-impaired driving.

Photo: Alison Tagert-Barone, National Park Service

Millions of people flocked to viewing sites like this one at Homestead National Monument in Nebraska to watch the 2017 total solar eclipse. The concentrated traffic created gridlock on roads across the country.

Total Solar Eclipse on August 21, 2017

Special Event with Coast-to-Coast Traffic Congestion

JONATHAN UPCHURCH

The author is a transportation engineering consultant based in Ivins, Utah, and Professor Emeritus at Arizona State University, Tempe.

The August 21, 2017, total solar eclipse was a special event unlike any other. Millions of visitors traveled to and from the narrow path of totality that extended across the United States, congesting the transportation network. Successfully managing traffic and parking was a major challenge for those who planned for and carried out the day's event management.

The millions of people drawn to locations along the eclipse path taxed limited transportation facilities, and traffic congestion was intense in many locations. Across the country, Interstate highways near the path of totality experienced traffic congestion shortly after the eclipse, with longer-than-normal travel times on Interstate highways. For example, travel from Casper, Wyoming, to Denver, Colorado—normally a 4-hour trip—took 10 hours or more. Traffic congestion on rural Interstate routes lasted for up to 13 hours after the eclipse.

Although transportation professionals have been conducting special-event traffic management for decades, this event was unusual. As the first total solar eclipse visible in the mainland United States since 1979, it was a very rare event and most agencies

Eclipse enthusiasts ride Amtrak's Southwest Chief from New Mexico to Missouri, near the path of totality. Amtrak ran several special trains tailored to the event.

Photo: Malcom K. Flickr

had no experience planning anything like it. Passing through 12 states from Oregon to South Carolina, the eclipse's path was linear in extent, with watchers concentrated around the centerline of the path. The event attracted enthusiastic eclipse watchers from around the world, called "eclipse chasers."

The eclipse lasted for a very short period—between 2 and 3 minutes for the length of totality—and although the arrival times of observers varied, their departure times were concentrated in a much smaller window. These factors combined to bring together large numbers of viewers and vehicles in small areas.

Forecasting traffic demand for this event was exceedingly difficult, but lodging facilities sold out a year in advance along much of the eclipse path—indicating that many areas would see huge influxes of people and vehicles. Some areas reached capacity and closed to inbound traffic before the eclipse even occurred.

Lessons Learned

Although the August 21, 2017, total solar eclipse was the first in the mainland United States in 38 years, the next eclipse is less than 6 years away—on April 8, 2024—and its path stretches from Texas to New England. The lessons learned in the 2017 eclipse can help transportation agencies better prepare for the 2024 eclipse. These findings include the following:

◆ **Huge numbers of viewers traveled to the path of totality**. The best estimate is that at least 5 million people traveled. See page 7 for more information on this estimate.

◆ **Almost all viewers traveled to the path of totality by motor vehicle**. Amtrak ran a special solar eclipse train from Chicago to Carbondale, Illinois. Some viewers flew via private or charter aircraft to airports within the path of totality. Although some small airports were concerned that they might run out of aircraft parking space, there are no known instances of this occurring. Some viewers flew commercial flights to nearby airports and drove to the path of totality. According to many anecdotes, seats on outbound flights from nearby commercial airports were unavailable after the eclipse.

◆ **Roadways experienced very little traffic congestion on the days leading up to totality**. The eclipse occurred on a Monday. Travel to the path of totality was spread over multiple days.

◆ **A major, immediate, post-eclipse exodus on Monday created traffic congestion on roadways leading away from the path of totality all across the United States**. The messaging used by many agencies was "arrive early, stay late." Although arrivals spread over multiple days, a large majority of eclipse watchers departed the same day. Some waited until Tuesday for their return trip; correspondingly, traffic levels were lower then. For example, the number of travelers heading south from eastern Wyoming to Colorado on Tuesday was 41 percent of the number of travelers on that route on Monday.

◆ **In the hours immediately following totality, almost every Interstate route passing through the**

path of totality showed red on Google Traffic maps. The screenshot from Google Traffic on page 9 was taken at approximately 3:30 p.m. EDT, about 45 minutes after the end of totality and well before the peak-period traffic congestion normally expected in the evening. Note that major urban areas outside the path of totality do not show traffic congestion.

◆ **On some Interstate routes, traffic congestion, slow speeds, and long travel times lingered for up to 13 hours after totality**. The headline at right, from the Lexington Herald-Leader in Kentucky, sums it up: "The rare eclipse was memorable. The ride home was something they want to forget."

◆ **Rural, nonfreeway routes also experienced significant traffic congestion, slow speeds, and long travel times**. An analysis by INRIX showed that four of the top five post-eclipse bottleneck locations, measured by duration and length of queue, were on nonfreeway routes. These four locations had congestion durations lasting from 7 to 15.5 hours; the maximum queue lengths at three locations ranged from 45 to 70 miles.

◆ **Evidence from three freeway locations, both urban and rural, showed that traffic flow on Monday afternoon degenerated to forced-flow, level-of-service-F conditions**. These facilities were not operating at anywhere near their capacity, which under ideal conditions is approximately 2,400 passenger cars per hour per lane. Average travel speed was about 20–30 mph and throughput was 1,000–1,500 vehicles per hour per lane.

◆ **Many state departments of transportation with roadways in the path of totality worked hard to minimize freeway lane closures for construction or maintenance**. If lane closures had not been minimized, congestion would have been much more severe.

◆ **Anecdotal and media accounts show that even some states not in the path of totality experienced increased freeway traffic congestion**. According to accounts, some nearby states allowed lane closures on August 21, causing congestion problems. The moral of the story is to prepare for increased traffic, even in areas far from the path of totality.

◆ **State transportation agencies worked hard on public messaging and communications**. Messages

Photo Courtesy Jonathan Upchurch

Western Kentucky Parkway eclipse traffic near Elizabethtown at 7:45 p.m. Monday, long after the eclipse ended. Steven Townsend Facebook post

STATE

The rare eclipse was memorable. The ride home was something they want to forget.

BY MIKE STUNSON
mstunson@herald-leader.com

August 22, 2017 11:37 AM
Updated August 23, 2017 12:08 PM

Photo: Jonathan Upchurch

A changeable message sign on I-15 in Utah warns of traffic delays related to the eclipse.

Cars crawl along I-15 in Idaho on the day of the eclipse.

Photo: Daniel Case, Wikimedia

about roadway safety—for example, "No Parking on Highway for Solar Eclipse" signs—were widespread, as were reminders to wear protective eyewear, expect traffic congestion, and to arrive early and stay late. These messages may have helped to spread out arrivals. These messages were displayed on changeable message signs and disseminated via other communication avenues. In 2024, stronger efforts to urge viewers to stay put and stay late can help deter the extreme post-eclipse peaking that occurred in 2017.

◆ **State and local agencies** deployed large numbers of service vehicles to respond to incidents and large numbers of flaggers and police to direct traffic at bottleneck locations.

◆ **To see the eclipse, viewers will position themselves at any location they believe to be legal**. These locations include highway rest areas, public lands, parks, and roadsides on lower-volume roads. Many venues were established to host eclipse viewers, including university stadiums, eclipse festivals, and parks. Vehicle parking is necessary at every location. Although rest facilities are not usually a transportation issue, viewers do need bathrooms wherever they choose to view the eclipse. Many transportation agencies deployed portable toilets at widespread locations.

◆ **The April 8, 2024, total solar eclipse may attract even greater interest than the August 21 event**. At the 2018 TRB Annual Meeting, an informal "show of hands" poll at a session on the August 21 eclipse asked two questions: 1) did you see totality on August 21 and 2) if so, are you intent on seeing

Photo: Eddie Yip, Flickr

Eclipse campers in Idaho. Although many public venues hosted organized gatherings, some viewers chose out-of-the-way locations. These had less traffic, but fewer facilities.

totality on April 8, 2024? Almost every person who raised their hand for the first question also raised their hand for the second question. Many first-time viewers will attend the 2024 eclipse because of what they heard from those who saw the eclipse in 2017. The event also will have a high number of repeat participants.

◆ **Most of the path of totality was cloud-free on August 21; in only a few locations, travelers were deterred by cloudy skies**. For the April 8, 2024, eclipse, planners need to assume that skies also will be clear and to prepare for large numbers of vehicles and people.

◆ **Attractions in and near the path of totality can expect high visitation on days before and after an eclipse**. For example, Yellowstone National Park had to close the entrance to Old Faithful and its 1,000-space parking lot on both Tuesday and Wednesday after the eclipse because the parking lot had filled.

◆ **For the April 8, 2024, event, border crossings between upstate New York and Canada and upper New England and Canada may be much higher than usual**. Canadians may want to enter New York to be closer to the centerline and to experience longer totality. Viewers on either side of the U.S.–Canada border may be searching for clear skies that are not available in their home country.

How Many People Traveled?

It was exceptionally difficult to predict the number of viewers who would travel to the path of totality. It had been 38 years since the last total solar eclipse on the U.S. mainland, so transportation agencies and others had no recent experience to draw upon.

A forecast model was created by Michael Zeiler, an employee of ESRI and the creator of the Great AmericanEclipse.com website. Using GIS tools, census data, and a road-network model of every street in the lower 48 states, Zeiler estimated that between 1.8 and 7.4 million people would travel to the path of totality. He also estimated the number of people who would travel to specific locations all along the path of totality.[1]

To document the actual numbers of people who traveled to the eclipse, the author of this article sought data from traffic-counting stations in Wyoming and Idaho. That data created a good estimate of actual numbers for those locations. Like all states, both Wyoming and Idaho have extensive networks of traffic-counting stations on the roadway system. The analysis utilized hourly traffic count data from selected dates before, after, and on August 21, 2017.

[1] Additional information on Zeiler's model can be found at www.greatamericaneclipse.com/statistics.

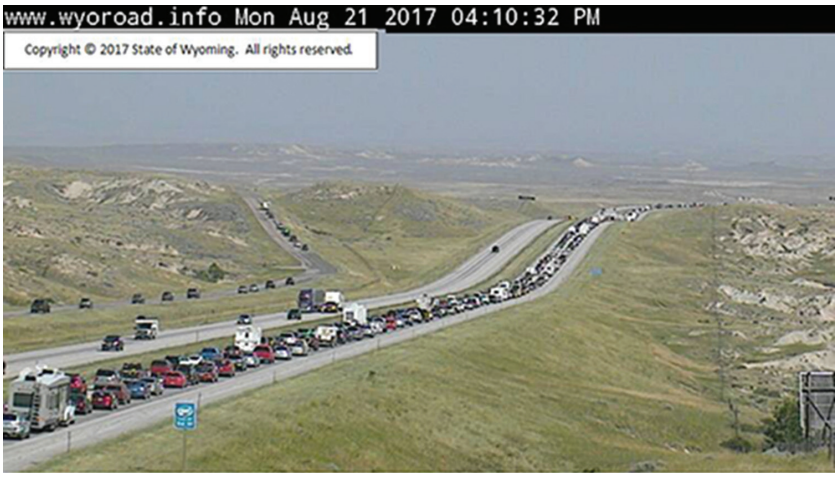


Photo: Wyoming DOT

A traffic camera captures the traffic congestion on I-25 on August 21, 2017.

Wyoming

The path of totality in Wyoming stretched from near Jackson in northwestern Wyoming to just north of Torrington in eastern Wyoming. Many eclipse observers traveled from the more-populated Front Range in Colorado (a population of more than 4 million) to points in eastern Wyoming. I-25 was the primary facility serving this population.

The author's analysis focused on post-eclipse traffic. Although a huge exodus occurred immediately after the eclipse, a significant number of eclipse viewers waited until the following day, Tuesday, August 22, to leave the eclipse path.

I-25 was the most heavily traveled route from the path of totality in eastern Wyoming to population centers along Colorado's Front Range. The generally east–west alignment of I-25 from Casper to Douglas to Glendo was located near the centerline of the path of totality. From Glendo, I-25 heads south toward Cheyenne and Colorado. All of I-25 is a four-lane

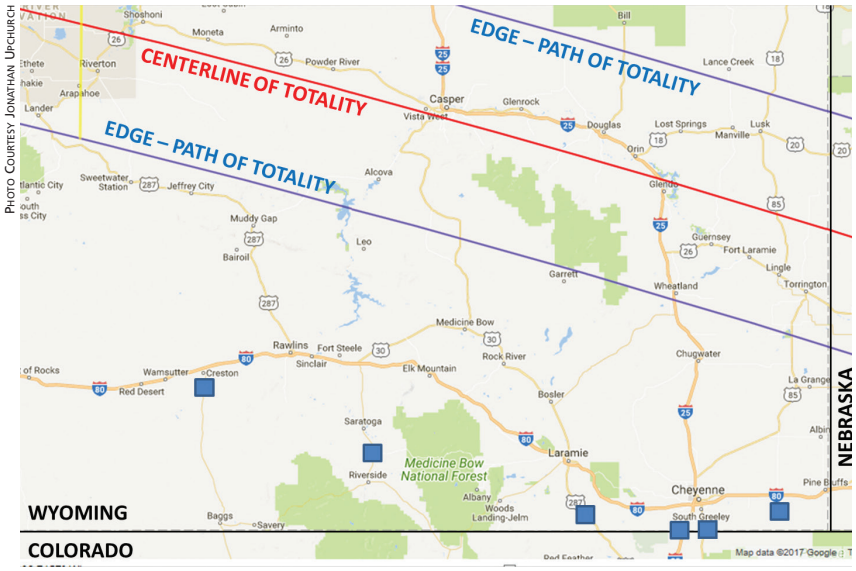


Photo Courtesy Jonathan Upchurch

Path of totality in eastern Wyoming and locations of traffic counting stations.

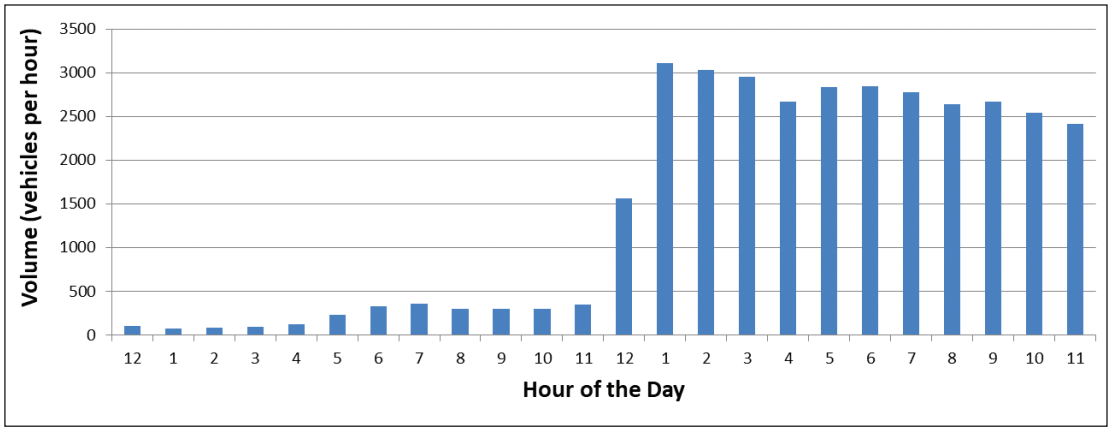


FIGURE 1 Southbound hourly traffic volume at I-25's Milepost 1 in Wyoming, August 21, 2017.

divided freeway, from Casper to Colorado.

Normally, the 278-mile trip from Casper to Denver on I-25 is approximately 4 hours driving time. After the eclipse on August 21, media commentaries and anecdotal accounts reported travel times of up to 10 hours from Casper to northern Colorado. A review of I-25 southbound traffic count data shows very heavy traffic volumes from noon until 1:00 a.m. the following morning. The traffic counting station at Milepost 1, 1 mile north of the Colorado–Wyoming state line, showed that volume jumped from 351 at 11:00 a.m., to 1,565 at noon, to 3,114 at 1:00 p.m. (Figure 1). Traffic volumes then declined slowly, to 2,303 vehicles per hour after midnight. Media accounts reported that traffic speeds from early afternoon to late night were very slow.

Using the Screenline A screenline is an imaginary line on a map that can be used to count traffic going from one side of the line to the other. A screenline was created covering the eastern half of Wyoming along the Wyoming–Colorado border, from Wyoming Route 789 on the west to the Nebraska border on the east. Unlike in the central and eastern United States, the roadway network in Wyoming consists of a small number of widely separated state highways. No other paved roadways offer alternative routes between these state highways. The roadway network is sparse and may lack the capacity for an event like the eclipse.

Traffic counts were available from six traffic-counting stations along this screenline at locations that would have captured almost all of the post-eclipse southbound traffic in the eastern half of Wyoming. Hourly traffic counts for the southbound direction, beginning at noon on Monday, August 21, and ending at 9:59 p.m. on Tuesday, August 22, were scrutinized.[2] This period captured the exodus of people headed south from the path of totality.

For each hour, the hourly count on August 21 was compared to the average of the hourly counts during the same hour on the preceding four Mondays and on the one following Monday, all acting as a baseline for comparison. August 22 hourly counts were compared in a similar way. Hourly counts, beginning at 10:00 a.m. on Monday, August 21, and ending at 10:00 p.m. on Tuesday, August 22, are depicted in red in Figure 2, which depicts the traffic volumes for all six traffic-counting stations combined. The baseline volumes on the comparison dates are shown in blue.

Analysis Southbound traffic counts on Monday (noon to midnight) were 48,275 vehicles higher than the baseline. Southbound counts on Tuesday (midnight to 9:59 p.m.) were 19,789 vehicles higher than

[2] Totality ended in eastern Wyoming at approximately 11:45 a.m. on Monday.

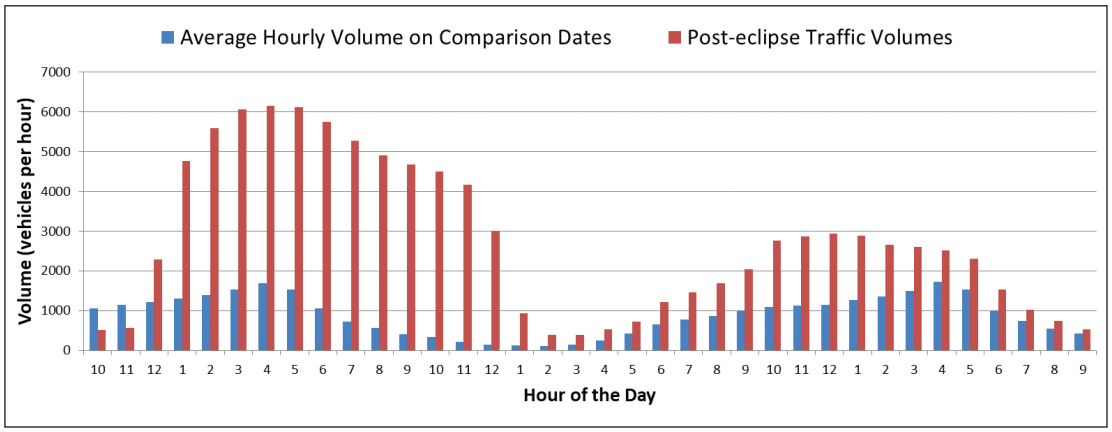


FIGURE 2 Southbound hourly traffic volume (red) in Screenline, Wyoming, August 21–22, 2017, versus comparison dates (blue).

the baseline. The combined total for both days was 68,063 extra vehicles—in other words, 68,063 more vehicles passed southbound from Wyoming to Colorado in the 34-hour period following the eclipse than would otherwise have been expected.

It is reasonable to assume that, for eclipse viewing, each vehicle would contain 3.0 persons. Three persons per vehicle × 68,063 vehicles = 204,190 persons who observed the eclipse in eastern Wyoming, coming from locations south of the Wyoming–Colorado border.

It is interesting to compare the above estimate of 204,190 persons with Zeiler's forecast. For the eastern half of Wyoming—the area captured by the traffic count data—Zeiler's high estimate was about 156,400. This included path-of-totality locations from Casper eastward to the Nebraska state line. Zeiler's estimate included visitors coming from both the north and the south, and included visitors from points north of the Wyoming–Colorado border that were not captured by the screenline analysis. Thus, the traffic count–derived estimate of 204,190 visitors greatly exceeds Zeiler's high estimate of 156,400.

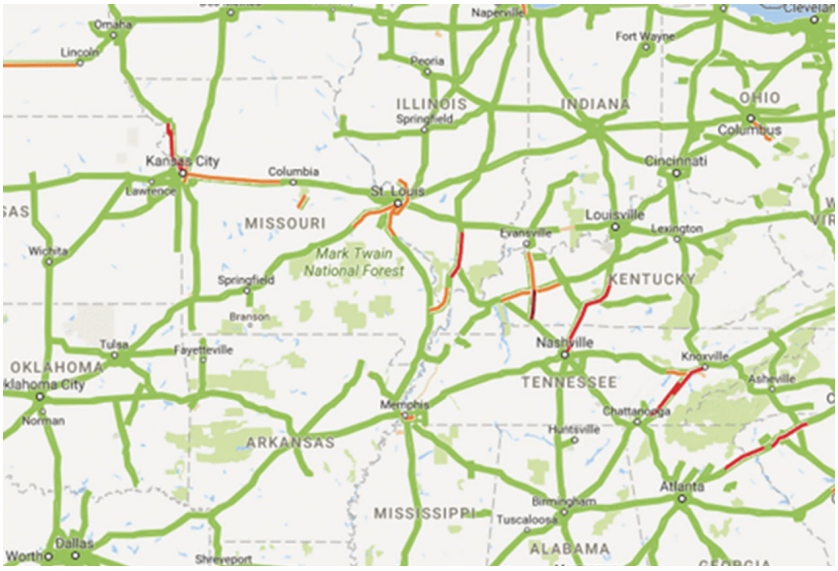
Idaho

A similar analysis was conducted for eastern Idaho, where I-15 brought travelers to the path of totality from the large population center of 2.4 million people along northern Utah's Wasatch Front.

The author's analysis—again based on traffic counts—estimated that 124,204 persons who observed the eclipse in eastern Idaho came from locations south of the Idaho–Utah border. Zeiler estimated that eclipse visitation to eastern Idaho would be between 70,000 and 280,000 persons. The actual, traffic count–derived visitation estimate of 124,204 falls within the range of Zeiler's high and low estimates. It should be noted, however, that Zeiler's estimate included visitors arriving from both the north and south as well as those who originated between the Idaho–Utah border and the path of totality.

Estimation of 2017 Viewing Total

The Wyoming and Idaho traffic counts provide two comparisons with Zeiler's estimates. In Wyoming, actual visitation was higher than Zeiler's high estimate. In Idaho, actual visitation was within the range of Zeiler's high and low estimates. If the Wyoming and Idaho experiences are representative of those of the other states—and noting Zeiler's estimate that nationwide, travelers to the path of totality numbered between 1.8 and 7.4 million—it is reasonable to conclude that at least 5 million people traveled to view totality.



Sections of red, showing slow traffic, in this Google Traffic screenshot on August 21, 2017, follow the path of the total solar eclipse across the Midwest and South.

Looking Ahead to 2024

Transportation professionals have been conducting special-event traffic planning and management for decades—athletic events such as the the Super Bowl, parades, holiday celebrations, and fireworks displays. The 2017 total solar eclipse was unlike any other special event, however. At 5 million participants, it was likely the largest special event in U.S. history. For comparison, 5 million people leaving the path of totality at once is like 71 sellout football games ending at the same time.

Several major population centers are located within a 3-hour drive of the path of totality of the April 8, 2024, solar eclipse. These include the metropolitan areas for Chicago (9.5 million); Houston (6.9 million); Toronto (6.4 million), Ontario, Canada; Boston (4.8 million); Detroit (4.3 million); St. Louis (2.8 million); Pittsburgh (2.3 million); and Cincinnati (2.2 million). Lessons learned from August 21, 2017—along with an understanding that viewers will travel in large numbers—can help transportation agencies be better prepared for the 2024 total solar eclipse.

Photo: Jonathan Upchurch

Eclipse totality.

PHOTOS: UNIVERSITY OF WATERLOO

Connected and Automated Vehicle Activities in Canada

GARRETH REMPEL AND DAVID MICHELSON

Rempel is CEO, TRAINFO, Winnipeg, Manitoba, Canada, and Michelson is Professor, Department of Electrical and Computer Engineering, University of British Columbia, Vancouver, Canada.

University of Waterloo graduate student researchers at work on Autonomoose. Canada is developing policy, technology, and infrastructure to advance automated and connected vehicles.

Like other countries, Canada is preparing for the vast potential and complex challenges of connected and automated vehicles (CAVs) and the transformative changes in transportation that these vehicles are expected to enable. Although it is not an exhaustive account, this article describes the development of national policies, regulatory approaches, and standards to ensure that these vehicles can operate across jurisdictional boundaries in Canada and the United States. Also addressed are research and development to advance CAV technologies; legislative changes to allow automated vehicle (AV) testing on public roads; and collaborative partnerships between public agencies, private companies, and academic institutions to conduct CAV pilot tests.

National Activities

National activities are those led by the federal government or national-level associations (see sidebar, page 15). The main federal government activities in Canada include

- Developing a national strategy to address vehicle safety, cybersecurity, and privacy issues;
- Working with the United States to devise standards and regulations facilitating innovation, aiding in the safe deployment of automated features, and ensuring the interoperable deployment of connected vehicles (CVs);
- Developing policy and guidance for testing CAVs in Canada;
- Conducting research and development; and

◆ Establishing funding programs to support CAV testing and deployment.

National-level organizations dealing with CAVs include the Transportation Association of Canada (TAC), Intelligent Transportation Systems (ITS) Canada, the Canadian Council of Motor Transport Administrators (CCMTA), and the Policy and Planning Support Committee under the Council of Deputy Ministers Responsible for Transportation and Highway Safety, among others. Each organization administers a committee dedicated to CAVs.

National Strategy Development

The Standing Senate Committee on Transport and Communications, part of the Senate of Canada, conducted a recent study on CAVs to understand how this technology will affect Canada and to identify the regulatory and technical issues associated with its deployment. In January 2018, the committee released the study report *Driving Change: Technology and the Future of the Automated Vehicle*.

Among the study's 16 recommendations were for Transport Canada and for Innovation, Science, and Economic Development (ISED) Canada to establish a joint policy unit that would coordinate federal efforts and implement a national strategy on CAVs, addressing issues of vehicle safety, cybersecurity, and privacy.

Working with international governments through the United Nations Economic Commission for Europe Working Party on Automated/Autonomous and Connected Vehicles, Transport Canada is developing guidelines and regulatory requirements that facilitate innovation and to aid in the safe deployment of automated features.

Regulatory Development

In 2011, Transport Canada and the U.S. Department of Transportation (DOT) established the Canada–U.S. Regulatory Cooperation Council to enable collaboration between governments and stakeholders and increase regulatory cooperation and alignment. The council's Connected Vehicles Working Group focuses on interoperable deployment of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure communications technology through collaborative standards development, research and testing, information sharing, and implementation activities such as development of security certificate management systems, equipment certification, and cybersecurity.

The working group has developed a four-part work plan to address security, spectrum allocation policy, standards, and information sharing.

PHOTO: PIXABAY

In Canada, the federal government and stakeholders collaborate to address security, standards, and policy; share information; and test the performance of CAVs.

◆ **Initiative 1: CV Cybersecurity, Equipment Certification, and V2V Communications Security** collaborates on policy and technical requirements to develop a cross-border CV security certificate management system proof of concept and to establish certification requirements for CV system components.

◆ **Initiative 2: Spectrum Policy Analysis** identifies opportunities for collaboration and exchange on ITS communications platforms, spectrum allocation, and spectrum policy for CV applications.

◆ **Initiative 3: Standards and Architecture** identifies new or revised standards required to support

Acronyms

ADS	automated driving systems
AV	automated vehicle
AVIN	Autonomous Vehicle Innovation Network
CAV	connected and automated vehicle
CCMTA	Canadian Council of Motor Transport Administrators
CV	connected vehicle
HTA	Highway Traffic Act
ISED	Innovation, Science, and Economic Development Canada
ITS	intelligent transportation system
MACAVO	Municipal Alliance for Connected and Autonomous Vehicles in Ontario
OGRA	Ontario Good Roads Association
TAC	Transportation Association of Canada
V2V	vehicle-to-vehicle

Photo: Virginia DOT

Truck platooning uses cooperative adaptive cruise control technology that enables trucks to travel in close formation, relieving congestion and saving fuel.

large-scale CV technology deployment and to integrate detailed Connected Vehicle Reference Implementation Architecture into overall Canada–U.S. national ITS Architecture updates.

◆ **Initiative 4: Information Dissemination and Sharing** engages stakeholders on binational and related international CV issues, such as hosting open public meetings including both Canadian and U.S. stakeholders.

Standards Development

Transport Canada is working with the Standards Council of Canada and CSA Group to survey the standards landscape, engage with stakeholders, and develop a CAV standards roadmap for Canada and, with ITS Canada, is updating the ITS Architecture for Canada to include new tools and CV requirements. Transport Canada also will consult with stakeholders and analyze requirements to advance a security credential management system in Canada to ensure that CVs and infrastructure are tested to performance and security standards.

Policy and Guidance for CAV Testing

Transport Canada and ISED Canada are working with other federal departments and provincial and territorial governments to develop a coherent national approach that facilitates the safe introduction of these technologies on Canadian roads. This includes an aligned approach for the testing and deployment of CAVs on public roads in Canada in the near term—and safe, sustained deployment over the long term.

Guidelines for Trial Organizations

Published by Transport Canada in June, these guidelines are directed at trial organizations and only apply to temporary trials of automated driving systems (ADS) in Canada—not to vehicles permanently deployed in the market.

Trial organizations are companies or organizations that seek to test ADS in Canada. They include original manufacturers of AVs; technology companies; academic or research institutions; and manufacturers of parts, systems, equipment, or components for ADS.

The guidelines promote Canada as a destination for CAV trials; clarify the various roles and responsibilities of federal, provincial, and territorial levels of government involved in facilitating these tests; and establish a set of voluntary minimum safety requirements that trial organizations must follow when operating in Canada. The guidelines take a safety-first approach, but also support innovation by compelling trial organizations to assess a comprehensive range of safety considerations and to declare that they have accounted for these risks when they submit an application for a trial to a province or territory.

Jurisdictional Guidelines for Safe Testing and Deployment of Highly Automated Vehicles

These guidelines, developed by CCMTA with support from Transport Canada—and to be published in 2018—address the administration, regulation, and control of AVs. Created for motor vehicle administrators and law enforcement, these guidelines offer a common approach to the safe testing and deployment of highly automated vehicles, providing strategies for vehicle registration, driver training, testing, and licensing programs; enforcement of traffic laws; and first response to traffic-related incidents.

Specifically, this document contains a set of voluntary guidelines and recommendations for the Canadian jurisdictions that choose to regulate ADS testing and deployment.

Safety Assessment for ADS in Canada

Transport Canada is also developing a safety assessment that focuses on vehicle safety issues not addressed in existing regulations. This assessment will be aligned with similar policy measures in the United States, such as the National Highway Traffic Safety Administration's *Automated Driving Systems 2.0: A Vision for Safety*.

The safety assessment will outline performance outcomes for industry members to consider as they review the safety and security of CAVs to be deployed that are SAE International Level 3 (environment detection) to Level 5 (human driving completely eliminated). The safety assessment offers a flexible tool for manufacturers to manage the safety

of emerging technologies, particularly for aspects that are still too early in development for regulations to be considered.

Research and Development

Researchers from Transport Canada and the University of California, Berkeley's Partners for Advanced Transportation Technology are developing and testing three-truck platooning technology using cooperative adaptive cruise control and CV technology. This joint project, conducted at Transport Canada's Motor Vehicle Test Centre in Blainville, Quebec, specifically involves fuel-economy testing based on SAE International's J1321 Type II procedure to evaluate the fuel-saving benefits of platooning for various aerodynamic tractor trailer configurations.

Program to Advance Connectivity and Automation in the Transportation System

Launched in September 2017 by Transport Canada, this program assists Canada's infrastructure owner–operators—provinces, territories, and municipalities—to prepare for the wider use of CAVs on roads. The program supports research, studies, and technology evaluations; the development of infrastructure codes, standards, and guidance materials; and capacity-building and knowledge-sharing activities through funding and leading studies, research, development, and demonstration projects.

Canadian Associations

Transportation Association of Canada CV/AV Working Group

This working group was created in 2015 to gather and share information with TAC members about CAVs and their impact on traffic operations and management, road safety, infrastructure design and maintenance, and transportation planning. Activities have included organizing webinars, workshops, and conference events; developing CAV project ideas for TAC; and creating a library of technical material.

ITS Canada CV/AV Technical Committee

This committee manages an international Google Group on CAVs and collaborates with other ITS Canada technical committees to ensure that the potential changes caused by these vehicles are considered appropriately within the organization.

CCMTA AV Working Group

This working group was created in 2014 as a forum for Canadian motor transport administrators to collaborate in monitoring emerging AV technology and issues, including regulatory developments in other jurisdictions, ongoing technological changes in the vehicle intelligence industry, the progression of the vehicle manufacturing industry, and the testing phases of the early-adopter jurisdictions.

The group also is developing vehicle policy regarding the administration, regulation, and control of AVs, including both noncommercial and commercial vehicles.

Provincial Activities

Provincial activities are those led by provincial governments or organizations. The main provincial-level activities are introducing legislation to allow testing on public roads; assessing readiness for CAVs; and coordinating research, development, deployment, and testing of CAVs.

Photo courtesy Garreth Rempel

The Transportation Association of Canada's CV/AV Working Group shares information on CAV initiatives via workshops, a technical library, webinars, and more.

Assessing Readiness

In January, the Council of Ministers Responsible for Transportation and Highway Safety released a report titled *The Future of Automated Vehicles in Canada,* which addresses the short-, medium-, and long-term policy implications of the introduction of CAVs on public roads. Written for Canada's Transportation and Road Safety Ministries, the report identifies gaps, opportunities, and ways to encourage cooperation across Canada and internationally.

Additionally, the report finds that the testing, evaluation, deployment, and regulation of AVs in Canada has been loosely coordinated and that, although some research and deployment activities are taking place across the country, many jurisdictions are not prepared to integrate AVs into their transportation systems.

The report offers two recommendations: 1) collaborating with jurisdictions and international partners to align testing and regulatory frameworks and 2) promoting and investing in industry and academia to test and evaluate AV technology on public roads.

Legislative Changes

Provinces are responsible for regulating roadways, and several have proposed or passed legislation to allow AVs. Examples include the provinces of Ontario, Manitoba, and Quebec.

Province of Ontario On January 1, 2016, Ontario became the first province to allow AV testing on public roads by launching a 10-year pilot project under the Highway Traffic Act (HTA). This allows the testing of AVs on all of Ontario's roads by eligible participants under certain conditions. The pilot framework ensures that roads remain safe but also supports economic growth and innovation. The framework also allows the province to establish rules, monitor industry and technology developments, and evaluate the safety of AVs before the vehicles become widely available to the public.

The Ministry of Transportation of Ontario will assess data and information from on-road AV testing, engage stakeholders, and make amendments to the pilot framework as required throughout the project.

Province of Manitoba In 2018, the Manitoba government will bring forward legislative amendments to allow the testing and use of AVs on provincial highways. Like other traffic safety statutes across the country, Manitoba's HTA was based on a human driver in physical control of a vehicle.

As a result, proposed amendments to the HTA would authorize projects for research and testing of vehicles and technologies on Manitoba highways. The long-term goal is to develop regulations that allow the public use of high-level AVs.

Photo: Matthew Henry, Unsplash

Leaside Bridge in Toronto. In 2016 Ontario became the first province to permit on-road testing of AVs.

Province of Quebec In 2018, the Province of Quebec amended its legislation to authorize pilot projects for testing AVs on Quebec roads. The Minister of Quebec sets the rules and conditions for implementation of any pilot project, which may last up to 5 years. The Minister also may offer an exemption from the insurance contribution associated with the authorization to operate a vehicle and set the minimum required amount of liability insurance that guarantees compensation for property damage caused by an automobile.

Research, Development, Deployment, and Testing

Municipal Alliance for Connected and Autonomous Vehicles in Ontario In 2016, the Ontario Good Roads Association (OGRA), through its Municipal Alliance for Connected and Autonomous Vehicles in Ontario (MACAVO), created an initiative for controlled AV testing. Under this initiative, OGRA is establishing a seamless, coordinated Preferred AV Test Corridor between Windsor and Ottawa and is working with several Ontario municipalities to identify preferred roads for AV testing—with an emphasis on municipal roadways.

To date, more than 2,000 centerline km of preferred roadways have been identified. MACAVO will help Ontario municipalities develop a synchronized set of logistics, policies, and communication channels to help advance the CAV industry in Ontario.

Autonomous Vehicle Innovation Network In 2017, the Province of Ontario launched the 5-year, $80 million Autonomous Vehicle Innovation Network (AVIN), which includes a demonstration zone in Stratford; a partnership fund to foster stakeholder collaboration in developing and commercializing CAV technologies; a talent development program to support internships and fellowships for students and recent graduates; and a central hub, or an online destination and specialized team focused on conducting research, sharing information, building connections, and raising awareness among industry, research institutions, and other stakeholders.

AVIN recently announced the creation of six regional technology development sites across the province. Each site will support the development of new technologies and will have a unique focus area: human–machine interface, multimodal and integrated mobility, vehicular networks and communications, vehicle cybersecurity and cross-border technologies, artificial intelligence, and high-definition mapping.

Municipal Activities

Municipal activities are those led by municipal governments or local organizations. Main activities at the municipal level include conducting pilot tests and developing initial plans to prepare for CAVs.

City of Ottawa, Ontario

In 2017, Ottawa became the first Canadian city to test an on-street AV that could communicate with live city infrastructure. Before this test, other AV tests in Canada took place in closed, segregated areas. The city partnered with BlackBerry QNX and its Autonomous Vehicle Innovation Centre to test CAVs in the Kanata North Technology Park, which is home to more than 70 companies in Ottawa's AV ecosystem.

The project involved equipping the test area infrastructure with technology to communicate with AVs via dedicated short-range communication transmitters at traffic signals, repainting street lines, and installing controllable LED street lights. Nokia also is expected to add LTE and 5G capability to the route.

In 2017, the City of Ottawa received funding from Transport Canada and the Ministry of Transportation of Ontario to deliver the Assisted Commercial Vehicle Eco-Driving Pilot Project. This initiative

Canadian Transportation Organizations

Transport Canada
This department, part of Canadian government, is responsible for developing transportation regulations, policies, and services.

Transportation Association of Canada
A not-for-profit, national technical association that focuses on road and highway infrastructure and urban transportation.

ITS Canada
National thought leader on advanced technologies and their application to the Canadian transport system.

Canadian Council of Motor Transport Administrators
Coordinates all matters dealing with the administration, regulation, and control of motor vehicle transportation and highway safety.

Council of Ministers Responsible for Transportation and Highway Safety
This council is one of Transport Canada's consultative mechanisms, not established by legislation, with the provinces and territories.

Innovation, Science, and Economic Development Canada
This organization is responsible for managing Canada's airwaves and overseeing its bankruptcy, incorporation, intellectual property, and measurement systems; providing financing and industry research tools to help businesses develop, import, and export; encouraging scientific research; and protecting and promoting the interests of Canadian consumers.

A meeting of MACAVO.

Photo courtesy Garreth Rempel

uses technology to connect 12 traffic signals with test vehicles along a 6-km stretch of Hunt Club Road between Cleopatra Drive and Uplands Drive. The technology notifies drivers about upcoming traffic signal changes and helps drivers determine optimum speeds to reduce fuel consumption and avoid hard braking.

Commercial vehicles involved in the test received in-vehicle tablets that relayed traffic signal information to drivers. Software and hardware was added to Audi vehicles, with information displayed directly on the dashboard. Testing and data collection has been completed and researchers at Carleton University in Ottawa are analyzing the data to measure fuel consumption reduction.

In Ottawa, a partnership between private and public organizations allowed the city to connect AVs to city infrastructure.

Photo: Pixabay

Cities of Vancouver and Surrey, British Columbia

In 2018, the cities of Vancouver and Surrey were shortlisted for a $50 million award through Infrastructure Canada's Smart City Challenge. Their joint proposal features Canada's first two collision-free, multimodal transportation corridors that link the two cities: the 3.4-km Surrey corridor connects Surrey Memorial Hospital and other key services to a major transit hub and the 2-km Vancouver corridor extends from Granville Island to Science World.

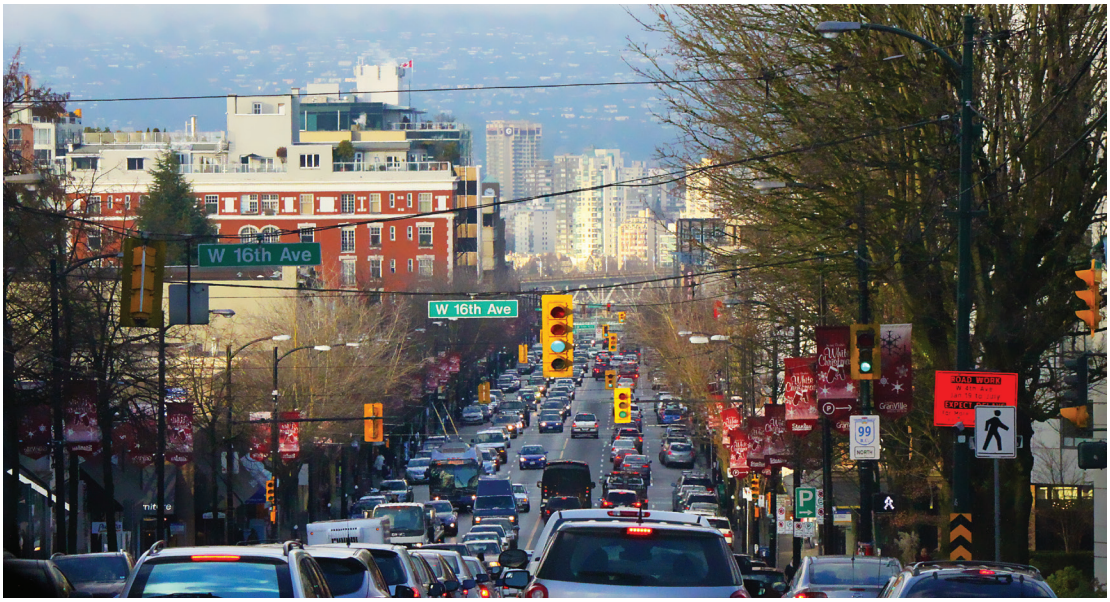
The proposal includes autonomous shuttles along the corridors; sensors in traffic signals, lighting, and other roadway infrastructure to generate data for real-time traffic signal adjustment and communication with AV shuttles; advanced data analytics integrating data from disparate sources to support corridor and AV operations; and enhanced user experiences through shared mobility options and optimizing trip planning.

City of Stratford, Ontario

The AVIN Technology Demonstration Zone in Stratford, Ontario, is operated by the Automotive Parts Manufacturer's Association. At the site, Ontario-based companies with CAV technologies can test, validate, and showcase innovative products to potential customers and partners—automotive suppliers, manufacturers, and original equipment manufacturers.

Performed in a controlled environment in accordance with applicable laws and regulations, the tests use city vehicle fleets and Stratford's connected infrastructure—ubiquitous high-speed Wi-Fi that covers the entire 12-km^2 city.

Photo: Valentina, Flickr



A proposed multimodal transportation corridor through Vancouver includes traffic signal sensors to communicate with vehicles.

City of Edmonton, Alberta

In fall 2018, the City of Edmonton will launch an all-electric AV pilot project that also is open for public testing. The shuttles' driverless technology includes collision-avoidance systems that detect vehicles, cyclists, pedestrians, and obstacles; the vehicles also are equipped with multiple safety features for vehicle braking, entry, and exit.

Each shuttle will have a trained operator onboard who is able to stop the vehicle at any point. The vehicles will operate at a maximum speed of 12 km/h, will include access ramps for mobility-challenged passengers, and will have capacity for 12 passengers.

The city also published a report in 2016, *Planning for Automated Vehicles in Edmonton*, to examine the potential impacts of AVs on passenger travel and land use. The report recommends actions for the city to prepare for AVs.

City of Calgary, Alberta

The City of Calgary is conducting a four-week, low-speed autonomous shuttle pilot to provide a last-mile connection between the Zoo light rail transit station and TELUS Spark Science Centre. Funded through Transport Canada's Program to Advance Connectivity and Automation in the Transportation System, the pilot is a collaboration with the City of Edmonton's project.

The 2017 report *Future of Transportation in Calgary* provides a high-level overview of the key trends occurring in transportation and gives information on what local governments are responsible for, the benefits and risks of each technology, and the best way for the City of Calgary to move forward.

University Activities

ACTIVE–AURORA Project

In 2014, the University of Alberta and the University of British Columbia launched the ACTIVE–AURORA project. The ACTIVE test bed in Edmonton is 60 km of public roads—highways, freeways, and arterials—equipped with 42 roadside units. Various applications tested so far include advisory driving speed, pedestrian warnings, high-collision location warnings, and emergency signal preemptions. The AURORA test bed, located in Vancouver, facilitates the testing of various CV technologies under controlled conditions.

Photo courtesy Garreth Rempel

A driverless shuttle, nicknamed "Ela," debuts in Calgary this fall.

Photo: Kurt Bauschardt, Flickr

Whitemud Drive in Alberta is one of three test beds chosen for the ACTIVE–AURORA project. Technology being tested includes pedestrian warning, advisory driving speed, and signaling.

University of Waterloo Centre for Automotive Research

The University of Waterloo Centre for Automotive Research, or WatCAR, focuses on collaborative research in automotive and transportation systems by facilitating relations between automotive industry members and University of Waterloo faculty researchers. An important component of their research is the Autonomoose: a Lincoln MKZ hybrid equipped with a full suite of radar, sonar, lidar, inertial, and vision sensors. The Autonomoose operates at SAE Level 3, with Level 4 capabilities expected in late 2018.

Researchers are working on custom autonomy software that focuses on improving self-driving capabilities in the weather conditions specific to Canada; optimizing self-driving for fuel efficiency and reduced emissions; and providing methods to design safe, robust, computer-based controls for self-driving vehicles.

Photo: University of Waterloo

Autonomoose, Canada's first autonomous vehicle.

iCity-CATTS

In 2017, the University of Toronto funded a 3-year program to study how smart transportation technologies such as AVs would affect people's transportation choices, how businesses provide transportation as a service, and how cities should plan for those changes. The iCity Centre for Automated and Transformative Transportation Systems, or iCity-CATTS, deploys a multidisciplinary team to create analysis tools, methods, models, and decision support systems to quantify the impacts of transformative transportation technologies on transportation demand, system performance, health, the environment, and society at large.

Carleton University

Carleton University's School of Information Technology received a $974,000 grant in 2017 from the federal Canadian Safety and Security Program to research cybersecurity issues with AVs. The university is partnering with Transport Canada and BlackBerry QNX for the 3-year project to identify AV security vulnerabilities, analyze the risk of attack, and develop advanced security solutions.

Conclusion

Canadian governments, universities, private industries, and citizens recognize the transformational impact of CAVs on transportation. Led by Transport Canada, the federal government is developing national strategies, policies, regulations, and standards and is launching initiatives to fund and support the research, development, deployment, and testing of CAV technologies. The Canadian government also is working closely with international jurisdictions and the United States to address technology interoperability, cybersecurity, and spectrum issues.

Canada already is heavily involved in many CAV-related activities and is preparing for increased future involvement. The country's major transportation associations are establishing dedicated committees to address the policy and technical issues of CAVs; provinces and municipalities are assessing their readiness for CAVs, changing legislation to allow AV testing on public roads, and conducting CAV pilot tests; and Canadian universities are conducting research and development and producing critical technologies required for CAVs.

Canada's research and development funding programs, access to a rich talent pool, and proximity to major automakers are attracting many of the largest telecom, technology, automaker, and Tier-1 supplier companies and establishing Canada's reputation as an important player in CAVs.

PHOTO: HAL DICK, FLICKR

Automated Transit Applications

Real-World Examples

RONGFANG LIU

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JFK Airport's AirTrain. Established, real-world automated transit technology may provide insight into the development of automated vehicles.

The rapid development of driverless cars by Google and others not only grabbed the attention of the general public, researchers, and government agencies, it also created the opportunity for a thorough examination of automated transit applications and their impact on and implications for society. According to Steven Shladover, a leader in autonomous vehicle research,

> "Some of the strongest progress in vehicle automation has already been made in the field of transit. Indeed, one could consider the wide variety of airport people movers and automated urban metros to be examples of existing deployed automated vehicles, except these are mechanically captive to their guideways" (*1*).

Automated transit comes in a variety of applications, both top- and bottom-supported (*2*). Some systems roll on rubber tires, some are pneumatically levitated, some are propelled with rotary electric motors, and some are cable-drawn. Many real-world applications—based on driverless metro (DLM), automated people mover (APM), and personal rapid transit (PRT) technologies in various planning, construction, and operation stages—may serve as theoretical and practical laboratories to examine various aspects of automated transit technologies and their successes and failures in meeting the travel needs of various markets.

According to a recent tally, more than 100 applications along the continuous spectrum of automated guideway transit (AGT) technologies can be seen

Paris Métro's Line 14 is completely automated.

PHOTO: PLINE, WIKIMEDIA

around the world (3). After more than four decades, AGT technology is no longer limited to airport use as shuttles or circulators but has expanded to downtown and metropolitan areas, as major activity-center circulators and public transit systems.

For detailed definitions of various automated transit applications and their respective characteristics, see the author's *Automated Transit: Planning, Operation, and Applications* (4). An excerpt from Chapter 4 of the book is included below to highlight a few case studies, from high- to medium- to low-vehicle capacity systems.

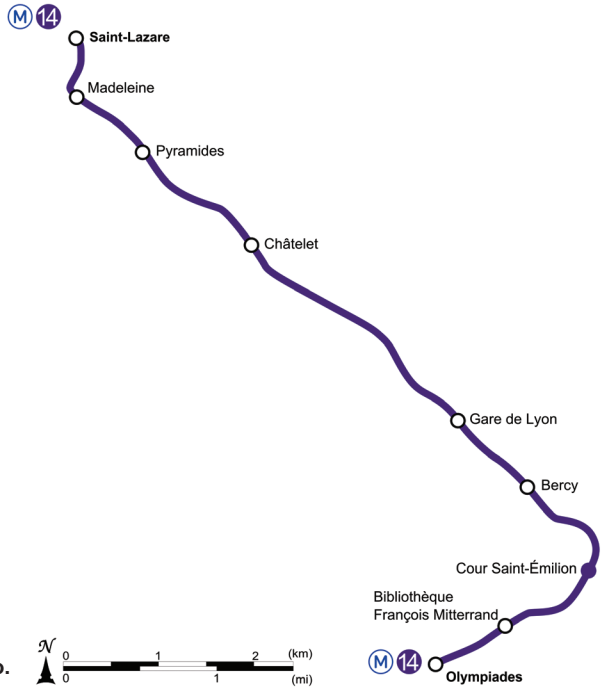

FIGURE 1 Route Map for Line 14, Paris Métro. (Source: M0tty, 2015.)

Driverless Metro in Paris

The Eiffel Tower is a symbol of Parisians' embrace of technology and innovation in the 19th century. The implementation of DLM in Paris in the late 20th century once again showed the French determination to lead in technology and innovation.

In 1987, the Regie Autonome des Transports Parisiens proposed "Project Météor" to create a new Métro Line 14 from Porte Maillot in the northwest of Paris to the Maison Blanche district in the southeast—an area that is poorly served by public transport despite its large population. To simplify its complicated operation, the line was modified later to originate from Saint-Lazare with the possibility of extension to Clichy and assimilation of the Asnières branch of Métro Line 13 (see Figure 1, at left).

Paris Métro Line 14 incorporated innovations that served as testing labs for the rest of the network—for example, the 120-m-long stations are larger and longer than old stations and thus can accommodate eight-car trains. Stations are more spaced out as well, allowing an average speed of nearly 40 km/h—close to double that of the other lines.

Photo: Erwin Soo, Flickr

A double-loop track surrounds Bukit Panjang, serving 14 stations and approximately 3 million people annually.

Most importantly, the line is completely automated and runs without any drivers. This was a first for Paris Métro as well as for a major metropolitan line in a national capital city.

Automated Light Rail Transit in Singapore

Amalgamating the advantages of Métro, light rail transit (LRT), and APM, a series of automated light rail transit (ALRT) applications have been implemented in various locations around the world. ALRT combines proven technology with two significant innovations: linear motors and steerable axle bogies, which together offer central control, minimize noise, and reduce wear and tear on rails laid to the standard gauge (5).

The Bukit Panjang ALRT line opened in Singapore in November 1999. As a feeder to mass rapid transit and bus services, the 7.8-km Bukit Panjang line plays a significant role in accomplishing Singapore's national transit access goal to establish public transportation access within a quarter-mile (400-m) walk of every citizen in the country (6). The Bukit Panjang line connects to the mass rapid transit line at Choa Chu Kang Station and loops around Bukit Panjang ("Long Hill"), a new town with more than 139,000 residents (7). The Bukit Panjang line is a critical element that makes the new town accessible and desirable as a residential location.

The Bukit Panjang line operates from 5:00 a.m. to 1:00 a.m. along a double-track loop with 14 stations. The headway is approximately 2–4 minutes for rush hour and 6 minutes for the rest of the day. Nineteen rubber-tired vehicles transported 10,000 peak-hour riders in 2015, translating to an approximate annual ridership of more than 3 million assuming an average peak-period loading of 10 percent of daily traffic.

The average speed of the Bukit Panjang ALRT line is about 25 km/h; it takes approximately 28 minutes to traverse the entire line. The cars have a capacity of 105 passengers—20 sitting and 85 standing.

Detroit Downtown People Mover

Unlike transit-scale applications of automated transit technology, which usually have fixed routes and schedules and charge transit fare, APMs generally serve as circulators or connectors to main transit,

Photo: Calvin Teo, Wikimedia

Automated light rail in Bukit Panjang, Singapore, provides transit access to more than 139,000 city residents.

Photo: Mr. Granger, Wikimedia

Detroit People Mover's Millender Center station is integrated into a building that houses a major hotel and residential apartments.

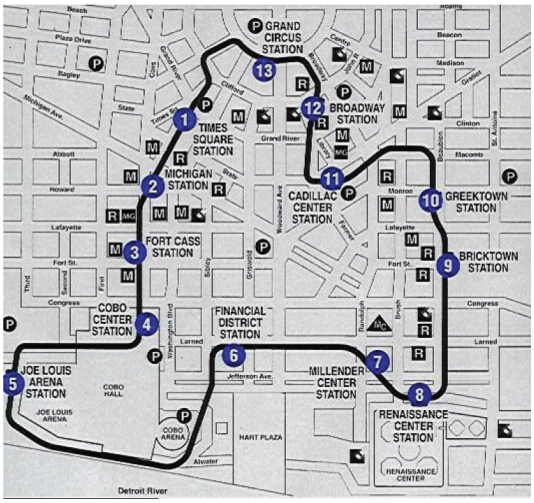

FIGURE 2 Detroit People Mover.

highway, or activity centers. Examples include downtown, airport, and major activity center circulators, or shuttles between two or more interesting points that may or may not require a fare. APM systems usually use intermediate-capacity vehicles—smaller than DLM trains and larger than PRT pod cars.

A product of the Downtown People Mover Program, or DPM, enacted by the U.S. federal government in the 1970s, the Detroit People Mover—one of three downtown people mover applications in America—opened its service in 1987. The fully automated guideway transit system operates on an elevated guideway that is 2.9-mile single-track loop, as shown in Figure 2 (above).

The Detroit People Mover connects 13 stations through the central business district of Detroit, with two-car trains running on an elevated one-way loop (*8*). Two of these stations, Millender Center and Cobo Hall, are integrated into buildings. The trains run every 3–5 minutes throughout the day between 6:30 a.m. and 2:00 a.m. on weekdays and for a shorter period on weekends (*9*).

The initial capital cost of the Detroit People Mover was $200 million and it requires $10 million per year to operate (*8*). The 75-cent fare (discounted 50 percent for seniors and riders with disabilities) covers only 15 percent of the operating expenses. The City of Detroit supplies the rest of the funds—$8.5 million per year.

Photo: Javier Rapaport, Flickr

The Detroit People Mover. Smaller, automated transit vehicles connect travelers to main transit, highway, or activity centers.

PHOTO: PIXABAY

JFK Airport's AirTrain combines APM technology with urban metropolitan applications.

AirTrain at JFK Airport

The AirTrain at John F. Kennedy (JFK) International Airport in New York is included in this article because of its unique combination of airport APM and urban metro in one AGT technology application. AirTrain connects JFK International Airport—the busiest international air passenger gateway to the United States (*10*)—to nearby destinations in New York City and New Jersey. The 8.1-mile-long APM, which cost $1.9 billion to build, began construction in 1998 and opened in December 2003. Its 10-station, 1.8-mile airport circulator loop and two extensions to urban transit systems equal 6.3 miles.

AirTrain uses AGT technology from Bombardier. The capacity of the system's trains ranges from one to four cars at 75–78 passengers per car. Train headway is approximately 10 minutes, taking about 2 minutes between terminals. AirTrain serves three main routes: All Terminals Route, Howard Beach Route, and Jamaica Station Route. As shown in Figure 3 (at right), the All Terminals Route is a circular route that connects all six terminal stations. The Howard Beach and Jamaica Station routes connect the terminals with regional mass-transit hubs, such as the New York subway and the Long Island Railroad (LIRR).

The initial goal of AirTrain was to provide air passengers and airport employees with rail access to JFK International Airport from the Howard Beach and Jamaica stations (*11*). When the APM was linked to a broader vision for the redevelopment of the Jamaica area and the larger Queens borough, an automated transit application was born.

As one of the nation's busiest transit hubs, Jamaica Station serves more than a quarter of a million commuters daily via three subway lines, 31 bus lines, and LIRR commuter rail lines. Shortly after the construction of AirTrain, the renovation of Jamaica station took place. This ushered in a series of infrastructure improvement projects, as well as economic development in the immediate surrounding areas. For example, JFK Corporate Square—a 300,000-sf office complex in downtown

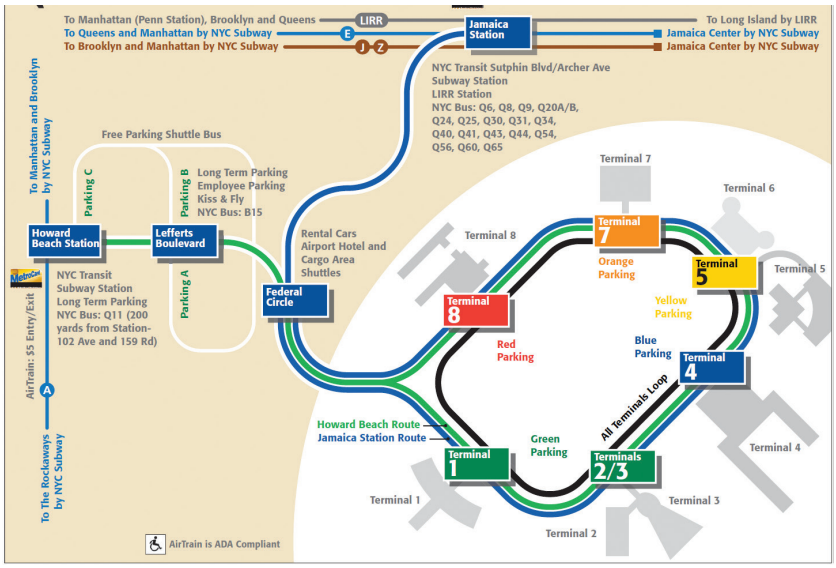

FIGURE 3 AirTrain at JFK International Airport. (Source: Port Authority of New York and New Jersey, 2005.)

New York's Jamaica Station serves as a hub for subway, bus, commuter rail, and AirTrain.

Photo: Travis Wise, Wikimedia

Jamaica—welcomed its first tenants in 2001 (*12*). In turn, further improvements to AirTrain have been included in multimillion-dollar joint capital projects by New York City and the Port Authority of New York and New Jersey.

Morgantown Group Rapid Transit

The Morgantown Personal Rapid Transit System is an automated tri-mode transit system—demand, schedule, and circulation—in northeastern West Virginia. The Morgantown people mover should be classified as group rapid transit because of its intermediate vehicle size and capacity. Each vehicle has a capacity of 21 passengers—eight seated and the rest standing. The system's operating characteristics are closely tied to PRT when it is on demand mode; that is, direct from origin to destination station.

The Morgantown Personal Rapid Transit System features a multiberth, bypassing-station layout. Each station is composed of off-line channels for vehicle berthing, a key feature that affords direct operation between origin and destination stations.

Ultra PRT at Heathrow International Airport

Although the concept has been around for more than a half a century, a true PRT application largely has not materialized, with only three limited PRT applications around world as of early 2018. These applications, with their small guideway footprints and small, four- to six-person vehicles, are located in Heathrow International Airport, London; Masdar City, Abu Dhabi; and Suncheon Bay, South Korea.

After starting on a small, testing scale, the initial Ultra PRT system at Heathrow International Airport has a 3.8-km (2.4-mi) double guideway that connects three stations—two in the Terminal 5 business car park and one at Terminal 5 itself, as shown below. The Ultra PRT fleet comprises 21 vehicles, or "pods," and total travel time between the two terminals is about 5 minutes.

As of May 2013, Ultra PRT's second anniversary of full operation, the pods collectively had operated for more than 26,000 vehicle hours, transported more than 1.2 million passengers, and traveled more than 2.5 million vehicle-km (*13*). Encouraged by positive experiences from operators and passengers,

Ultra PRT at Heathrow International Airport.

Photo: Ultra Global Limited 2013

Photo: Brian M. Powell, Wikimedia

The Morgantown Personal Rapid Transit System has size and capacity of a rapid transit vehicle.

Heathrow Airport Holdings Limited is considering the expansion of the Ultra system (*13*).

Conclusion

Automated transit applications come in many forms that may be called different names depending on their configuration, operating environment, and service characteristics. A common thread connecting these members of the AGT family is operation via central control systems without onboard human drivers—similar to automated roadway vehicles. Unlike automated buses and automated roadway vehicles, however, many of which are still in various developing and testing stages, each form of AGT has one or more applications in real-world operation.

Building on the extensive research conducted over more than half a century and expansive communications with a large network of professionals, *Automated Transit: Planning, Operation, and Applications* presents a comprehensive review of automated transit technology and its applications and offers some lessons for the ongoing development of automated vehicles.

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Photo: Jonathan Miske, Flickr

Data-Driven Project Selection

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An intersection of Minnesota's original Interregional Corridor System. Capacity projects focused on the main highways connecting regional economies.

State DOTs are moving rapidly toward performance planning and programming techniques. A major motivation for this shift is that, now that they are required to meet federal performance measures, states have an interest in developing project selection systems to help meet those measures most effectively.

This has led to a massive cultural shift that has transformed the transportation industry. The American Recovery and Reinvestment Act of 2009 (ARRA) and subsequent U.S. Department of Transportation (DOT) discretionary grant programs made calculations such as benefit–cost ratios, reliability, and return on investment commonly understood. Outside of the transportation industry, these calculations would help governments meet increased calls for transparency and merit-based processes.

This article highlights three statewide performance-based, data-driven project selection processes. All were created for different reasons, but all share common factors in the development of their process and the criteria selected.

Minnesota's Corridors of Commerce Program

Since the early 2000s, Minnesota DOT's traditional planning and project development process has focused primarily on preservation. As a result, major legacy capacity expansion projects that once were moving through the agency's pipeline now are not likely to be constructed. In 2013, the affected communities successfully lobbied the Minnesota legislature to create the Corridors of Commerce program.

This new program focused on constructing major-capacity projects on the state's Interregional Corridor (IRC) System. Developed in the 1990s, the IRC System served as the backbone connecting the state's regional economies. In the past, these

highway corridors saw focused capacity investment through Minnesota DOT's traditional process until the agency's attention shifted to pavement and bridge preservation (*1*). Today, the IRC System largely has been retired; however, because of legislative requirements, it was used for the Corridors of Commerce process.

Although the newly created Corridors of Commerce program had a defined network, the legislation did not offer prescriptive guidance on how to select projects. The law listed general selection criteria but left Minnesota DOT significant discretion on which criteria to use and did not limit the use of any additional criteria (*2*).

Selection Criteria

After three selection processes, the state legislature decided to revisit the program in 2017, solidifying eligibility requirements and establishing eight prescriptive selection criteria (*3*). The law requires Minnesota DOT to use all eight criteria—no more and no less—and to publish project evaluation scores once projects are selected (see Table 1, at right). This left Minnesota DOT to develop a transparent, quantifiable project selection process that would be used to award newly appropriated funding in 2018—the first step of which was to gather and make eligibility determinations on submitted projects.

The law requires Minnesota DOT to accept project recommendations from the general public; however, proposed projects also must meet a strict set of six eligibility requirements to be considered for the program. An eligible project must be:

- Consistent with the Statewide Multimodal Transportation Plan's five objectives (open decision-making, safety, connectivity, system stewardship, and healthy communities);
- Located on a statewide IRC or on a trunk, or state, highway within Minnesota DOT's Metro District (Minneapolis–St. Paul area);
- Focused on developing capacity or improving freight mobility;
- Able to start construction within 3 years (or longer, if approved by the Minnesota Transportation Commissioner);
- Able to be fully funded without exceeding total dollars available to the project; and
- Not listed in the State Transportation Improvement Program (STIP).[1]

[1] STIP is the formal 4-year programming document required by U.S. DOT to obligate federal surface transportation funding. By excluding projects that are listed in the current STIP, the process deliberately focused on projects not already in the Minnesota DOT project development pipeline.

TABLE 1 Legislative Selection Criteria for Minnesota DOT

	Legislative Criteria	Scoring Methodology
Return on Investment	A return-on-investment measure that provides for comparison across eligible projects.	Overall project effectiveness was measured by dividing the travel time and crash reduction savings by the total Corridors of Commerce funding requested.
Economic Competitiveness	Measurable impacts on commerce and economic competitiveness.	Using the U.S. Department of Commerce's Regional Input–Output Modeling System economic multipliers, job creation numbers were calculated using localized multiples for each Minnesota DOT district.
Freight Efficiency	Measures of AADT and commercial VMT, which may include data near the project location on that trunk highway or on connecting trunk and local highways, and measures of congestion or travel time reliability, which may be within or near the project limits, or both.	Two equally weighted criteria were used: heavy commercial AADT and travel-time reliability. Reliability figures were calculated using the National Performance Management Research Data Set.
Safety	Improvements to traffic safety.	Since the return-on-investment criterion used crash reduction savings as a key factor, Minnesota DOT elected to use a combination of average total crashes and fatal or severe crashes over the past 5 years.
Regional Connections	Connections to regional trade centers, local highway systems, and other transportation modes.	To accomplish this, Minnesota DOT developed a scoring matrix that assigned a score based on a project's facility and project type. Projects that closed a gap in a larger corridor on an Interstate scored better than those building passing lanes on a rural two-lane highway.
Policy Objectives	The extent to which the project addresses multiple transportation system policy objectives and principles.	Minnesota DOT developed a scoring matrix to measure a project's ability to support the policy objectives of the Statewide Multimodal Policy Plan, including 1) open decision-making, e.g., asking if a project has a plan, and 2) system stewardship and healthy communities.
Community Consensus	Support and consensus for the project among members of the surrounding community.	Points are awarded for letters and formal resolutions of support from MPOs, affected communities, and chambers of commerce.
Regional Balance	Regional balance throughout the state.	After the projects were scored and ranked against each other statewide, projects would be selected to ensure regional balance.

NOTE: AADT = average annual daily traffic; VMT = vehicle miles traveled; MPO = metropolitan planning organization.

Construction of an intermodal facility in Cincinnati, Ohio, was a multiphase Transportation Review Advisory Council–approved project.

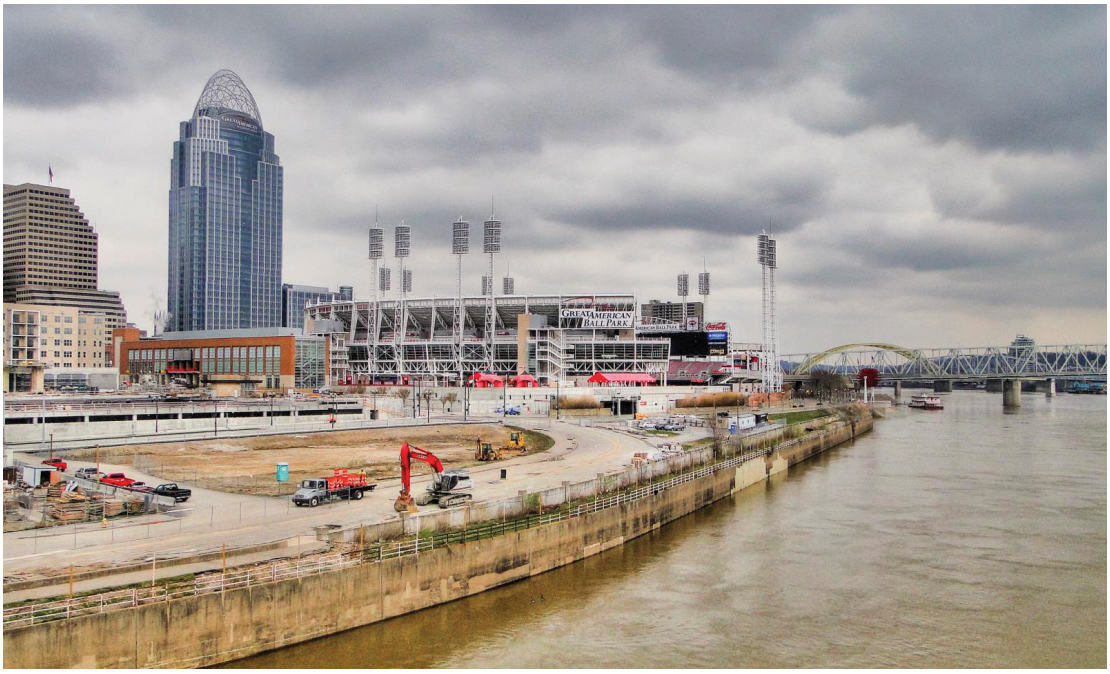

Photo: Paul Cincinnati, Flickr

Although these criteria narrow down the list of submissions, they are not specific enough to create a homogeneous list of projects. This left Minnesota DOT with the challenge of developing project selection methodologies that aligned with the law, but were comprehensive enough to compare projects of varying type, geographic location, and levels of technical development.

Throughout 2017, Minnesota DOT worked internally to analyze the merits of various options. Once a set of favored project-scoring methodologies was selected, the agency conducted a series of public outreach activities to gather feedback. The final scoring methodologies were released with a call for projects in January 2018 (*4*).

Elk River, Minnesota. One of the original Corridors of Commerce projects will convert Highway 169 into a freeway and will construct an interchange at Main Street, seen here.

Photo: Wikimedia

Results

Traditionally, Minnesota DOT employs a concept known as "regional balance" for many of its programs, which ensures equitable funding between the Metro District and Greater Minnesota regions. The agency adopted a 50–50 funding split for the Corridors of Commerce program and shared their decision at the public outreach events held before the selection process began (*5*).

In early May, considering only the new criteria's quantitative scores, Minnesota DOT awarded four projects totaling $417 million from the 2017 appropriation. Although the selected projects were split almost equally between Metro and Greater Minnesota, the latter were located just outside of the Metro District, along corridors that non–transportation professionals might consider to be within the Minneapolis–St. Paul area (*6*).

The May 2018 project announcement took place while the state legislature was still in session. In response, Greater Minnesota legislators appropriated an additional $400 million for the Corridors of Commerce program—with a small caveat. The bill language includes an additional requirement that projects could not be awarded within the counties already receiving Corridors of Commerce funding in 2018 (*7*).

On May 30, Minnesota DOT awarded a second round of Corridors of Commerce projects according to the new requirements (*6*).

Ohio's Transportation Review Advisory Council

In 1997, the Ohio General Assembly created the Transportation Review Advisory Council (TRAC) to develop and oversee a process to select projects for Ohio DOT's Major New Capacity Program. Projects included in this program are "greater than $12 million, request Major New funding, and add capacity to or reduce congestion on an Ohio DOT transportation facility." Every couple years, TRAC evaluates its 4-year programming document and makes adjustments based on available funding, progress towards project development, and a series of project selection criteria.

In 2015, TRAC revised its traditional highway performance–related criteria to include freight and transit categories with corresponding criteria comparing projects across modes. Additionally, TRAC added criteria to measure economic performance, local area investment, and non–Ohio DOT funding commitments (*8*).

Transportation Factors

TRAC accounts for traditional transportation performance using a series of measures: traffic performance, benefit–cost, air quality, functional classification, and connections to an Ohio DOT network known as the Strategic Transportation System (STS). Although the evaluation factors for highway projects are fairly straightforward, Ohio DOT developed a series of equivalent measures for transit and freight (see Figure 1, at right) (*8*).

In addition to these factors, the TRAC awards points to projects that improve access to or flow on the STS, which identifies corridors that link the "state's most used and valuable aviation, bicycle, highway, maritime, rail, and transit corridors, and the diverse multimodal transportation facilities connecting them …. and represents the backbone of Ohio's transportation network" (*9*).

Economic Performance Factors

TRAC added criteria in the early 2000s to measure the potential impact of submitted projects. The first criterion focuses on existing jobs, an indicator of potential job retention. The second criterion, job creation, uses the Ohio DOT Statewide Transportation Model—which has a post-process economic impact module—to identify job creation over 20 years. Although this provides a consistent analysis for projects across the state, it does not consider local considerations, like development stipulations. Additionally, TRAC uses the Ohio DOT model to score projects on their ability to improve Ohio's gross state product.

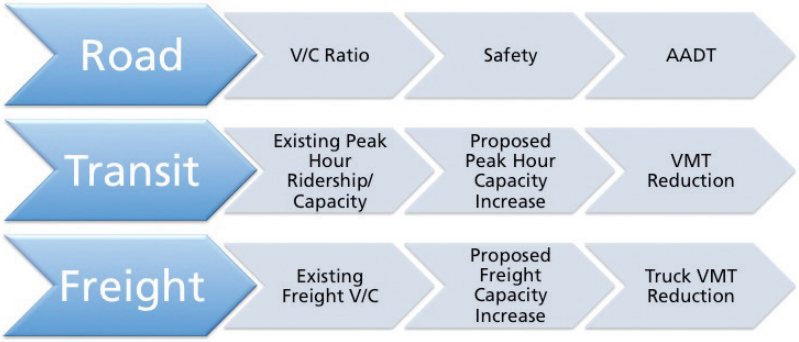

FIGURE 1 Ohio DOT evaluation factors for highway, transit, and freight projects. (V/C = volume–capacity; AADT = average annual daily traffic; VMT = vehicle miles traveled.)

The scoring framework also considers a project's potential to alleviate economic distress. Points are awarded for county-level average unemployment and poverty. TRAC also evaluates how effective a potential project's impact could be by integrating the job creation and Ohio gross state project calculations as a function of the total economic distress points awarded (*8*).

Local Investment Factors

This criterion focuses on the economic development potential and investment within a project's area. TRAC evaluates the percentage of acres served by utilities, existing building square footage, transit availability, and the overall building vacancy rate. TRAC also will consider the ratio of past and future public- and private-sector investment in the area as a function of total project cost. This criterion is designed to favor economic development areas that have a distinct plan as well as prior investment (*8*).

Photo: Erik Drost, Flickr

An update of the West Shoreway in Cleveland, approved by TRAC, creates multimodal connections and increases access to Lake Erie.

Photo: Nytteno, Wikimedia

Kentucky's Strategic Highway Investment Formula for Tomorrow, or SHIFT, funds the operation of the Augusta Ferry, which transports passengers across the Ohio River.

Project Funding Plan Factors

The final category awards points based on the availability and diversity of funding sources—specifically, non-Ohio-DOT funding sources. The first two scoring criteria focus on non-Ohio-DOT funding percentages allocated to the total project and requested project phase. The final criterion looks at the diversity of funding sources; for example, a project must have at least three funding sources to score any points. The goal of this last criterion is to incentivize nontraditional funding sources, like value capture and tolling (*8*).

Kentucky's SHIFT Process

Following the completion of the 2016 Kentucky Highway Plan, Governor Matthew Bevin directed the Kentucky Transportation Cabinet (KYTC) to develop an objective, data-driven approach to prioritizing and funding highway improvements for its next 6-year highway plan (*10*).

What became known as the Strategic Highway Investment Formula for Tomorrow (SHIFT) began as a multidisciplinary committee charged with developing the program's scoring criteria. The committee analyzed other states' project processes and KYTC's capabilities. They worked with Kentucky's area development districts (ADDs) and metropolitan planning organizations (MPOs) to develop a collaborative process that worked statewide—a series of criteria that focused on five components: safety, asset management, economic growth, congestion, and benefit–cost (see Table 2, below) (*10*).

TABLE 2 Kentucky Selection Criteria

Selected Criteria		Statewide Points	Regional Points
Safety	Crash history and roadway characteristics	10	20
Asset Management	Bridge and pavement needs addressed by the proposed project	15	10
Economic Growth	Accessibility and connectivity needs based on improvement type, county economic indicators, and AADT	20	15
Congestion	Volume and V/C ratio	20	10
Benefit–Cost Analysis	Travel-time and crash reduction savings divided by the project cost	20	15
Local Priorities	Kentucky Transportation Cabinet District Boost		15
	ADD/MPO Boost		15

NOTE: V/C = volume–capacity; AADT = average annual daily traffic; ADD = area development district; MPO = metropolitan planning organization.

Project Selection Process

The development of the 2018 Kentucky Highway Plan began with a call for projects from KYTC districts and their ADD and MPO partners. The resulting 1,200 projects were scored and prioritized using the SHIFT scoring criteria (see Figure 2, page 31).

The overall scoring process was divided into two parts: statewide and regional scoring processes (*10*).

Statewide Process Projects located on the National Highway System statewide, safety and mobility projects, and statewide economic development projects all were scored against each other (*10*).

Regional Process All remaining projects, including those not selected in the statewide process, were assigned to one of four regions defined by KYTC. These regions were designed to be contiguous with KYTC districts that have similar terrain, mileage, and urban–rural populations.

Although the statewide process is completely quantitative, only 70 percent of the regional process's points are based on analytical analysis. KYTC assigned the remaining 30 percent of the points in consideration of local and district priorities. These subjectively based "boosts" ensure that the process accounts for local knowledge and the qualitative aspects of projects that are not necessarily captured in a strictly mathematical formula (*10*).

Results

The SHIFT process created a defensible, transparent programming tool to help KYTC assign projects within a fiscally constrained 6-year plan. It is important to note, however, that the SHIFT results were not the only factors utilized to create the final funded project list. According to the agency, "these [additional] considerations include investments to date and associated impacts to communities, fulfillment of previous commitments, and completion of significant corridors."

Additionally, the SHIFT program identifies a clear, defensible list of highway needs. The 1,200 projects submitted and scored by the process account for nearly $9 billion, but the 6-year plan identified only

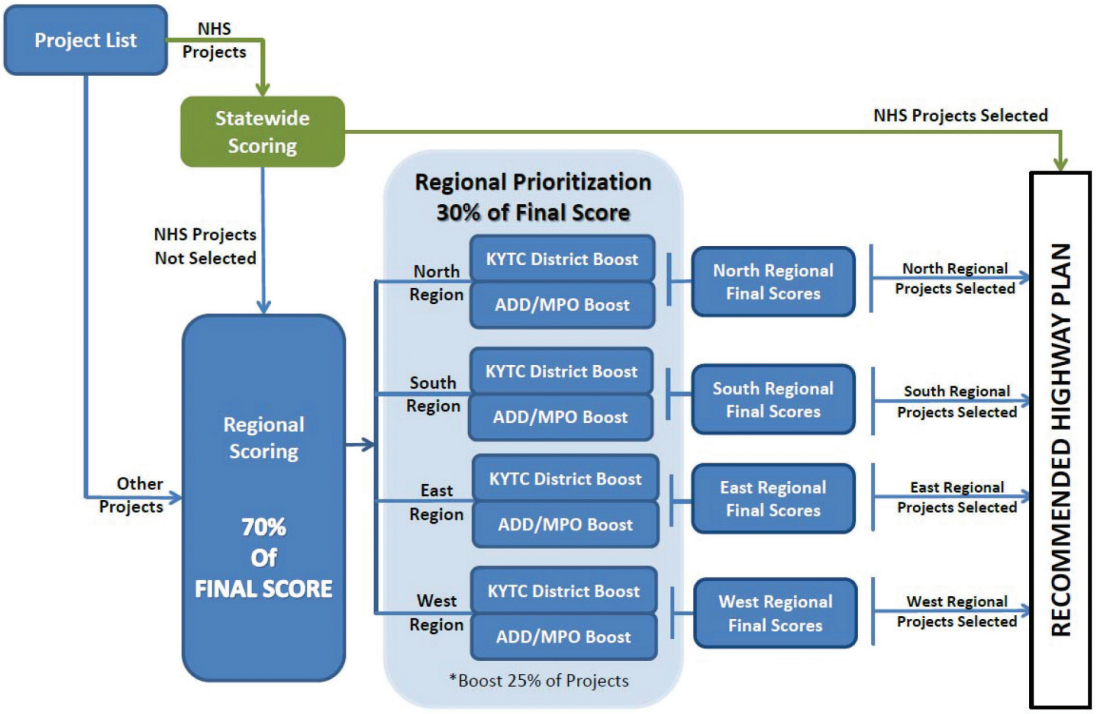

FIGURE 2 SHIFT Statewide and Regional Processes (*10*). (NHS = National Highway System; KYTC = Kentucky Transportation Cabinet; ADD = area development district; MPO = metropolitan planning organization.)

$2.6 billion of available state and federal funding. Along with creating a data-driven highway plan, the process created a vetted list of highway needs—not just a wish list—and a solid funding gap. These figures can be used to advocate for new funding and financing programs within the Commonwealth (*10*).

Conclusion

Although the impetus for each state's performance-based, data-driven project development processes were different, the implementation of these processes by Minnesota, Kentucky, and Ohio shared many commonalities. All processes integrated traditional roadway measures, but more telling were their efforts to capture the economic and holistic impacts on nearby communities.

How each state went about capturing these impacts varies greatly, however. Ohio DOT and KYTC employed a commonly used—yet proprietary—economic impact tool, and Minnesota focused on developing an absolutely transparent process by using Regional Input–Output Modeling System multipliers. Both approaches are appropriate, but this demonstrates the "missing middle" between complex economic models and complete transparency. A similar challenge exists in the development of benefit–cost analyses for discretionary grant programs.

As an industry, transportation has rightly focused on job creation and overall impact as key economic metrics. As tools evolve, however, so must metrics. For example, a key missing aspect from many analyses is the impact of a singular project on the accessibility between economic nodes within a state or megaregion.

As this work continues nationally, abstract methods to capture economic impact will transition into complex economic models, much the way travel-demand models have over the past 20 years.

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PHOTO: FLICKR

Every Day Is Freight Day

Finding the Balance with Continuous Transportation Planning

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Freight mobility requires continuous planning and balance between modes, objectives, and livability.

The development of a transportation plan can lead to two outcomes: either the plan is the first step toward action and implementation, or the plan is considered a completed project and disconnected from implementation. Good plans include objectives and strategies for transitioning the plan into action and for igniting continuous planning as an ongoing process. The challenge is to develop transportation plans that are thorough and that accurately address needs but that still are multimodal and balanced.

Many jurisdictions—states, metropolitan planning organizations (MPOs), and municipalities—have moved to continuous planning to stay current with continuous change, needs, and trends. Good modal plans support an agency's long-range transportation plan, which should be comprehensive and provide strategy for how transportation supports all needs, including freight, rail, transit, aviation, bike and pedestrian, and maritime. Many jurisdictions realize that all modes of transportation must provide options and redundancy to users. Mobility offered by multiple means of transportation improves quality of life for all; in this way, multimodal transportation planning and a continuous planning process set the conditions for maximizing mobility most effectively.

Finding the Balance

Virtually all state departments of transportation (DOTs), MPOs, regional planning organizations, cities, and counties develop comprehensive transportation plans to improve mobility and quality of life and to provide future direction. Many plans can be categorized as long-range transportation plans, corridor or regional transportation plans, various modal-specific plans, or economic development plans.

Photo: Virginia DOT

Although they sometimes compete for freight service, each transportation mode has unique strengths and weaknesses.

Transportation plans differ among jurisdictions. Many agencies have needs and issues that are similar but that vary in magnitude and complexity. As such, the prioritization of needs and actions should have different balance points. Balance means optimizing the transportation strategy to solve issues and needs and at the same time employing and harmonizing various transportation modes.

Freight Modes in Balance

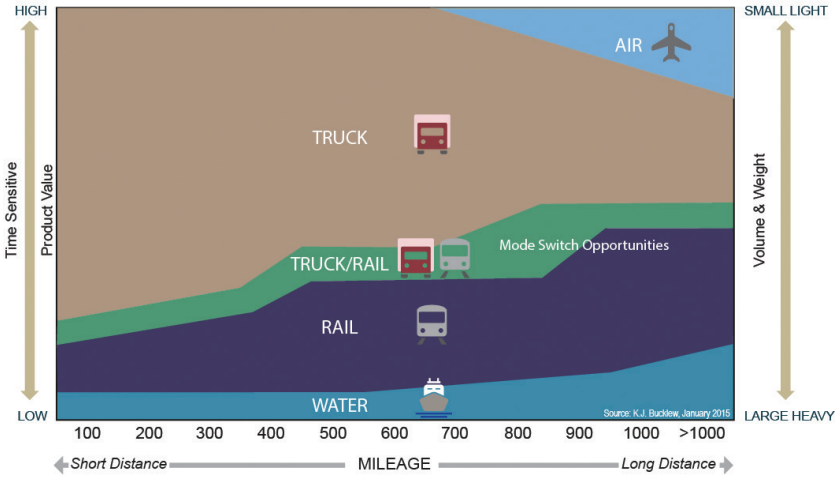
To some degree, transportation modes compete and each mode has inherent, comparative strengths and weaknesses. In freight transportation, each mode is unique in its characteristics, operating models, and cost structure. Some competitive service overlap occurs among the modes, depending on shipment distance, geography, operating speed and velocity, and customer requirements. To a much larger degree, however, the freight modes complement each other, providing shippers various modal options to match customer service needs and transportation costs (see Figure 1, at right).

Good planning supports objectives and actions to address the unique, specific needs of each jurisdiction. Conversely, some plans minimize certain aspects of transportation planning and modes depending on expertise, knowledge, and senior leadership guidance. Some emphasize bike and pedestrian, greenway, environmental, or safety issues and others focus on general-purpose transportation mobility, complete streets, transit, and bus rapid transit.

Specialized modal planning may focus on aviation systems, freight rail, passenger rail, pipelines, or maritime ports and waterways. Still relatively new are comprehensive multimodal freight mobility plans. Both the Moving Ahead for Progress in the 21st Century Act and the Fixing America's Surface Transportation Act articulated the needs and requirements for states to develop multimodal freight mobility plans. Likewise, MPOs must address and incorporate freight movement into their transportation planning process.

A challenging aspect of transportation planning includes the questions of where to fit freight mobility into the overall, comprehensive plan; how to prioritize freight issues and needs; and how to harmonize

FIGURE 1 Domestic freight modal selection. (Source: Bucklew, 2015.)



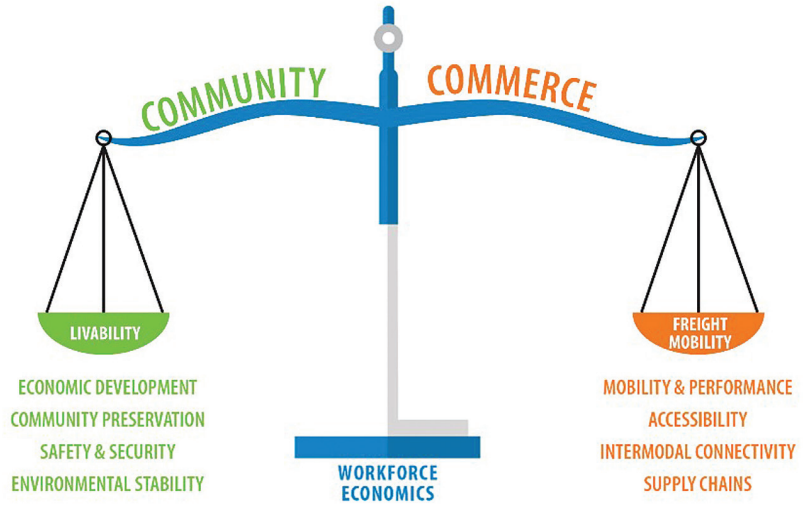


FIGURE 2 Multimodal freight transportation plan: an integrated and balanced approach.

all the modal needs into an integrated, synchronized plan. Such a plan should strive for balance among all the competing needs and issues. All these needs and issues are important but should be prioritized.

Community and Commerce in Balance

Communities require an environment that is conducive to a good quality of life. The subjective term "livability" encompasses factors that provide access to markets, such as goods and services and life support; environmental friendliness, such as walkways, bicycle, transit, clean air, and noise mitigation; utilities, such as electricity, sewers, waste removal systems, Internet access, and water; family needs, such as schools, churches, shopping, and entertainment venues; and other needs and conveniences. Freight mobility needs are similar to those of livability, but community and commerce need some separation between them to be effective. Underscoring both is land use; the availability, mobility, and technical skills of the workforce; and economics (see Figure 2, at left).

Since World War II, the national and global population has trended toward urbanization. Goods and services are produced and consumed primarily in urban areas.[1] As such, the urban population demands that community and commerce coexist but do not conflict. A key link in this continuum is freight mobility—the trucks, railroads, barges, ships, aircraft, and pipelines that move goods and commodities to meet consumer demands. The challenge for the transportation planner is to find a balance between community needs and commercial needs that satisfies all. Because no two jurisdictions are alike, this balance will vary among states and MPOs.

Communication between private-sector freight stakeholders and public-sector residents is key. No solution is one-size-fits-all—every state or community is different and has different needs. As society becomes more urban, people have less private space

[1] Agriculture remains the rural industry of choice because of specific land, water, and environmental requirements.

PHOTO: JAXPORT, FLICKR

Cargo moves between ships and rail at the Talleyrand Marine Terminal, operated by the Jacksonville Port Authority. Multimodal plans often take into account a region's specialized needs and requirements.

for personal enjoyment and rely more on shared public space to fill their recreational and social needs. Similarly, residential space in the urban environment is dense; often, freight needs and livability needs compete for the same geography and transportation infrastructure.

Developing a holistic transportation plan—one that addresses community and commerce needs—requires information, stakeholder involvement, and the understanding that trade-offs must be made.

Continuous Planning

Every day is freight day—freight planning must be continuous to stay ahead of the dynamic, ever-changing freight mobility environment.

As Dwight D. Eisenhower often stated, "Plans are worthless, but planning is everything."[2] Simply, the risk is that plans may not result in what was expected. A good transportation plan should incorporate plausible future scenarios that facilitate options. At best, transportation plans are an 80-percent to 90-percent solution at the time of adoption. As time passes, these plans become dated and must be revised periodically to stay relevant. Because of this, states and MPOs have implemented planning processes that allow for continuous planning.

The transportation plan is only the first step in establishing an ongoing transportation planning process, which must be flexible and adaptive to be effective. Plans have an inherent level of risk and uncertainty, and that risk should be managed via a planning process—one linked to implementation—that continually assesses the array of possible future scenarios. Implementation of the plan can be daunting and challenging, but it is an ongoing activity—as is maintaining a continuous planning process (Figure 3, at right).

Battle Rhythm

The U.S. Army coined the phrase "battle rhythm" and has used this process for many years to articulate the continuous flow of planning and operations necessary to maintain combat momentum: a deliberate sequence of events—planning, administration, intelligence, operations, logistics, communications, and more—to synchronize current and future activities. In essence, battle rhythm is a continuous planning process, albeit flexible and adaptive. A key ingredient to the success of the battle rhythm process is that planners and operators communicate and collaborate on planning efforts so that the Army does not lose momentum on the battlefield, which is critical for operational success.

[2] From Remarks at the National Defense Executive Reserve Conference, November 14, 1957.

FIGURE 3 Freight plan implementation.

Transportation plans come and go, often conceived after the enactment of a federal reauthorization bill. Federal funding is a major source of state and local resources, so these agencies are somewhat encumbered to develop plans that meet federal requirements. Because of this, the plan has a finite life. A continuous planning process, however, is flexible; can incorporate changing needs, issues, and requirements; and facilitates trends, allowing agencies to maintain momentum. A synchronized transportation rhythm that ties planning directly to investment and development could create a nearly seamless process that provides momentum for implementation.

The comprehensive transportation plan should focus on an agency's strategy, goals, objectives, and performance measures, and should establish the investment methodology and process. Continuous planning then focuses on monitoring needs and issues, measuring the transportation system per-

Photo: Roy Luck, Flickr

A train carries ethanol across Texas. State transportation planning requires the assessment of state needs and the prioritization of programs and projects.

formance, evaluating policies and programs, identifying solutions (that is, projects) to needs, selecting and prioritizing projects, and matching funding and financial options. The comprehensive plan also guides development of specific modal plans and corridor studies.

Real-World Examples

Several states have an ongoing transportation planning process. Florida and Texas regularly review projects, programs, and policies to ensure that higher-priority needs are being addressed. Although these DOTs have different planning rhythms, these rhythms are tailored to their specific requirements and to the needs of freight system users. The characteristics of successful ongoing planning include private-sector stakeholders and a process that is openly understood, or transparent.

Some MPOs, such as the Delaware Valley Regional Planning Commission, keep a continuous focus on how the region can set the conditions for freight mobility efficiency and reliability. Other states and MPOs are moving beyond periodic planning to a process that involves integration with regular performance management—that is, monitoring and measuring—and, in turn, continuous or more-frequent planning.

Most, if not all, state freight plans seek to solve various local needs in a collective sense. The Kansas Freight Plan describes the state's transloading facility program. Each locally identified need—approximately 60—are scattered throughout Kansas. Thus far, the state has initiated two transloading facilities designed to transfer bulk grain from trucks to rail cars. The focus of this public–private partnership program is economic development, because it supports agribusinesses' need to choose between truck and rail to meet customer demands and to reduce freight transportation costs.

TABLE 1 Changes in Freight Perspective

Legacy	Today
Regulatory	Economic development
Safety	Competitiveness
Capacity needs	Investment prioritization
Moving vehicles	Moving people and freight
Vehicle volumes	System performance
Separate modal networks	Integrated freight system
Separate modal movements	Intermodal connectivity
Individual jurisdictions	Commerce corridors
Independent decisions	Partnership with users
Reactive	Proactive

Key Components

Although multimodal freight plans have been widely accepted thanks to federal reauthorization bill mandates and forward-thinking freight champions, these plans are relatively new to the transportation-planning curriculum. Three key aspects have propelled freight planning to the forefront of transportation innovation, however:

Photo: Maureen, Flickr

The Trans-Alaska Pipeline. Multimodal planning must incorporate all freight transportation modes.

◆ **Freight planning is multimodal**. It incorporates all freight transportation modes: trucking, rail, marine, aviation, and pipelines, as well as the intermodal connectivity between modes. Freight planning also includes economic development, workforce mobility, safety, and environmental needs in creating an implementation plan that prioritizes investments and policies.

◆ **Private-sector stakeholders—users of the freight system—are included in the development of the multimodal freight plan**. The private sector comprises the bulk of the membership of state and MPO freight advisory committees (FACs). The FAC advises on freight mobility issues and needs from a user perspective and is a source for recommending projects, policies, and programs to enhance freight mobility. This public–private partnership infuses the freight plan with enhanced knowledge, experience, modal diversity, geographical representation, and, most importantly, better solutions.

◆ **Every day is freight day**. Supply chains are dynamic, economic conditions are fluid, funding is volatile, and freight must move. As such, agencies and freight planners are realizing that freight mobility requires them to think differently and to focus more on functionality and the user's perspective. Legacy factors still must be considered, but in service of developing a more efficient, reliable, and safer transportation system (Table 1, page 36).

Forward-Thinking Planning

Intelligent transportation systems (ITS) and information technology (IT) have developed at a rapid pace. The variety of options can be chaotic and disruptive, but ITS and IT can act as capacity multipliers. Instead of transportation agencies building their way out of congestion, they can use less-costly solutions to operate their way out of these issues. Big-data sources, utilized with new analytical methods and tools to manage and integrate multiple datasets, can provide timely data and more accurate information to support recommendations. All of this requires continuous planning to incorporate and meld ITS and IT solutions and big-data analysis into capacity investments and maintenance–preservation projects (Table 2, at right).

The future requires transportation planners to be holistic, forward thinking, collaborative, and innovative, and to know and understand how transportation system users operate. Gone are the days when a planner handed the plan to engineers and moved on to the next plan—planners are architects that must remain engaged in a continuous process. Planning is the skill of seeing the future now. As the adage goes, "it wasn't raining when Noah built the ark."

TABLE 2 Freight Mobility Technology

Clean Energy	• Alternative fuels: natural gas (CNG and LNG), propane, hydrogen, electric and battery operation • Aerodynamics: improved components
Routing and Wayfinding	• Satellite-based navigation • Online mapping • Route optimization and dispatching models
Safety and Regulatory	• Electronic logging devices • Positive train control • Weigh-in-motion
Security	• Cargo and container detection systems
Operational	• Digital FTL freight brokers (e.g., Transfix) • Robotics and automation • Off-hour delivery
Smart Infrastructure	• Electronic sensors • Autonomous (gantry) loading • Vehicle-to-infrastructure communication
Communications	• Satellite-based (e.g., Qualcomm) • Telematics
Vehicles	• Truck platooning • Autonomous vehicles • Urban delivery trucks • Flex barges • Automomous container ships • Hyperloop • Cargo airships • Self-operating barges • Vehicle-to-vehicle communications • Drones • Freight Shuttle System
Management Systems	• Internet of things • Supply chain dynamics, just-in-time delivery • Cargo radio-frequency identification • Barcoding • Vehicle tracking devices • Fuel optimization models • Artificial intelligence

NOTE: CNG = compressed natural gas; LNG = liquefied natural gas; FTL = full truckload.

NASEM WORKSHOP SUMMARY

Achieving Rural Health Equity and Well-Being

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The Roundtable on Population Health Improvement and the Roundtable on the Promotion of Health Equity of the National Academies of Sciences, Engineering, and Medicine held a joint workshop, "Achieving Rural Health Equity and Well-Being: Challenges and Opportunities" on June 13, 2017, in Prattville, Alabama. The two roundtables brought complementary but distinct perspectives and expertise to the workshop.

The Roundtable on the Promotion of Health Equity serves as the conveners of the nation's experts in health disparities and health equity, with the goal of raising awareness and driving change in health and healthcare among underrepresented racial and ethnic populations; amplifying research, policy, and community-centered programs; and catalyzing new leaders, partners, and stakeholders. The Roundtable on Population Health Improvement is a forum that facilitates cross-sector dialogue on various dimensions of the social determinants of health to help catalyze action toward a stronger, more healthful, and more productive society.

The workshop on rural health equity explored the impacts of economic issues, immigration, and racial inequities in the rural communities of the United States as well as asset-based approaches to addressing these challenges. The planning committee organized panels on 1) how regional philanthropic organizations leverage resources to help address unique local and regional needs, 2) how local finance and community advocacy organizations can create the conditions for economic pros-

PHOTO: PIXABAY

A recent NASEM workshop examined rural health equity as it relates to economics, immigration, and racial inequality.

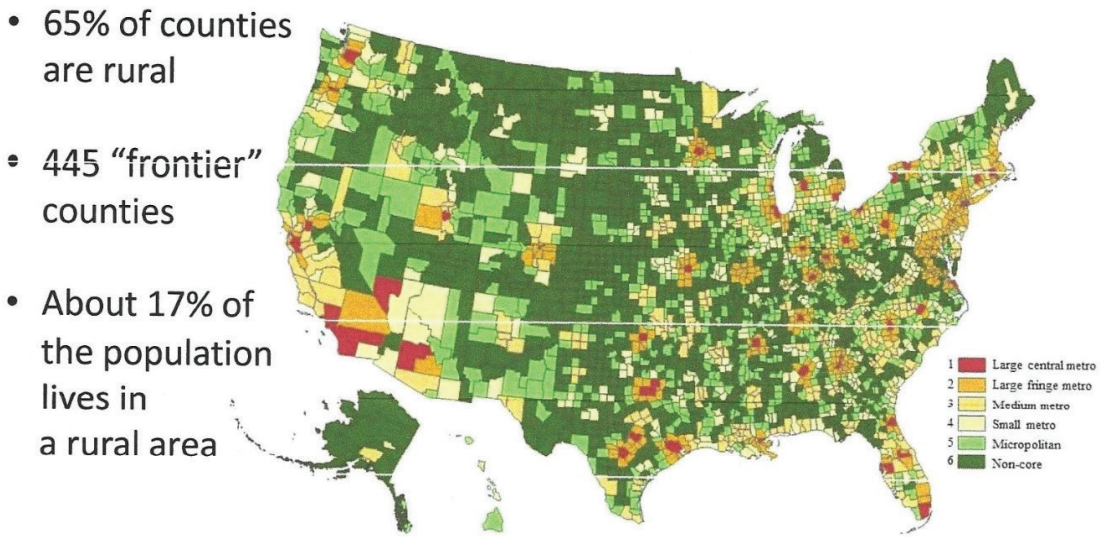

FIGURE 1 Land area (green) in the U.S. classified as rural. (Source: Tom Morris/ Ingram and Franco, 2012.)

perity, and 3) how health-sector institutions can ensure access to quality healthcare services for rural communities.

The panels were not charged specifically with examining transportation, but the role of transportation as a determinant of rural health equity and well-being came up in many panel discussions. This article highlights parts of the workshop proceedings, *Achieving Rural Health Equity and Well-Being: Proceedings of a Workshop*, that address how transportation issues have shaped rural health equity issues.[1]

Defining Rural Communities

Rural America is not just a smaller version of urban America, observed Tom Morris, associate administrator in the Federal Office of Rural Health Policy in the Health Resources and Services Administration of the U.S. Department of Health and Human Services (HHS). On average, rural areas have higher levels of poverty, higher percentages of older adults, and slower-growing or declining populations.

The U.S. Census Bureau uses a system based on census tracts to define "rural." In his presentation, Morris used the Office of Management and Budget's definition, which identifies approximately 17 percent of the population as living in rural areas that are spread across about 80 percent of the country's land mass (Figure 1, above). About two-thirds of the nation's approximately 3,100 counties and county equivalents are rural—including about 450 geographically remote and isolated "frontier" counties.

[1] The entire publication is available at www.nationalacademies.org/hmd/Reports/2018/achieving-rural-health-equity-and-well-being-proceedings.aspx.

Impact of Social Factors on Health

Michael Meit, codirector of the National Opinion Research Center Walsh Center for Rural Health Analysis and senior fellow at the University of Chicago Public Health Research Department, described the major effects of social factors on health. He cited *Healthy People 2020 Framework*, which emphasizes areas for improving Americans' health outcomes by the year 2020 and divides the social determinants of health into five categories:[2]

◆ Economic stability—poverty, employment, food security, and housing stability.

◆ Education—high school graduation, enrollment in higher education, language and literacy, and early childhood education and development.

[2] www.healthypeople.gov/sites/default/files/HP2020Framework.pdf.

Idaho's Southwest District Health dispatches "drive-through clinics" to bring vaccines and medical care to county citizens. Community organizations are crucial partners for ensuring health access in rural areas.

Photo: Laura Gilmore, Flickr

Photo: ThoseGuys119, Flickr

Regulations often prevent available resources like school buses to be used in filling transportation-related gaps in healthcare access.

◆ Social and community context—social cohesion, civic participation, perceptions of discrimination and equity, and incarceration and institutionalization.

◆ Health and healthcare—access to healthcare, access to primary care, and health literacy.

◆ Neighborhood and built environment—access to healthy foods, quality of housing, crime and violence, and environmental conditions.

"In every rural meeting we have done, the two issues that come out at the top in terms of infrastructure capacities are transportation and broadband," stated Meit.

Morris agreed about the importance of transportation. "Sometimes we make it harder than it needs to be," he added, referencing the use of existing transportation options to solve transportation deficits. For instance, a Head Start van may not be able to transport anybody else besides Head Start participants because of liability issues. School buses can only transport students, and senior services transportation can only take seniors.

Factors Affecting Resiliency

The United States has been adding jobs since about 2010, although the numbers have slowed in the past few years. Rural America has underperformed in employment growth for both the nation as a whole and urban America. Brian Lewandowski, who studies regional economies, discussed a recent study in Colorado that compared growth in population, employment, income, housing prices, and other economic metrics.

The study found that human-made resources such as Interstates, highways, community colleges, universities, airports, and hospitals provide a competitive advantage to communities. According to the focus groups in the study, other factors that boost resiliency include industry diversity, strong leadership, and access to transportation.

Lewandowski also discussed the effects of local leadership on community resiliency: "We heard many stories and anecdotes about leaders who have come together to help build something in their community. If it is putting away land for an industrial complex, if it is building a trail along the river, if it is saving the railroad and turning it into a tourism amenity, there are countless stories of things communities have done in the past that are paying dividends today."

Foundations Working to Improve Communities' Health

Speakers discussed how foundations are part of a "third sector" (after government and industry), leveraging resources to bring about change in communities. In particular, leaders of local and regional

Photo: Royalbroil, Flickr

Lakeview Medical Center serves Rice Lake, Wisconsin—a town of 8,000. A Colorado study shows that in rural communities, resources such as hospitals, universities, and airports help ensure resiliency.

Photo: Donovan Shorty, Flickr

A woman in Window Rock, Arizona, participates in Just Move It, a noncompetitive running and walking program of the Navajo Nation that recently celebrated its 25th anniversary.

foundations discussed how their organizations have applied resources to build on their communities' strengths in rural areas.

Ashley Browning, an educational planner in the Office of Continuing Medical Education of East Tennessee State University's Quillen College of Medicine, described a Knoxville, Tennessee, foundation called the Appalachian Community Fund, for which she is secretary of the board of directors. The fund's mission is to build a sustainable base of resources to help community-led organizations in central Appalachia overcome and address issues of race, economic status, gender, sexual identity, and disability. Browning described one of the transportation-related initiatives of the Appalachian Community Fund, in which it challenged and postponed a road project that would have destroyed Chattanooga's Lincoln Park neighborhood—a historically African-American neighborhood that contained old Negro League ballfields.

Speakers also discussed the Con Alma Health Foundation, the largest foundation solely dedicated to health in New Mexico. Its mission is responding to the health needs of the culturally and demographically diverse people and communities of New Mexico, improving health status and access to healthcare, and advocating for policies that will address the health needs of all. Con Alma executive director Dolores Roybal explained that the foundation provides grants to local organizations focusing on health equity rather than health disparities, with health broadly defined to include behavioral, oral, environmental, and spiritual aspects. "Health is much more than healthcare. That is why we fund things like housing, transportation, and economic development," Roybal noted.

Tax Initiatives as a Policy Lever for Improved Health Outcomes

One group that successfully advocated for—and implemented—a tax initiative for improving their community's health outcomes was the Diné Community Advocacy Alliance (DCAA). Based out of the Navajo Nation in Arizona, DCAA was formed in response to the high rates of obesity, diabetes, and related complications among residents of Navajo, or Diné, communities. The alliance is composed of grassroots-level health advocates from various communities that work to raise awareness, inform, educate, and mobilize community members to combat obesity, diabetes, and other chronic health issues.

Although the Navajo Nation is the size of West Virginia, it has only 11 grocery stores. In many cases, people have to drive hundreds of miles—one way—to buy groceries. Furthermore, one out of three members of the Navajo Nation has diabetes. "Every Navajo family is affected by this," said Denisa Livingston, a member of the Navajo Nation and a community health advocate for DCAA.

DCAA's Healthy Diné Nation Tax Initiative changed the taxes on healthy and unhealthy foods to address these and other health problems. Specifically, through its advocacy efforts, DCAA was able to eliminate a 5 percent Navajo Nation sales tax on healthy foods and to add a 2 percent sales tax on unhealthy foods.

Children's Health Fund joined Ford Health System to launch a new mobile medical unit that will serve students in Detroit, Michigan.

PHOTO: SENATOR STABENOW, FLICKR

Just in the first quarter of 2017, Livingston noted, the 2 percent tax raised $2.6 million to fund community wellness projects in all 110 Navajo chapters. These community-based and owned projects address improvements to the physical and social environment in Navajo communities. Allowable projects include those that improve the built recreational environment, the social setting, education, community food and water initiatives, and health emergency preparedness; for example, developing biking and walking trails and farming and gardening initiatives. According to Livingston, the goal is to "allow community members to take control over their social environments and physical environments to implement what is needed in their area."

Taking Healthcare to Rural Areas

As part of its work over the past three decades, the Children's Health Fund (CHF) operates more than 50 state-of-the-art mobile medical clinics that provide comprehensive healthcare for some of the country's most medically underserved children. The clinics are "doctor's offices on wheels," said Dennis Johnson, CHF executive vice president for government affairs and policy director for the Earth Institute's National Center for Disaster Preparedness at Columbia University.

Johnson focused on the need for transportation services: "Mobility has always been a key consideration in developing programs to address access barriers. We were sending mobile units out to deliver healthcare." Other social determinants of health also had an influence on the program—including socioeconomic status, citizenship status, and cultural barriers—but "transportation was a big issue," he explained.

Transportation Difficulties and Health

According to CHF surveys, 39 percent of U.S. residents reported that public transportation was not available in their community and 11 percent of U.S. households reported that they did not own a working vehicle. Although automobile ownership did not vary significantly by area of residence, the availability of public transportation did (see Figure 2, page 43). In rural areas, only 25 percent of people reported access to public transportation.

The lack of transportation caused 4 percent of U.S. children—regardless of income, insurance status, or area of residence—to miss a healthcare appointment in the year before the survey, including 9 percent of children in poor and low-income families. Of those who missed an appointment, 63 percent missed two or more visits during the year, and 31 percent of parents reported that they later sought emergency care for the condition associated with the healthcare appointment. Two to three million children in the United States were missing routine healthcare because of transportation difficulties.

Transportation difficulties affect health in many

ways, Johnson observed. Besides creating missed opportunities for immunizations and routine well-child care, a lack of transportation increases the incidence of untreated chronic illnesses, the use of emergency rooms and ambulances for nonemergency care, and the rate of preventable hospitalizations. Medical transportation provider organizations must commit to being part of the healthcare team to create a more seamless system and improve health access, Johnson added.

To quantify the severity of the issue, CHF developed the Health Transportation Shortage Index. It rates factors associated with barriers to primary-care access, including area of residence; poverty, which serves as a proxy for not owning a vehicle; health professional shortages; safety-net healthcare resources; and the public transportation infrastructure. The index generates a score from 0 to 14, with scores of 8 or higher indicating that communities are at risk of inappropriate health access because of transportation problems.

Children's Health Project

As an example of a rural program, Johnson described the Idaho Children's Health Project in south central Idaho, which serves a population of low-income, uninsured, and migrant seasonal farm workers. CHF participates in the program through a dental health mobile clinic. Among the major challenges the program faces are a lack of transportation and of Medicaid providers, the geographic spread of community-based health facilities and of the patient base, the growth in the permanent population of formerly migrant workers, and Idaho's rejection of Medicaid expansion under the Affordable Care Act.

Insurance coverage is not sufficient for the people served through the Children's Health Project and elsewhere, Johnson noted. Transportation deficiencies lead to suboptimal access to primary care and suboptimal management of chronic conditions. The result can be overutilization of emergency care services, increased referrals to more costly specialists, increased healthcare costs, and poorer health outcomes. "The takeaway for us is that, in rural America, transportation access is the critical connective tissue supporting health access, opportunity, and, ultimately, equity," he observed.

Johnson closed with several recommended actions that apply both in Idaho and in rural communities more broadly:

- Monitoring nonemergency medical transportation providers to ensure that they provide appropriate access;
- Educating and convening stakeholders, which could make them more aware of the ways in which transportation access affects health;
- Improving care via partnerships with hospitals, community health centers, and other human-services providers; and
- Fostering collaborative planning to better serve community needs through outreach to and engagement of state transportation officials.

Conclusion

Achieving health equity and facilitating access to healthcare in rural areas presents a host of unique challenges—some demographic, some economic, some social. Unique solutions to transport people to healthcare and to bring healthcare to them are needed, especially for those without access to a vehicle or public transit and for those who are elderly or disabled.

Health equity and healthcare access also involve the influence that those in rural areas should have on their built environment—that is, the ability to construct infrastructure for active transportation, to maintain infrastructure that sustains the community, and to oppose infrastructure that can negatively affect the community.

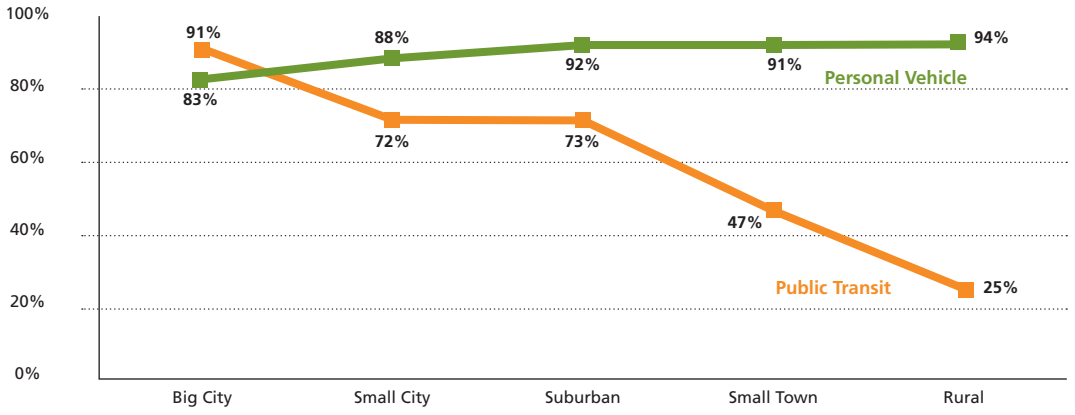

FIGURE 2 The availability of public transportation is significantly lower in small towns and rural areas than in cities and suburbs. (Source: Dennis Johnson.)

Safely Transporting Hazardous Liquids and Gases in a Changing U.S. Energy Landscape

MICAH D. HIMMEL

The author is Program Officer, Consensus and Advisory Studies Division, Transportation Research Board, National Academies of Sciences, Engineering, and Medicine, Washington, D.C., and served as study director for this project.

In the mid-2000s, legislation mandating the use of fuel ethanol as a gasoline additive in the United States and technological innovations in oil and gas extraction—hydraulic fracturing and horizontal drilling—in previously unproductive regions enabled a jump in production, dubbed the domestic energy revolution. This trend led to sudden and unanticipated demands on pipelines, railroads, and barges for the transport of crude oil, natural gas, natural gas liquids, and ethanol shipments in parts of the nation previously unfamiliar with these kinds of long-distance, bulk shipments. With this dramatic increase came many concerns about the safe transportation of hazardous energy liquids and gases.

The new shipments of these energy liquids and gases come from the country's most productive hydraulic fracturing fields in places like North Dakota, Pennsylvania, and neighboring states—located far from refinery and petrochemical centers in established oil and natural gas markets. With limited access to an in-place network of transmission pipelines, producers of oil and natural gas liquids from these regions have turned to trains and barges to transport their products to distant markets (Figure 1, page 45). Likewise, ethanol plants in Illinois, Iowa, Nebraska, and other corn-producing states in the Midwest are located far from some of the country's largest consumers of gasoline: the major population centers on the East and West Coasts and in the Southeast and Southwest (Figure 2, page 45).

PHOTO: ELIAS SCHEVEL, FLICKR

In 2013, a train carrying crude oil derailed in Lac-Mégantic, Quebec, killing more than 40 people and destroying all but three of the downtown area's buildings.

TRB sponsored a study by a committee of experts (see box, page 46) to examine the safety performance of long-distance freight modes with a focus on the domestic energy revolution. *TRB Special Report 325: Safely Transporting Hazardous Liquids and Gases in a Changing U.S. Energy Landscape,* reviews the response of the U.S. pipeline, rail, and barge

PHOTO: PHOTOLIBRARIAN, FLICKR

Concerns over safely transporting fuels have grown as new refineries sprout up long distances from major population centers.

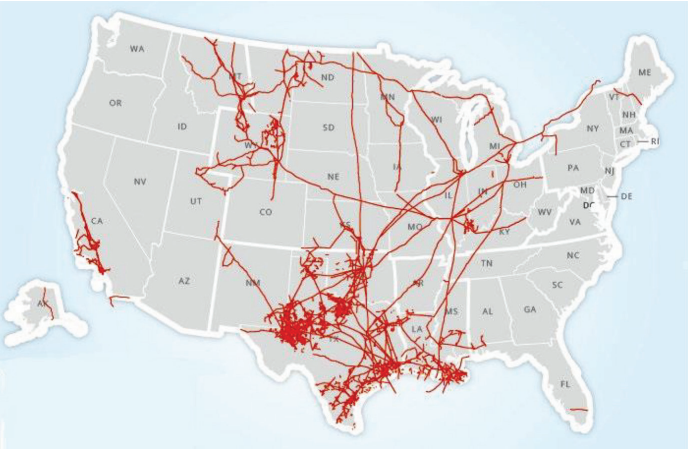

FIGURE 1 U.S. crude oil transmission pipeline network. (Source: American Energy Mapping, 2013.)

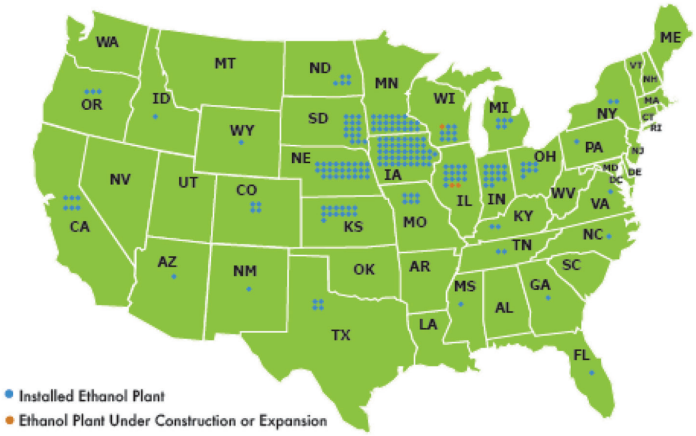

FIGURE 2 Fuel ethanol production facilities in 2016, by state. (Source: Renewable Fuels Association.)

industries to the surge in shipments after 2005 in domestic crude oil, fuel ethanol, and natural gas production. The report considers serious accidents that occurred—including the catastrophic 2013 train derailment in Lac-Mégantic, Quebec—and credits transportation service providers and regulators for their overall performance transporting the vast majority of this new hazardous traffic without incident, enabling the country to capitalize on its new energy resources.

Observations

Overall, the committee found that pipelines and waterways have accommodated major portions of the growth in domestic energy liquids and gases, and they have done so without creating major new safety problems and within the basic framework of their longstanding regulatory and safety assurance systems. The committee also made the following observations.

◆ **The Marine Transportation System offers a model for a robust safety assurance system.** Although the increase in barge movements of crude oil over the past decade has not attracted much public attention, the total volumes of oil transported by barge have exceeded those transported by rail. When the committee examined the safety record of energy liquids movement by waterways, it found no reports of ethanol or natural gas liquids releases in the past 10 years and only rare reports of crude oil releases. A series of incidents 30 years ago led to statutory and regulatory safety reforms, producing a robust and anticipatory safety culture that can serve as a model for other energy transport modes.

◆ **Railroads have an opportunity to create a**

Photo: U.S. Coast Guard

U.S. barges carrying two million gallons of crude oil in the Gulf Intracoastal Waterway. Increasingly, oil transported by barge exceeds that carried by rail.

A DOT-117 specification tank car built with hardened safety features for shipments of flammable liquids on display as part of Norfolk Southern's Operation Awareness and Response.

more robust safety assurance system. This stronger safety assurance system for moving crude oil and ethanol resembles those of the maritime and pipeline carriers. Before 2005, railroads had minimal experience carrying ethanol and crude oil in large quantities (Figure 3, below). The surge in domestic production of oil and ethanol resulted in a glut of energy resources in parts of the country that lacked sufficient barge and pipeline takeaway capacity (Figure 4, below). Therefore, railroads began to transport hazardous energy liquids in tank cars that had not previously carried these flammable materials in bulk, using shippers that lacked experience transporting them. Preventing the derailment of these older railroad tank cars is imperative, the report concludes. In addition to tank car design, postincident investigations of severe train derailments involving flammable liquids indicate that track wear and defects are common causal factors. Questions remain about the technical basis for the track inspection standards, which set an allowable failure rate, and whether these allowable rates and repair priorities should be adjusted for routes used by tank car unit trains.

◆ **Emergency response preparedness has improved, but with geographic inconsistency**. The committee found several opportunities for improvement in emergency response preparedness. Many communities do not know how to respond to large-scale incidents involving trainloads of flammable

Committee for a Study of Domestic Transportation of Petroleum, Natural Gas, and Ethanol

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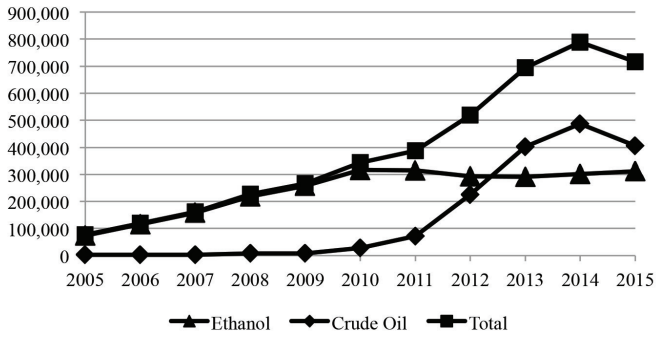


FIGURE 3 U.S. crude oil and ethanol rail carloads, 2005–2015. (Note: One carload equals approximately 700 barrels. Source: Association of American Railroads.)

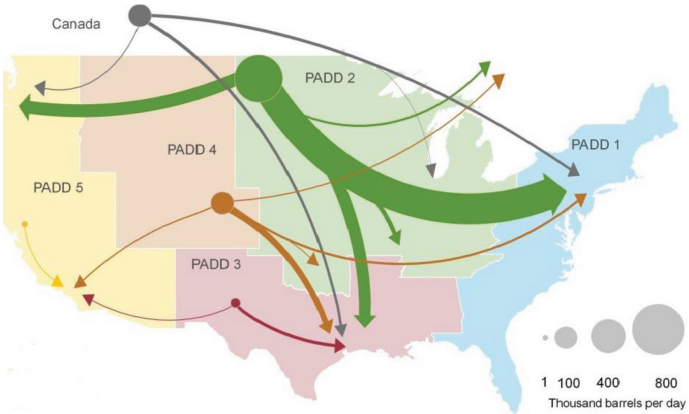


FIGURE 4 Location and volume of rail traffic of North Dakota Bakken crude oil (in green), 2014. (Source: U.S. Energy Information Administration)

liquids. Industry and government authorities must broaden awareness of best practices in preparing for and responding to incidents and in fully exploiting training opportunities, especially among rural communities served by volunteer fire departments.

Recommendations

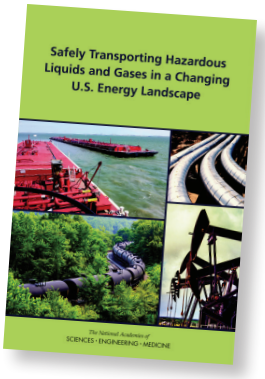
The committee recommended that the Pipeline and Hazardous Materials Safety Administration (PHMSA) undertake a comprehensive review of the successes and failures in responding to transportation safety challenges since 2005, to inform the development of more anticipatory and robust safety assurance systems. PHMSA should review federal emergency preparedness grants to ensure that planning and training opportunities respond to the needs of communities. Moreover, PHMSA and other safety regulators should encourage pipeline, barge, and rail carriers to use quantitative risk analysis tools more often to inform decisions about priorities for equipment and infrastructure maintenance and integrity management as well as about the routing of energy liquids by rail.

The Federal Railroad Administration (FRA) should enable and incentivize frequent and comprehensive inspections of rail routes that carry energy liquids traffic regularly and should enable new capabilities in autonomous systems, high-resolution imaging, and sensor technologies, according to the study committee.

PHMSA and FRA also should take advantage of increased experience with tank car unit train movements—including accident experience—to systematically model all the factors that can cause and affect the severity of flammable liquids train crashes, including the propagation of internal rail defects and the kinetics that arise from multicar derailments.

The recommendations in Special Report 325 are intended to make the energy liquids and natural gas transportation safety assurance system more anticipatory, responsive, and risk-informed. Working together, industry, regulators, and the emergency response community will improve their ability to reduce the occurrence and severity of incidents involving transportation of these commodities. These stakeholders will need to share information and develop more robust risk analytics, create and apply incentives to further the use of automation and other technological innovations for monitoring the safe operation and condition of equipment and infrastructure, and regularly review the effectiveness of safety regulations.

Crude oil–loading rack for unit train service.



TRB Special Report 325: Safely Transporting Hazardous Liquids and Gases in a Changing U.S. Energy Landscape, is available from National Academies Press at www.nap.edu/catalog/24923/safely-transporting-hazardous-liquids-and-gases-in-a-changing-us-energy-landscape; to view the book online, www.trb.org/Main/Blurbs/176638.aspx.

Photo: Erik Strickland, Flickr

National Transportation Safety Board investigators respond to a tank car derailment in Pennsylvania in 2017.

Leveraging Technology to Develop and Implement a Pavement Marking Management System in Florida

BOUZID CHOUBANE

The author is State Pavement Materials Engineer, Florida Department of Transportation, Gainesville.

According to the Federal Highway Administration (FHWA), more than half of all traffic fatalities occur at night—even though three-quarters of travel occurs in daylight hours (*1*). When factoring in miles driven, the fatality rate at night is triple that of daytime. Although factors such as alcohol and fatigue contribute to this rate, pavement markings that provide appropriate visibility levels and facilitate safe nighttime driving have been shown to reduce crashes (*1*). Retroreflective markings reflect the light from a vehicle's headlamps back to the driver's eyes.

This retroreflectivity, or retroreflection, typically comes from the application of small glass spheres that are partially embedded into the pavement marking material.

Problem

Pavement markings are an important aspect of a safe transportation system, conveying vital roadway warnings and guidance information to the traveling public. It is therefore beneficial to maintain acceptable visibility levels on pavement markings in all weather and lighting conditions. To ensure that these levels are maintained adequately, the retroreflectivity must be periodically monitored and quantified accordingly.

Historically, retroreflectivity of in-service pavement markings has been measured with handheld devices and visual inspections. Visual surveys are considered subjective and handheld measurement is tedious and potentially hazardous, however.

All the monitoring data must be managed effec-

PHOTO: JORDAN SANGERMAN

Retroreflectivity of pavement markings increase their visibility and safety. Florida DOT's pavement marking management system assists in the timely maintenance of these markings.

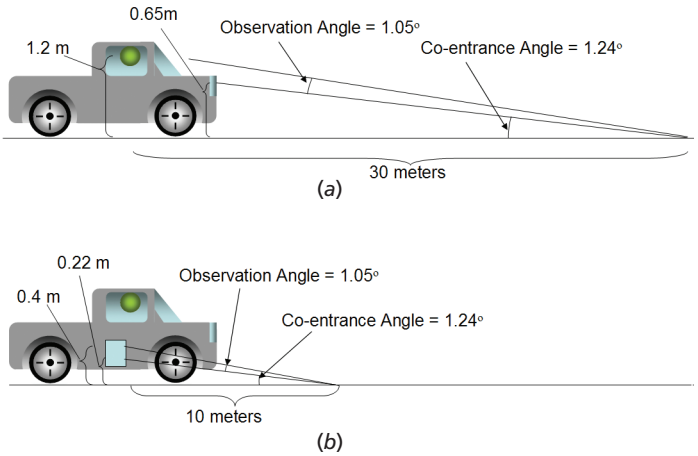


FIGURE 1 Standard 30-m geometry (*a*) and one-third scale (*b*).

tively and systematically, and because of this, it is essential to design and implement a comprehensive system for pavement marking management. Such a system would provide useful and objective information for more consistent, cost-effective, and data-driven decision making.

Solution

Consequently, the Florida Department of Transportation (DOT) focused on noncontact, sensor-based technology capable of assessing pavement markings continuously at highway speeds with improved safety and efficiency (2–4). The use of mobile technology for measuring retroreflectivity has allowed Florida DOT to develop and implement a pavement marking management system (PMMS) to improve the safety and nighttime visibility of its roadways. This approach offers Florida DOT an efficient, less-subjective methodology to identify conditions that are detrimental to roadway safety and to strategize ways to mitigate solutions, including the selection of appropriate materials and application techniques.

Florida Retroreflectivity Data Collection

Florida DOT's mobile system measures the retroreflectivity according to the "30-m geometry" described in ASTM E1710 (5). The 30-m geometry consists of the following assumptions: a typical passenger vehicle headlamp height of 0.65 m (2.1 ft), a driver eye height of 1.2 m (3.9 ft), and a distance of 30 m (98 ft) between the headlamps and the ground-based retroreflectance target. To reduce the size of the measuring device, a proportional scale is used: one-third of the 30-m geometry, shown in Figure 1 (above). Detailed description of Florida's system and other related information can be found elsewhere (2–4).

As with any testing using subject-driven, instrumented devices, the major concerns of the end usefulness of the resulting data are accuracy and precision. Although a level of uncertainty is always inherent to any measurement process, it also must be appropriately quantified or assessed. Florida DOT conducted a comprehensive study to assess the precision of its system in terms of repeatability and reproducibility (3). The overall pooled standard deviation was determined to be 12.0 mcd/m^2/lux within a device and 18.8 mcd/m^2/lux between devices. The overall pooled coefficient of variance was estimated to be 2.8% within a device and 4.7% between devices. More details can be found elsewhere (3).

To standardize the testing, including the data-collection activities, Florida DOT developed a test method for measuring retroreflectivity of pavement marking materials (6). A standard naming convention was included to identify each pavement stripe, regardless of the number of lanes. This test method also normalizes the data acquisition system, operational procedure, and reporting, as well as equipment calibration and precision.

Florida PMMS

All pavement marking retroreflectivity measurements are stored in a comprehensive database accessible via intranet and a web-based interface. It also includes other vital roadway information, such as feature codes from Florida DOT's Roadway Characteristics Inventory database (average daily traffic, speed limit, pavement type, and more). The database stores pavement marking data in 0.1-mi increments and includes the ability to store and retrieve 40 years of data. Some of the additional features include a mobile-friendly, web-based interface to query and filter the retroreflectivity data based on set criteria.

The information in the web-based interface is cross-referenced with video image files and data mapping with a geographic information system (GIS) application using linear reference system information (Figure 2, page 50). The GIS map uses dif-

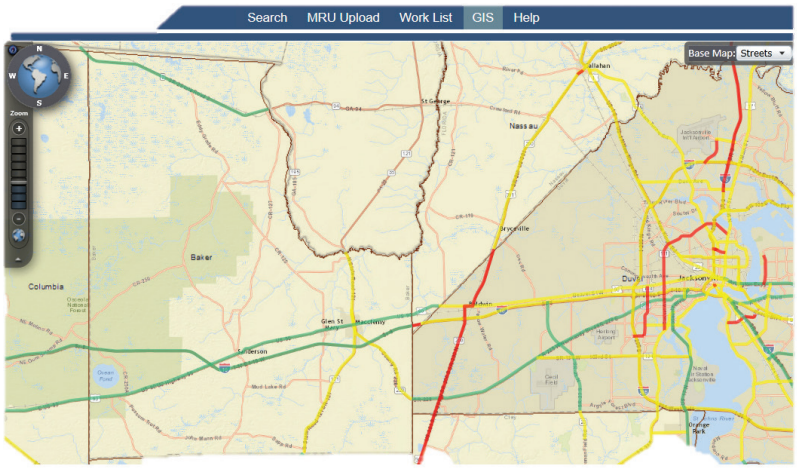


FIGURE 2 GIS viewer application of a county roadway section.

ferent colors for different ranges of retroreflectivity values as defined by the user and allows the user to download the retroreflectivity data for any given roadway as an Excel file.

Application

In 2012, Florida DOT implemented PMMS. The primary objective of the system is to evaluate and manage the statewide pavement marking retroreflectivity in a systematic and efficient manner. A total of 25,000 lane-miles of pavement markings are evaluated annually, with a primary emphasis on yellow center lines and white line (edge and skip) markings. Moreover, to ensure the reliability of the retroreflectivity data, Florida DOT conducts independent field quality assurance testing.

In addition to providing data in the PMMS database and allowing immediate access, a notice is sent upon completing the survey on any given county. Moreover, at the end of each survey year, Florida DOT issues an annual report with essential information on the condition of the Florida State Highway System pavement markings collected that year. The comprehensive PMMS database, county completion notification, and annual facts and figures reports on statewide pavement marking performance are examples of the rich information the PMMS provides to Florida DOT districts to make data-driven decisions and to manage statewide pavement markings cost-effectively and in a timely manner.

Benefits

The Florida PMMS offers an efficient, safer, and less-subjective methodology to monitor and assess the safety and night visibility of the state's roadway system. It ultimately results in a more effective and strategic use of state funds through informed decision making and by ensuring the safety of the traveling public.

Florida TaxWatch recently honored the PMMS with a Productivity Award and highlighted this work, noting that it "significantly and measurably increases productivity and promotes innovation to improve the delivery of state services and save money for Florida taxpayers and businesses." PMMS creates an estimated savings of more than $1.7 million each year versus the traditional approaches.

With the advance in autonomous vehicle and connected vehicle technologies, the information contained in the PMMS may also be valuable to the latest national research effort on the effect of different performance characteristics of pavement markings on the ability of machine vision systems to detect and recognize pavement markings.

Contact

For more information, contact Bouzid Choubane, State Pavement Materials Engineer; Florida Department of Transportation, 5007 NE 39th Avenue, Gainesville, FL 32609; 352-955-6302; bouzid.choubane@dot.state.fl.us.

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

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Suggestions for Research Pays Off topics are welcome. Contact Stephen Maher, Transportation Research Board, Keck 486, 500 Fifth Street, NW, Washington, DC 20001; 202-334-2955; smaher@nas.edu.

CALENDAR

TRB Meetings

September

16–18 Disrupting Mobility Summit*
Cambridge, Massachusetts

19–21 Annual Conference of the Florida Association of Environmental Professionals*
Orlando, Florida

25–27 Managing Roadways and Transit
Bellevue, Washington

30–Oct. 3 23rd National Conference on Rural Public and Intercity Bus Transportation
Breckenridge, Colorado

October

4–6 International Symposium on Emerging Trends in Transportation*
Waikiki Beach, Hawaii

9–10 Transportation Resilience Innovations Summit and Exchange
Denver, Colorado

22–24 European Road Congress: Corridors for Shared Prosperity and Sustainable Mobility*
Dubrovnik, Croatia

November

5–7 1st International Conference on Stone Matrix Asphalt*
Atlanta, Georgia

7–9 Forum on the Impact of Vehicle Technologies and Automation on Users: Vulnerable Road Users and Driver Behavior and Performance*
Iowa City, Iowa

24–28 GeoMEast International Conference: Sustainable Civil Infrastructures—Structural Integrity*
Cairo, Egypt

27–28 6th Florida Automated Vehicles Summit*
Tampa, Florida

December

2–5 6th International Symposium on Nanotechnology in Construction*
Hong Kong

January 2019

13–17 TRB 98th Annual Meeting
Washington, D.C.

March

24–27 Geo-Congress 2019: 8th International Conference on Case Histories in Geotechnical Engineering*
Philadelphia, Pennsylvania

April

7–9 14th National Light Rail and Streetcar Conference*
Jersey City, New Jersey

9–10 Innovations in Freight Data Workshop
Irvine, California

15–17 International Conference on Demand Responsive and Innovative Transportation Services
Baltimore, Maryland

23–25 2nd International Intelligent Construction Technologies Group Conference*
Beijing, China

Upcoming Webinars

September

25 Meteorological Effects of Roadway Noise

26 Establishing a Coordinated Local Family Assistance Program for Airports

27 Practices in Rural Regional Mobility: Case Studies and Lessons Learned

October

2 A Transit Agency Guide to Evaluating Secondary Train Detection/Protection Systems in Communications-Based Train Control Systems

9 Just How Important Are Service Design Models to ADA Paratransit?

23 Battery Electric Buses—State of the Practice

25 Examining the Effects of NEMT Brokerages on Transportation Coordination

31 Moisture Damage in Asphalt Pavements: Forensic Analyses and Research Needs

Additional information on TRB meetings, including calls for abstracts, meeting registration, and hotel reservations, is available at www.TRB.org/calendar, or e-mail TRBMeetings@nas.edu.

*TRB is cosponsor of the meeting.

Barbara Harsha

BLH Consulting LLC

Executive Director of the Governors Highway Safety Association (GHSA) for 25 years, Barbara Harsha has extensive expertise on highway safety and federal highway safety statutes and regulations. As principal with BLH Consulting LLC from 2013 to 2017, Harsha specialized in behavioral highway safety issues such as occupant protection, drunk driving, teen driving, and distracted driving.

Harsha received a master's degree in urban planning from the University of Southern California and a bachelor's degree from Washington University in St. Louis. She worked as a transportation planner with the Southern California Association of Governments in Los Angeles and then for 10 years for the National League of Cities, a major public interest group in Washington, D.C., serving as a senior policy analyst for the League's transportation committee and, later, as the Director of Policy Development.

"Research is the linchpin to everything a state highway safety office does."

"Research is central to transportation planning and implementation in general and to behavioral highway safety specifically," Harsha comments. "States and localities have limited resources and must use those resources on effective transportation strategies. Research helps them determine what is effective and what should be implemented on a priority basis."

In 1988, Harsha joined GHSA, a nonprofit organization that represents state highway safety offices. She directed the work of the organization's Washington office, providing services to the membership; representing GHSA in a variety of capacities, including with Congress and federal agencies; and administering federal grants.

"As the director of an organization representing state highway safety offices (SHSOs) and focused on the behavior of drivers and other vulnerable road users, I saw firsthand how critical research was," Harsha observes. Under her leadership, GHSA developed and updated its Model Minimum Uniform Crash Criteria (MMUCC), developed highway safety and traffic records performance measures now used by many states in their highway safety plans, developed the first *Countermeasures that Work* research summary of behavioral countermeasures for the National Highway Traffic Safety Administration (NHTSA), and created many planning and management guidance documents for states.

"Once the countermeasures detailed in *Countermeasures that Work* are implemented, either statewide or at specific locations or corridors, states use research to monitor implementation," Harsha notes. "In other words, research is the linchpin to everything a SHSO does. Without research, the SHSO would likely implement programs that are only marginally effective and that waste limited federal and state resources."

As principal of BLH Consulting, Harsha coauthored "Mapping to MMUCC," a NHTSA-funded guideline to help states determine how to measure their compatibility with MMUCC; served on a panel on drugged driving funded by the Foundation for Advancing Alcohol Responsibility; participated in an Alabama Department of Transportation peer-review panel on highway safety workforce development; and helped the American Association of State Highway and Transportation Officials (AASHTO) create a strategic highway safety research plan.

Harsha worked closely with national organizations representing state-level safety—AASHTO, the International Association of Chiefs of Police, the American Association of Motor Vehicle Administrators, the Commercial Vehicle Safety Alliance, and the National Association of State Emergency Medical Services Officials—as well as with a wide variety of foundations and associations including AAA, the AAA Foundation for Traffic Safety, and Mothers Against Drunk Driving. She helped to develop a set of core competencies for highway safety professionals and guided GHSA's focus on the issue of highway safety workforce development. She has been interviewed by the print, radio, and broadcast outlets such as the *Washington Post*, *New York Times*, *USA Today*, CBS Radio, the *Los Angeles Times*, and the Peggy Smedley show.

Harsha brought her comprehensive knowledge of highway safety to her longtime service on Transportation Research Board (TRB) committees and project panels. She joined the Planning and Administration of Transportation Safety Committee in 1989 and in 1995 began a 15-year tenure on the Transportation Safety Management Committee. She also served on the Task Force on Women's Issues in Transportation, which became a full committee in 2000, and on the Occupant Protection Committee.

Harsha joined the TRB Task Force on Highway Safety Workforce Development in 2007; when it became a full committee in 2013, she served as cochair. She also was a member of several National Cooperative Highway Research Program panels on topics including on Guidance for the Implementation of the Toward Zero Deaths National Strategy on Highway Safety, Development of a Comprehensive Approach for Serious Traffic Crash Injury Measurement and Reporting Systems, and Cost–Benefit Metrics for Behavioral Highway Safety Countermeasures.

Cameron Kergaye

Utah Department of Transportation

After graduating from the University of Utah, Cameron Kergaye joined the Utah Department of Transportation (DOT) in 1992 as an engineer, working on assignments in various fields from construction to roadway design to traffic safety. He progressed through the ranks to become Director of Research and Innovation at the agency. He now focuses on establishing a culture of innovation for implementing transportation improvements and on leading research and development initiatives.

"The Utah DOT Research and Innovation Division pursues innovative solutions to Utah's transportation challenges," Kergaye comments. "We work with transportation professionals, consultants, and academic researchers to find safer and better ways to move people and goods."

"The Utah DOT Research and Innovation Division pursues innovative solutions to Utah's transportation challenges."

After working as a materials engineer at Utah DOT, managing a bituminous lab and implementing standards to achieve accreditation, Kergaye served for 2 years as quality manager of Utah's I-15, providing design–build oversight of acceptance testing and independent assurance management.

In 2003, after several years managing divisions within Utah DOT's Engineering Services—consultant services, access management, statewide permitting, utilities and railroads, and value engineering—Kergaye took a fellowship at the American Association of State Highway and Transportation Officials (AASHTO). As an engineering fellow at AASHTO, he was responsible for work on technical committees and transportation policy research.

Kergaye returned to Utah DOT in 2005 and held several project and program management positions over the next few years. He managed state and local transportation projects, from concept and design to construction; directed technical support for statewide program and project management; and provided program delivery support for new agency initiatives, such as zero-based budgeting. He received a Ph.D. in civil engineering in 2009.

"We look to apply innovations developed from within the organization or tested in other states," Kergaye notes.

The Research and Innovation Division solicits and develops ideas from Utah DOT staff, ranging from human resources efficiencies to paperless processes to inventive equipment elements. Of the 215 ideas brought forward, 152 have been implemented and 63 are in development.

Among Utah DOT's current pilot projects are a hydraulic lift mounted onto a vacuum truck for increasingly heavy grates and manhole covers, submitted by engineers in Region 2. A group at Brigham Young University is designing this lift and will conduct tests. In Region 3, green-painted bicycle lanes are under construction. Other innovations include a barrier straightening tool, hood brackets for Mack trucks, a traffic cone holder for a vacuum truck, a hitch-mount concrete mixer, and racks to hold wing blades.

Recent Utah DOT safety research received recognition from AASHTO as one of its designated high-value projects of 2018, also known as the "Sweet Sixteen." The Planning and Traffic and Safety divisions initiated the research in 2015 and retained consulting firm RSG, Inc., to conduct the study. The research identified a process to improve long-range planning prioritization by using forecasted safety metrics in place of the existing Utah DOT Safety Index—a metric that had been based on historical crash data.

The research team developed a Safety Forecast Model using AASHTO's *Highway Safety Manual* safety performance functions and crash modification factors, along with roadway characteristics and future condition data. The Safety Forecast Model compared predicted crashes based on the 2015–2040 Utah DOT Long-Range Plan build scenario to predicted crashes based on the no-build scenario. Using case studies, the research team determined that project prioritization changes if the ranking considers future safety impacts rather than relying solely on historical crash data. The research team also determined that the Safety Forecast Model could be used to recommend safety projects and to perform systemic safety analyses. The results will be incorporated into the state's future long-range plans.

Kergaye has served as the TRB State Representative from Utah since 2010. He is a longtime member of the Technology Transfer Committee and also serves on the Conduct of Research Committee, the AASHTO Special Committee on Research and Innovation, the AASHTO Research Advisory Committee (RAC). Kergaye is chair of the Coordination and Collaboration Subcommittee and has served as AASHTO RAC Region IV Chair, Vice Chair, and Secretary.

Kergaye also serves as the Vice Chair of the Western Road User Charge Consortium Steering Committee; on the advisory board of the National Institute for Transportation and Communities; and as a member of American Society of Civil Engineers, the Institute of Transportation Engineers, and the Project Management Institute.

Getting the Public Involved in Long-Term Transportation Planning

11th Annual Competition Identifies Best Practices

TERRI H. PARKER

With outreach strategies ranging from a meeting-in-a-box dinner party to innovative social media campaigns to a coloring-book van, the five winners of the 11th annual Communicating Concepts to John and Jane Q. Public competition illustrated how to demonstrate the value of long-term transportation planning.

The Minnesota Department of Transportation (DOT) received top honors for its entry, Statewide Multimodal Transportation Plan–State Highway Investment Plan Joint Update. The project team collected and leveraged robust public engagement data to implement and evaluate innovative tools and launch new partnerships to reach underserved communities. The tools, techniques, and plans developed with a strong focus on plain language and accessibility. This 8-month engagement effort incorporated innovative tools and techniques: stakeholder forums, roving tablet computer surveys, a coloring-book van, ad campaigns, and more.

The City of Boulder, Colorado, received honors for its entry, Engaging the Future Generation of Transit Riders. This project built upon the 21-year success of the city's HOP Bus to enhance customer experiences and address changes in land use and transportation options. City staff worked with the organization Growing Up Boulder to introduce city staff to students and teachers at Whittier International Elementary School for the opportunity to engage youth and learn how transit could be improved for people of all ages.

The North Jersey Transportation Planning Authority (NJTPA) and Rutgers University worked together on their winning entry, Innovative Public Outreach for the NJTPA's Plan 2045: Connecting North Jersey. They conducted research and developed a public outreach campaign that was inclusive and effective for the diverse region it served. Activities included Plan 2045–branded pop-up booths at nearly a dozen community events and a "Set the Table!" dinner party program for young adults featuring a meeting-in-a-box with activities, questions, and feedback forms for hosts to guide conversations.

California High-Speed Rail: Connecting the Next Generation Through #iWillRide Campaign, an entry submitted by the California High-Speed Rail Authority, was recognized for its public outreach campaign targeted at millennial generations and beyond. Originally founded by college students, the statewide campaign is a unique tool for creative thinking and for sharing innovative approaches to inform students about the future of transportation.

Pennsylvania DOT was honored for PennDOT's Twelve-Year Program Update Public Outreach Campaign, which was developed with assistance from McCormick Taylor, Inc. Pennsylvania DOT modernized public outreach strategies and communication methods involved in its planning process with a customized web-based survey, online public meeting, and a Director's Challenge that included a creative social media campaign.

For more information about these entries, and to learn about the 2018–2019 competition, visit the website for the TRB Committee on Public Involvement at http://sites.google.com/site/trbcommitteeada60.

PHOTO: RISDON PHOTOGRAPHY

Winners of the John and Jane Q. Public Competition at the TRB 2018 Annual Meeting in January.

The author is Director, Marketing and Communications, Texas A&M Transportation Institute, College Station.

ACRP Design Competition Winners Awarded

Three university teams took home top honors in the Transportation Research Board's 2018 Airport Cooperative Research Program (ACRP) University Design Competition for Addressing Airport Needs. The teams presented their winning designs at an award ceremony in Washington, D.C., in July.

An undergraduate team from the University of Rhode Island won first place in their category for a drone-based inspection system, titled "Eagle Eye," that would automate aspects of daily airfield inspections, and—as an added benefit—aid in wildlife management. A Purdue University team won first place for their use of smart technologies to monitor airport aprons, and graduate students from the College of Aeronautics at the Florida Institute of Technology won for their creation of a lidar and pressure plate system that would alert air traffic controllers of impending runway incursions.

The competition, founded by Federal Aviation Administration (FAA) in 2008 and moved to ACRP in 2014, challenges students to create technical innovations in one of four areas: Airport Operation and Maintenance; Runway Safety, Runway Incursions, or Runway Excursions; Airport Environmental Interactions; and Airport Management and Planning. Teams are required to work with a faculty advisor, airport operators, and industry experts to gain guidance and assess the practicality of their design solutions.

The Virginia Space Grant Consortium in Hampton manages the competition on behalf of ACRP, and volunteer panels consisting of FAA representatives, airport industry experts, and academic practitioners meet each spring to select winners. The winning teams receive $3,000 and the opportunity to present their designs at an industry professional conference or workshop this fall.

Submissions are now open for the 2019 competition, and guidelines can be found online at www.vsgc.odu.edu/ACRPDesignCompetition/index.html.

Inaugural TCRP Day

The Transit Cooperative Research Program (TCRP) develops near-term, practical solutions to problems facing public transportation. On June 6, the Transportation Research Board (TRB), in cooperation with the Federal Transit Administration (FTA), and the American Public Transportation Association (APTA), held the first-ever TCRP Day nationwide to raise awareness of the program, highlight its research in action, and encourage transit professionals to become involved.

Organizations across the U.S. were challenged to hold brown-bag lunches or to present information tables at their workplaces to educate colleagues about TCRP. An online toolkit provided to hosts included the following:

- A video of industry professionals explaining how specific reports influence their work;
- Suggested interactive activities;
- Social media suggestions;
- PowerPoint presentation detailing the work that TCRP does, the benefits of participating in it, how to become involved, and examples of research;
- Flyers with lists of TCRP's most popular publications and popular publications by topic area; and
- A list of upcoming reports and webinars.

The culmination of TCRP Day was the networking event "Transit on the Terrace," held at the TRB offices in Washington, D.C. The event was cosponsored by AECOM and attended by more than 60 individuals, including transportation professionals, state and local government officials, equipment and service suppliers, and research organization representatives.

Christopher Hedges, Director, Cooperative Research Programs, served as the Master of Ceremony and introduced the guest speakers, Matt Welbes, Executive Director, FTA; Paul Skoutelas, President and CEO, APTA; and Scott Baker, Senior Consulting Manager, AECOM. The guest speakers provided congratulatory remarks on the accomplishments of the TCRP Program. Welbes summed up his remarks by noting that "TCRP has been central to accelerating key practices in the public transportation industry" and that "the TCRP program is something that works."

APTA President and CEO Paul Skoutelas (*far right*) spoke about TCRP at the Transit on the Terrace gathering June 6 in Washington, D.C.

Photo: Wikimedia Commons

The Razorback Regional Greenway in Fayetteville is one of the many bicycle and pedestrian trails in Northwest Arkansas.

Bicycling Investment Reaps Benefits

Investing in bicycle infrastructure in Northwest Arkansas has paid off—literally. A new study shows that cycling in the region's extensive trail system now provides $137 million in benefits to the economy each year.

BBC Research & Consulting used a combination of literature review, surveys, and economic and health benefit analyses, using both private and public data, to estimate the economic, business, and health effects of bicycling and to determine the return on investment of the new infrastructure.

The study shows that northwest Arkansas residents spend more than $20 million annually on cycling, but that 55 percent of the bicyclists who use the trails come from outside the region—accounting for more than $25 million in tourist spending at local businesses each year. Use of the trails also is attributed to $85 million annually in health-related benefits. According to researchers, 27 percent of locals rode bikes six or more days in the previous year—a rate 11 percentage points higher than the national ridership average.

The study was commissioned by the Walton Family Foundation, in collaboration with PeopleForBikes and BikeNWA. The trails, which include a 36-mile shared-use paved trail that links major cities in the region, were supported by local and state funding as well as grants from the Walton Family Foundation and the U.S. Department of Transportation.

For more information and to read the report, visit www.waltonfamilyfoundation.org/about-us/newsroom/bicycling-provides-137-million-in-economic-benefits-to-northwest-arkansas.

Rumble Strips Deter Wrong-Way Drivers

Although U.S. vehicle crash deaths have declined overall in the past decade, wrong-way (WW) driving crashes continue to cause approximately 355 fatalities per year. WW driving countermeasures tested by various states include traditional and innovative signs, pavement markings using retroreflective paint, and technology systems, but researchers at the National Center for Asphalt Technology in Auburn, Alabama, are taking a different approach: rumble strips that generate elevated sound and vibration for WW drivers.

Five types of directional rumble strips were tested by full-size passenger vehicles at speeds of 10, 15, 20, 25, 35, and 45 mph for both WW and right-way driving. Researchers identified the three design patterns that best generated sound and vibration for WW drivers, and then conducted additional speed tests with those to designs to estimate the best response to typical WW driving speeds for recommendation in different off-ramp construction types.

The report, published by the University of Minnesota Roadway Safety Institute and the Center for Transportation Studies, can be found at www.cts.umn.edu/Publications/ResearchReports/reportdetail.html?id=2654.

Skateboarding as New Mobility Mode

As commuters seek alternatives to cars, skateboarding as a travel mode is on the rise. Researchers around the country are seeing skateboard commuting increase, in particular around universities and as transit-to-destination travel. In Los Angeles, California, more than 30,000 commuters per day use skateboards to get to and from buses and trains.

Researchers at the University of California, Davis, conducted interviews, travel surveys, and observations, and showed that skateboarding is two to four times faster than walking, and sometimes faster than bicycling and with more convenience and less cost. The speed of skateboards versus walking also expands the number of reachable destinations for travelers.

In many cities, however, skateboards face harsher regulations and restrictions than other modes of travel, as well as perceptions of higher safety risks.

For more information, visit https://transfersmagazine.org/faster-than-walking-more-flexible-than-biking-skateboarding-as-a-real-mobility-mode.

INTERNATIONAL

Walkability Linked to Lower Likelihood of Childhood Obesity

Photo: Pixabay

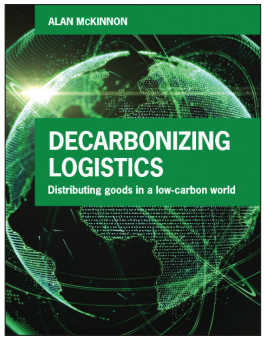
Children who live in walkable neighborhoods have lower body mass index (BMI) and smaller waistlines, according to a study published in Preventive Medicine magazine. A Montreal research team analyzed data over the course of 2 years for 391 children with a family history of obesity in Montreal, Canada. The team measured BMI and waist–height ratios of the children at baseline and follow-up, and integrated the data with built environment features, such as traffic calming features, pedestrian aids, and facilities.

Researchers found that urban design that encourages walking—like pedestrian crossing lights and signs and wider sidewalks—as well as play areas and bicycle-friendly areas, reduce the likelihood of childhood obesity. Unexpectedly, they also found that BMIs were lower in neighborhoods that had walkable convenience stores, demonstrating the need for more fine-tuning of data.

For more information, visit https://m.medicalxpress.com/news/2018-03-link-urban-childhood-obesity.html.

Decarbonizing Logistics: Distributing Goods in a Low-Carbon World

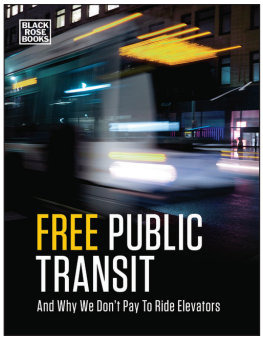
Alan McKinnon. Kogan Page, London, 2018; 310 pp.; $60; 978-0-74948-380-7.



Logistics account for 9% to 10% of global carbon dioxide emissions. This book assesses a broad range of decarbonization options for the main freight transportation modes from both technological and managerial perspectives and offers practical advice to managers and public policy makers on transitioning logistics to a low-carbon economy.

Free Public Transit and Why We Don't Pay to Ride Elevators

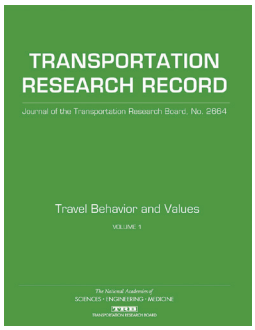
Edited by Judith Delheim and Jason Prince. University of Chicago Press, Illinois, 2018; 250 pp.; $26.99; 978-1-55164-657-2.



In a world of growing gridlock, pollution, and inequality, more than 100 cities worldwide have implemented free public transit. This book explores the successes and roadblocks of 14 countries that have provided free public transit in the face of rapidly changing transportation options and technology.

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

TRB PUBLICATIONS



Travel Behavior and Values, Volumes 1–3

Transportation Research Record 2664–2666

Research on travel behavior presented in these volumes includes the effects of income on travel mode choice, car ownership trends, the impact of technology on multimodality, and the role of social media platforms on trip planning.

2017. Subscriber category: planning and forecasting. For more information, visit https://trrjournalonline.trb.org/toc/trr/2017/2664/+, https://trrjournalonline.trb.org/toc/trr/2017/2665/+, or https://trrjournalonline.trb.org/toc/trr/2017/2666/+.

Network Modeling

Transportation Research Record 2667

Solving the routing problems of school buses, maximizing platoon formations, and estimating patterns on signalized arterials are some of the topics presented in this volume.

2017. Subscriber category: planning and forecasting. For more information, visit https://trrjournalonline.trb.org/toc/trr/2017/2667/+.

Demand Forecasting, Volumes 1–2

Transportation Research Records 2668–2669

Explored in these two volumes are topics related to travel demand forecasting, including ridesharing in high occupancy vehicle lanes, dynamics of daycare drop-off, and departure time choices.

2017. Subscriber category: planning and forecasting. For more information, visit https://trrjournalonline.trb.org/toc/trr/2017/2668/+ or https://trrjournalonline.trb.org/toc/trr/2017/2669/+.

Finance and Pricing

Transportation Research Record 2670

The 11 papers in this volume offer methods and analysis of such transportation finance matters as toll collection, fuel tax, and public–private partnership investments.

2017. Subscriber categories: policy, economics. For more information, visit https://trrjournalonline.trb.org/toc/trr/2017/2670/+.

Social Economic, Sustainability, and Human Factors in Transit

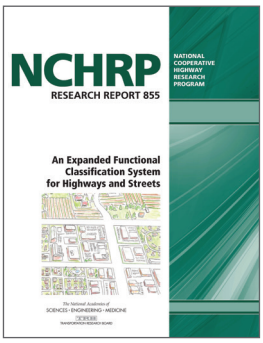
Transportation Research Record 2671

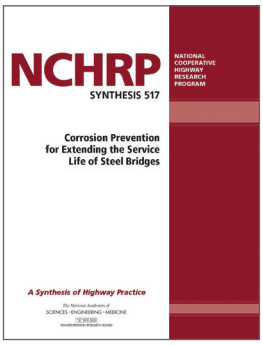
Transit corridor livability, low-income commuter approaches, and global urban passenger demand and carbon dioxide emissions are a few of the subjects covered in this volume.

2017. Subscriber category: society. For more information, visit https://trrjournalonline.trb.org/toc/trr/2017/2671/+.

The TRR Online website provides electronic access to the full text of more than 15,000 peer-reviewed papers that have been published as part of the Transportation Research Record: Journal of the Transportation Research Board *(TRR) series since 1996. The site includes the latest in search technologies and is updated as new TRR papers become available. To explore TRR Online, visit www.TRB.org/TRROnline. In 2018, SAGE began publishing the TRR. For more information, see http://journals.sagepub.com/home/trr.*

TRB PUBLICATIONS *(continued)*





An Expanded Functional Classification System for Highways and Streets
NCHRP Research Report 855

This report builds on preliminary engineering of a design project, including purpose and need, context beyond rural and urban, accommodations of modes other than personal vehicles, and overlays for transit and freight. A web-only document accompanies the report.

2018; 84 pp.; TRB affiliates, $50.25; nonaffiliates, $67. Subscriber categories: design, pedestrians and bicyclists, planning and forecasting.

Guidance for Evaluating the Safety Impacts of Intersection Sight Distance
NCHRP Research Report 875

This report offers insight on how to estimate the effect of intersection sight distance on crash frequency and describes data collection methods and analysis.

2018; 44 pp.; TRB affiliates, $39.75; nonaffiliates, $53. Subscriber categories: highways, design, safety and human factors.

Performance-Based Mix Design for Porous Friction Courses
NCHRP Research Report 877

This report addresses the limitations of porous friction courses (PFCs) and proposes solutions for achieving balance in mix design of PFCs and standardized mixture designs to increase durability and functionality.

2018; 142 pp.; TRB affiliates, $58.50; nonaffiliates, $78. Subscriber categories: design, materials, pavements.

Optimal Replacement Cycles of Highway Operations Equipment
NCHRP Research Report 879

This report presents a process for determining replacement needs for highway operations equipment, identifying candidate equipment units for replacement, and preparing annual equipment replacement programs. Included with the report is a guidance document and an Excel-based replacement optimization tool.

2018; 116 pp.; TRB affiliates, $55.50; nonaffiliates, $74. Subscriber categories: maintenance and preservation, vehicles and equipment.

Corrosion Prevention for Extending the Service Life of Steel Bridges
NCHRP Synthesis 517

This synthesis provides information on choosing materials and coatings to prevent corrosion and documents ways to develop an effective maintenance plan for newly constructed and in-service bridges and transportation structures.

2018; 84 pp.; TRB affiliates, $50.25; nonaffiliates, $67. Subscriber categories: bridges and other structures, design, maintenance and preservation.

The Renewal of Stormwater Systems Using Trenchless Technologies
NCHRP Synthesis 519

Technologies for renewal of stormwater systems are summarized in this report, to include new, emerging, and underutilized trenchless methods. Future research needs also are addressed.

2018; 56 pp.; TRB affiliates, $45; nonaffiliates, $60. Subscriber categories: construction, geotechnology. hydraulics and hydrology.

Integrated Transportation and Land Use Models
NCHRP Synthesis 520

Presented in this synthesis is information on how select agencies are using sketch planning models and advanced behavioral models to support decision-making, the performance of these models, and principles of land use and transport integration.

2018; 90 pp.; TRB affiliates, $52.50; nonaffiliates, $70. Subscriber category: planning and forecasting.

Investment Prioritization Methods for Low-Volume Roads
NCHRP Synthesis 521

Current practices used by transportation agencies to make investment decisions about low-volume roads are examined in this synthesis. Also addressed are the challenges of communicating these investments to stakeholders.

2018; 74 pp.; TRB affiliates, $48; nonaffiliates, $64. Subscriber categories: economics, highways, maintenance and preservation.

Aggregate Quality Requirements for Pavements
NCHRP Synthesis 524

Documented in this synthesis are a wide range of transportation agency requirements for the quality of aggregates for various pavement types.

2018; 96 pp.; TRB affiliates, $52.50; nonaffiliates, $70. Subscriber categories: highways, materials, pavements.

Practices in One-Lane Traffic Control on a Two-Lane Rural Highway
NCHRP Synthesis 525

Identified in this synthesis are innovative practices and devices for establishing one-lane traffic control on rural two-lane roads, including roundabouts. Applications include portable rumble strips and driveway assistance devices.

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

2018; 83 pp.; TRB affiliates, $62.25; nonaffiliates, $83. Subscriber categories: maintenance and preservation, operations and traffic management, highways.

Inertial Profiler Certification for Evaluation of International Roughness Index
NCHRP Synthesis 526

This synthesis explores the national and international states of practice of inertial profiler certification, to ensure accurate project data are collected to fulfill requirements of the MAP-21 and FAST Acts.

2018; 96 pp.; TRB affiliates, $52.50; nonaffiliates, $70. Subscriber categories: construction, highways, pavements.

Airport Air Quality Management 101
ACRP Research Report 185

This report is an introduction to air quality management for airport employees who are not environmental specialists. An airport air quality resource library accompanies the report.

2018; 68 pp.; TRB affiliates, $48; nonaffiliates, $64. Subscriber categories: aviation, environment.

Airport Participation in Oil and Gas Development
ACRP Synthesis 87

Provided in this synthesis are practical considerations and responses involving gas and oil extraction, including lessons learned during the rise and fall of gas prices over the last decade. A compilation of regulatory frameworks, available leases, permits and ordinances, and case examples are presented.

2018; 90 pp.; TRB affiliates, $52.50; nonaffiliates, $70. Subscriber categories: aviation, energy.

Clean Vehicles, Fuels, and Practices for Airport Private Ground Transportation Providers
ACRP Synthesis 89

Identified in this synthesis are effective approaches and best practices employed by airports that encourage private ground transportation providers to run more environmentally friendly operations.

2018; 64 pp.; TRB affiliates, $45; nonaffiliates, $60. Subscriber category: aviation.

Incorporating ADA and Functional Needs in Emergency Exercises
ACRP Synthesis 90

This synthesis explores how airports can include persons with disabilities and others with access or functional needs into emergency exercises.

2018; 50 pp.; TRB affiliates, $42; nonaffiliates, $56. Subscriber category: aviation.

Tools and Strategies for Eliminating Assaults Against Transit Operators, Volumes 1 and 2
TCRP Research Report 193

This two-volume report addresses transit workplace violence prevention, including transit operator skills and training. Volume 1, *Research Overview*, provides the materials and methodology used to produce potential countermeasures and strategies to prevent or mitigate assaults against transit operators. Volume 2, *User Guide*, includes an operator assault risk management toolbox and provides transit agencies with guidance in the use and deployment of the vulnerability tool and the route-based risk calculator.

2018; Volume 1: 156 pp.; TRB affiliates, $62.25; nonaffiliates, $83. Volume 2: 126 pp.; TRB affiliates, $58.50; nonaffiliates, $78. Subscriber categories: public transportation, security and emergencies.

Broadening Understanding of the Interplay Among Public Transit, Shared Mobility, and Personal Automobiles
TCRP Research Report 195

Explored in this report is the effect of app-based transportation network companies on public transit ridership, single-occupancy vehicle trips, and traffic congestion.

2018; 94 pp.; TRB affiliates, $52.50; nonaffiliates, $70. Subscriber category: public transportation.

Transit Technical Training, Volume 1: Guide to Applying Best Practices and Sharing Resources
TCRP Research Report 199, Volume 1

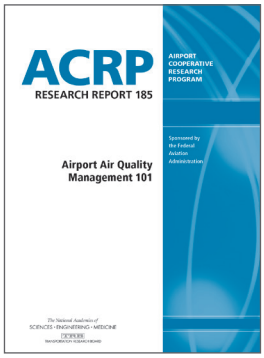
This guide documents the best models of technical training programs serving U.S. and international transportation agencies and related industries. A training resource catalog to help agencies provide technical training for their agencies is described and linked.

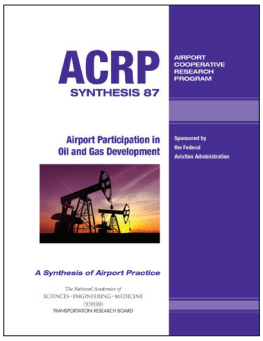
2018; 104 pp. Subscriber categories: public transportation, administration and management. For more information, visit www.trb.org/Main/Blurbs/177692.aspx.

Transit Technical Training, Volume 2: Guide to Overcoming Barriers to Implementing Best and Innovative Training
TCRP Research Report 199, Volume 2

This report examines the barriers to implementing transit technical training and provides agencies with strategies and resources for overcoming these barriers with effective and innovating training programs.

2018; 117 pp. Subscriber categories: public transportation, administration and management, education and training. For more information, visit www.trb.org/Main/Blurbs/177693.aspx.





LETTER TO THE EDITOR

Role of High-Speed Rail in Interregional Travel

The May–June 2016 issue of *TR News* (No. 303, a theme issue on bus transportation) included seven articles on a bus renaissance and downplayed other passenger transport modes. The final article, written by Thomas Menzies (pp. 38–42), which summarizes *TRB Special Report 320: Interregional Travel—A New Perspective for Policy Making*, covers a much broader and more important topic: interregional travel. The chairman of this study committee was Martin Wachs.

According to the Menzies article, the report examines travel by different modes on distances of up to 500 miles, which represent more than half of intercity trips. This category of travel has experienced revolutionary growth in the past 60 years via the development of a new mode of transportation: high-speed rail (HSR). A reader might expect Special Report 320 to present an up-to-date review of the operation and construction of HSR in about 20 countries, discuss the reasons why the United States is so far behind its peers in building HSR, and suggest constructive measures to develop this new mode in many of the nation's interurban corridors.

As described by the article, however, Special Report 320 is inadequate. Presented here are several examples of the report's fundamental mistakes in defining the purpose and scope of the study; information about HSR development; comparison of different modes of interurban travel; and, particularly, conclusions and recommendations.

Degradation of the U.S. passenger railroad system was not a natural development—it was a result of national transportation policies that invested billions of dollars into highways and air transportation. Meanwhile, Amtrak is supported at the survival level. Legislation that founded Amtrak imposed the objective of self-sufficiency, which is not required for any other transportation mode. Even today, Congress forces Amtrak to work toward a minimum deficit as its goal, instead of maximum ridership. This results in astronomically expensive train fares and a failure to attract a large, latent volume of passengers. Special Report 320 does not mention this fundamental problem in transportation policy.

The committee writing Special Report 320 did not distinguish Amtrak from HSR and did not recognize HSR as a new mode of interurban transportation in the same way that jet planes are a different mode than propeller planes.

Short-, medium- and long-distance trips are not defined and the terms are used interchangeably.

The methodology for comparing different modes of interurban travel is incorrect. The major difference between traveling by HSR and by cars and buses in mixed traffic on highways—HSR features fail-safe control and offers reliability, comfort, and speeds that are approximately three times faster—is not stated clearly.

Information and data about HSR in other countries are obsolete and incorrect: the report refers to the "European and Japanese systems" as they were in the 1990s, but mostly ignores the extensive HSR projects of recent decades. Chinese HSR, which now represents more than half of HSR mileage in the world, is mentioned on only half a page, with a comment that this country is not capable of producing such national systems. This is contrary to historical examples in the United States of building national canal, railroad, and the Interstate Highway System.

The highly successful diversion of travel from airlines to HSR for distances up to 800 miles—such as in France, Japan, China, Korea, and Taiwan—receives little mention.

A negative tone about HSR penetrates the entire report, and great emphasis is placed on the incorrect claim that HSR might only be feasible for the Boston–Washington, D.C., corridor.

In the article, the section "Learning from Experience Abroad" distorts worldwide success in building HSR systems, suggesting that these were unique and risky in Europe and Japan. Successful HSR systems built since 1990—including revolutionary innovations in China—are not mentioned.

Conclusions of Special Report 320 focus on the means—the organizational aspects of planning, rather than goals—of needed modes of transportation. One conclusion is that information on travel volumes on different modes is inadequate, and that a greater effort should be made to collect it. In fact, all recent studies of economic development in the Northeast megalopolis have assumed the existence or recommended construction of a high-capacity, high-speed transportation system between Boston and Washington, D.C. The recommendation to focus on data collection appears to be made to delay, rather than accelerate, efforts to build HSR in the United States.

As presented by the article, the conclusions of Special Report 320—that intercity buses are promising and that HSR is not, except maybe in the Northeast Corridor—are simply wrong. Any professional study using a systems approach methodology to compare the most efficient public transportation modes would follow the extremely successful HSR systems in countries such as France, China, Spain, and Japan, rather than the short-term solutions used in developing countries with buses in mixed traffic and operating on increasingly congested highways. Often, HSR systems attract so many new passengers to public transportation that buses also increase ridership as feeders to HSR.

Another fundamental weakness of Special Report 320 is that it relies heavily on extrapolation of trends, which is not planning. Planning methodology analyzes past trends to see whether they should be extended, modified, or even reversed. Planning via trend extrapolation is a common mistake in the methodology of many urban transportation planning studies.

How could such a deficient and incorrect report be produced? The list of study committee members features many persons with international reputations in highway and air transportation, but very few of them have any publications in or experience with conventional rail and, particularly, HSR.

To respond to the need for improvements of intercity transportation studies and planning intermodal interurban transportation, the author of this letter has written a paper to be submitted for publication that defines 10 major errors found in Special Report 320. A draft of that manuscript was sent to 16 persons with extensive knowledge and experience about HSR and other intercity public transport systems. Useful comments from these reviewers were incorporated into the paper.

—Vukan R. Vuchic
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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.

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

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

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

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

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