TR NEWS
March–April 2019 NUMBER 320

Renewing the National Commitment to the Interstate Highway System

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PLUS

Critical Issues in Transportation 2019

Collaborative Research at Ohio DOT

Better Airport Restroom Design

TRB 98th Annual Meeting Photo Highlights

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TRANSPORTATION RESEARCH BOARD

The National Academies of
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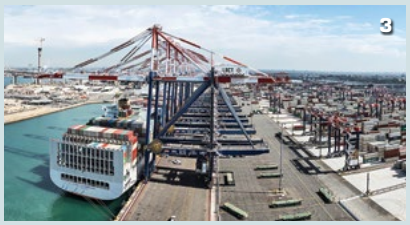

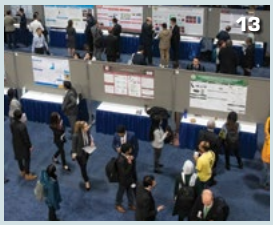

COVER Bridge replacement on the original I-80 San Francisco–Oakland Bay Bridge. An article in this issue of *TR News* examines the research and policy issues surrounding the maintenance and rehabilitation of the Interstate Highway System. (Photo: Frank Schulenburg, Flickr)

Coming Next Issue

Photo: Heather Allen

A mother escorts her children to school. The effect of transportation access on the economic development of women and girls is among the topics explored in the May–June 2019 issue of TR News.

The May–June 2019 issue of *TR News* addresses women and gender in transportation. Developed by the TRB Standing Committee on Women's Issues in Transportation, this theme issue will explore topics including statistics about the negative effects of women's unequitable transportation access on the global economy; women and transit; a case study from Austria on women's travel constraints; and the challenges that minority, low-income women face as pedestrians and bicyclists.

Also in This Issue:

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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CRITICAL ISSUES IN TRANSPORTATION 2019

Photo: National Renewable Energy Lab

KATHERINE F. TURNBULL

The author is Executive Associate Director, Texas A&M Transportation Institute, College Station; past chair of the TRB Executive Committee; and current chair of the TRB Executive Committee Subcommittee for Planning and Policy Review.

Above: *Critical Issues in Transportation 2019* addresses 12 interrelated transportation topics in need of research, policy discussion or collaborative problem solving. Some entities, such as the Port of Long Beach in California, may face nearly all of the issues.

TRB released its first critical issues list in 1974. For 45 years, regular updates to the list have focused attention on key transportation issues and opportunities shaping research, policies, programs, and projects at the national, state, and local levels.

The development of *Critical Issues in Transportation 2019* was led by the TRB Executive Committee Subcommittee on Planning and Policy Review, with participation from the chairs of TRB's more than 220 standing committees and task forces, sections, and groups, as well as the Marine Board, sponsors, and key stakeholders.

Highlighting the importance of the report, the National Academies Report Review Committee oversaw peer review of and subsequent approval of the document through a rigorous report review process. Because of this, for the first time, the *Critical Issues* document is a publication of the National Academies of Sciences, Engineering, and Medicine.

Critical Issues

Presented in *Critical Issues 2019* are high-level, challenging questions about 12 interrelated topics. These framing questions focus on critical issues facing transportation in the next 10–20 years that can be addressed

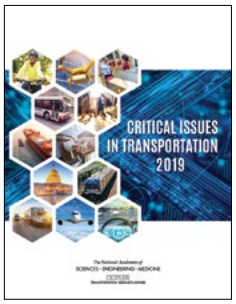


Photo: Antonio R. Villaraigosa, Flickr

A container is placed on an electric port truck in the Port of Los Angeles. *Critical Issues 2019* covers topics important to ports: goods movement, energy and sustainability, and transformational technologies.

through research, policy discussion, and collaborative problem solving in the near term.

The Executive Committee examined the many factors influencing the transportation system's ability to meet the diverse needs of society in an era of unprecedented change: demographic changes, economic growth, technology advancements, and new energy resources, as well as safety, security, equity, and resilience concerns.

Although the critical issues are presented from a U.S. perspective, most of the topics are global in scope. In addition, the United States can benefit from international research and experience, informing the discussion of appropriate policies and programs.

The following 12 topics form the basis for *Critical Issues 2019*:

- Transformational technologies and services,
- Energy and sustainability,
- Serving a growing and shifting population,
- Resilience and security,
- Safety and public health,
- Equity,
- Governance,
- System performance and management,
- Funding and financing,
- Goods movement,
- Institutional and workforce capacity, and
- Research and innovation.

These topics include ongoing concerns as well as new and emerging issues. The framing questions reflect both the increasing complexity and challenges facing society and all transportation modes and the opportunities for innovative solutions. A few topic areas are highlighted below to offer a perspective on the new and emerging issues.

Transformational Technologies and Services

This topic reflects the rapidly changing environment of connected, automated, and autonomous vehicles, marine vessels, and aircraft. Also addressed are the combination of new technologies and innovative entrepreneurship that have led to innovations in ride-, car-, and bikesharing as well as in e-commerce.

Framing questions focus on the impact of Uber, Lyft, and other transportation network companies (TNCs) that have emerged in the past decade as new travel options in urban areas. To ensure mobility enhancements for all population segments and to avoid unintended consequences, it is imperative to gain a better understanding of the operation and use of these services and their influences on vehicle ownership, public transit ridership, vehicle miles traveled, and vehicle emissions.

> For 45 years, regular updates to the list have focused attention on key transportation issues and opportunities shaping research, policies, programs, and projects at the national, state, and local levels.

Other questions in this topic address the safe introduction of connected and automated vehicles as well of as fully autonomous vehicles, vessels, and aircraft. Identified are the many issues associated with security, human factors, regulatory oversight, insurance, and consumer acceptance of connected and automated vehicles as well as their interaction with pedestrians, bicyclists, and other vulnerable road users.

Additional framing questions focus on current and future communication tech-

Photo: Boenau, Pixabay

Innovations in ride-, car-, and bikesharing transform mobility and have significant impacts on transit use, vehicle ownership, and emissions.

Photo: Jerry Huddleston, Flickr

The costs of moving agricultural and energy products from rural areas affect the prices paid by consumers for the products.

nologies, including dedicated short-range communications and fifth-generation Wi-Fi, or 5G, and on the roles of federal, state, and local agencies in regulating and overseeing pilots, demonstrations, and deployment of different technologies.

Transformational technologies and services influence many of the other cross-cutting topics in *Critical Issues 2019*. For example, individuals with disabilities and those without smartphones, credit cards, or bank accounts may not be able to access TNC services, and this raises equity concerns. Transformational technologies also factor into questions on sustainability, funding and financing, and future workforce needs.

Serving a Growing and Shifting Population

This topic recognizes that, although urban areas are the nation's economic engine, it also is vital to address transportation needs in megaregions and rural areas. The challenges and opportunities in megaregions and rural areas are very different, but both areas provide essential support to the economy and quality of life in the United States.

The continuing growth of megaregions contributes to increasing traffic congestion, and the movement of people and goods across metropolitan areas and state lines creates unique issues. Questions on the most appropriate modes are presented, as well as on funding and financing methods for multiagency, multiple-jurisdiction projects.

Rural areas face significant challenges that affect all segments of society. Railroads, the inland and coastal water systems, roads, airports, and pipelines all support the movement of agricultural products and energy extraction and production, influencing the prices consumers pay in stores and at the gas pump.

Like their urban counterparts, rural residents need mobility and safe travel options. Rural transit systems face increasing demands to serve a population of residents that are older, have disabilities, or need to travel long distances to health care and social services. Rural residents involved in traffic crashes, including single-vehicle lane-departure crashes, face long travel distances to hospitals, compromising emergency response times and chances for survival.

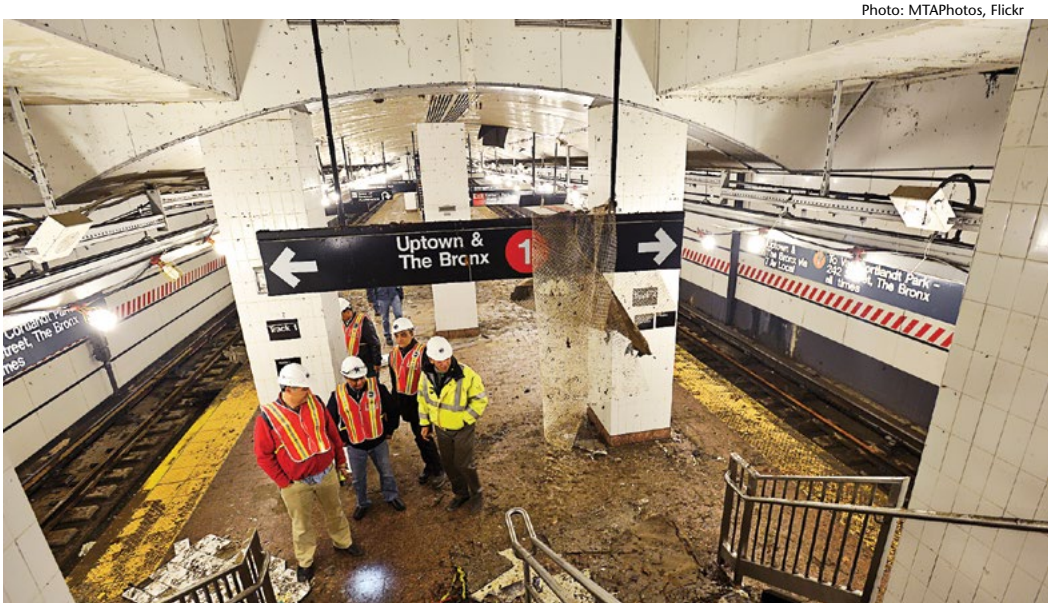
The rural transportation network offers access to national and state parks, recreation areas, and cultural sites for residents and visitors. Transportation is vital to the travel and tourism industry, supporting local jobs in rural areas throughout the country.

Framing questions for this cross-cutting topic include examining cost-effective transportation modes and policies to improve internal megaregion travel, ensuring connectivity to other regions, and innovative mobility services providing access to jobs, public and private services, education, and health care for rural residents.

Resilience and Security

Hurricanes Harvey and Maria in 2017 are just two recent examples of extreme weather events disrupting the lives of millions of people and costing billions of dollars in infrastructure and property damage. Intense rainfall, superstorms, tornadoes, and fires have taken their toll on transportation facilities across the country.

Photo: MTAPhotos, Flickr



Metropolitan Transportation Authority workers survey Hurricane Sandy damage at the South Ferry subway station in New York in 2012. As extreme weather events become more common, strategies to mitigate damage become more necessary.

Manmade disasters, including terrorism and cyber attacks on infrastructure, also can cause major damage and distress to the transportation system.

Framing questions focus on developing strategies to meet threats and to mitigate the vulnerabilities of communities throughout the country as well as on the public- and private-sector groups responsible for the transportation system. Other questions address incorporating climate-science data into transportation planning and project development, expanding cybersecurity within transportation agencies, and enhancing security in all modes. Also suggested is an increase in methods of sharing best practices among public- and private-sector partners.

Photo: Sadie Colbert, U.S. Air Force

Primary among new safety challenges in transportation is mobile phone distraction, affecting drivers, pedestrians, and aircraft and rail operators.

Safety and Public Health

Safety continues to be a critical transportation issue—and well it should be, considering the nearly 40,000 fatalities on the nation's roadways each year. With safety-enhancing advancements in roadway and vehicle design, the framing questions on this topic have changed. Many questions now focus on such issues as distracted drivers and pedestrians, whose attention often is split between driving or walking and using electronic devices—for example, texting on cell phones. Texting by operators also has been a concern in recent helicopter and rail crashes.

Framing questions across all modes on this topic focus on interventions for reducing crashes involving distractions, alcohol and drug impairments, and operator fatigue, and on strategies to reduce the growing number of pedestrian and cyclist injuries and fatalities.

By grouping safety and public health, *Critical Issues 2019* further focuses framing questions on the impacts of emissions, noise, urban heat islands, the spread of infectious diseases, and other related concerns. Developing new methods and technologies to reduce vehicle-based emissions continues to be an important area of study.

The growth of unmanned aerial vehicles and unmanned aircraft systems also is covered in this topic, with questions addressing these new sources of safety risk and their regulation and user acceptance.

Photo: Paul Novarese, Flickr

Memphis International Airport, home to the FedEx Express global hub, operates the second-busiest cargo operation in the world. *Critical Issues 2019* addresses needed system efficiency for freight movement.

Goods Movement

The nation's economy depends on an efficient system for moving freight domestically and internationally. This topic also recognizes that freight transportation is a complex system involving private carriers that operate on both public and private infrastructure, with federal, state, and local agencies regulating many aspects of the system. The growth in international trade, e-commerce, and urban freight delivery all affect different elements of the transportation system.

Framing questions address the use and impact of transformational technologies in all freight modes, innovative applications for urban goods movement, new analytical methods and sources of freight data, and labor shortages in trucking and freight operations. Other questions address the impacts of ocean megavessels, truck size and weight, and airport freight capacity.

Using *Critical Issues 2019*

Identifying these critical issues is just the beginning of the process. The impact comes in how the issues are used to undertake research, policy discussions, and outreach to improve transportation. The *Critical Issues 2019* document helps guide TRB activities and is a valuable resource for sponsors, stakeholders, and other groups.

TRB is the go-to place for unbiased, forward-looking research, innovative solutions, and information sharing to address cross-cutting, critical topics. The TRB Executive Committee is using the

identified issues to update its strategic plan and to organize policy sessions, including a January 2019 session on rural transportation and a planned session on distracted driving in June.

Many of the experts on these *Critical Issues 2019* topics are active in TRB. The standing committees and task forces address the critical issues at Annual Meeting sessions, specialty workshops, and conferences. Committees develop research problem statements focusing on the topics, and many embark on other activities to engage key stakeholders. Additionally, the critical issues are often used in formulating and updating committee triennial strategic plans to help focus activities.

The groups overseeing TRB's Cooperative Research Programs, including the National Highway Cooperative Research Program and the Transit Cooperative Research Program, benefit by using the critical issues to develop or refine problem statements. Groups and researchers also can use the issues to identify research for the different synthesis and Innovations Deserving Exploratory Analysis programs.

Sponsors, universities, and other stakeholder groups regularly use TRB's *Critical Issues* document to help guide research, education, professional capacity building, and outreach activities. University Transportation Centers sponsored by the U.S. Department of Transportation often address aspects of the critical issues identified by TRB.

As TRB approaches its centennial in 2020, the development of *Critical Issues 2019* has never been more important, relevant, or meaningful.

The *Critical Issues 2019* document can also help facilitate and enlighten policy discussions at the federal, state, and local levels that then may lead to actions addressing key concerns and improving the transportation system for all users.

Communicating the critical issues to the public and to various interest groups can further enlighten the conversation on national, state, and local transportation; providing ongoing information on cross-cutting issues as research results become available adds value to these discussions. *Critical Issues 2019* will continue to foster international collaboration and cooperation on research and information sharing. Learning from projects in other countries and sharing findings with colleagues abroad can enhance collaborative relationships across the international research community.

As TRB approaches its centennial in 2020, the development of *Critical Issues 2019* has never been more important, relevant, or meaningful. After all, if the questions surrounding how to improve the transportation system were easy, they would have been answered by now. TRB is well positioned to identify and address critical issues and ensure that transportation meets the future needs of all segments of society in an ever-changing world.

Photo: Rick Schwartz, Flickr

I-75 over the Manatee River in Florida. Researchers, policy makers, and transportation agencies can use the issues outlined in *Critical Issues 2019* as a valuable guide for improving transportation nationwide.

Renewing the National Commitment to the Interstate Highway System

Photo: Alan Stark, Flickr

A FOUNDATION FOR THE FUTURE

MONICA A. STARNES

The author is Senior Program Officer, Consensus and Advisory Studies Division, Transportation Research Board, National Academies of Sciences, Engineering, and Medicine, Washington, D.C.

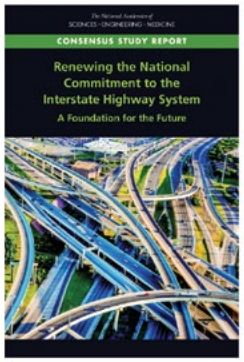
Above: The intersection of I-10 and I-17 in Arizona. The Interstate Highway System provides significant and critical infrastructure for the movement of goods and people, but faces such challenges as aging assets, escalating traffic, and safety issues.

For more than 50 years, the Interstate Highway System has conferred broad, deep benefits and has been pivotal in shaping and supporting demographic, spatial, economic, and social development in the United States. Interstates are the main corridors for passenger and freight movement within both rural and urban areas.

Despite its crucial role in the economy and society, however, the Interstate Highway System's future is threatened by a persistent and growing backlog of physical and operational deficiencies and by large, looming challenges. Many Interstate highway segments are older than 50 years, carry much heavier traffic than anticipated, and operate well beyond their design life—all without having undergone major upgrades or reconstruction. These aging, heavily used segments are poorly equipped to accommodate even modest projections of future traffic growth, much less the magnitude of growth experienced over the past 50 years.

Interstate highways must be preserved, rehabilitated, and modernized to adapt to the country's changing demographic, economic, climatic, and technological landscape.

Congress asked TRB to form a special committee tasked with conducting a study to inform pending and future federal investment and policy decisions related to the Interstates. Congress asked the committee to make recommendations on the "features, standards, capacity needs, application of technologies, and intergovernmental roles to upgrade the Interstate Highway System" and to advise on any changes in law and resources. The resulting report, *Special Report 329, Renewing the National Commitment to the Interstate Highway*



System: A Foundation for the Future suggests a path forward to meet the growing, shifting demands of the 21st century.

Looming Challenges

The prospect of an aging and worn Interstate Highway System that operates unreliably is troubling, particularly with the prospect of a quickly transforming vehicle fleet and the vulnerabilities caused by climate change. Unless a commitment is made to remedy its deficiencies and prepare for future challenges, the Interstate Highway System risks becoming increasingly congested; far more costly to operate, maintain, and repair; and vulnerable to the effects of a changing climate and extreme weather. These looming challenges are listed below.

AGING ASSETS IN NEED OF REBUILDING

Many of the Interstate pavements built in the 1950s and 1960s were designed for 20-year service lives, but more than 50 years have passed without reconstruction of road foundations—and the pavements have sustained much higher traffic loadings than projected. While these foundations are being rebuilt, sufficient resources will be needed to preserve, restore, and rehabilitate the system's thousands of aging bridges and other assets.

ESCALATING URBAN TRAFFIC LEVELS

Large portions of the Interstate Highway System, especially in metropolitan areas, experience chronic congestion and struggle to accommodate the demands of local and long-distance travelers. Since most of the country's population and economic growth is forecasted to occur in these large metropolitan areas, congestion will continue to worsen unless capacity is added and managed more actively.

DEMANDS FOR MORE SYSTEM COVERAGE

Although thousands of miles of high-quality highways other than Interstates connect the country's population centers, some smaller communities and emerging cities may view lack of access to the Interstate Highway System as detrimental to their growth and development, particularly since the Interstate Highway System includes the country's main trucking corridors and links to other modes.

EXPECTATIONS FOR CONTINUAL SAFETY GAINS

The Interstates are the nation's safest highways, but they still account for more than 5,000 traffic deaths annually. As new highway and vehicle technologies are introduced, reconstruction work increases, and physical and operational measures are taken to accommodate growing traffic demand, an emphasis on ensuring safety performance will be critical.

TRANSFORMATIONS TO THE VEHICLE FLEET

New vehicle technologies likely will alter the operations and safety performance of the highway system, including the Interstates. The system will need to be made adaptable to changing vehicle capabilities—but transportation agencies should avoid premature investments in assets and the introduction of standards that would hinder useful development pathways.

CHANGING CLIMATE CONDITIONS

During the 1960s and 1970s, when much of the Interstate Highway System was being built, little was known about the threat of climate change. Transportation agencies across the country will need to change how they plan, design, construct, operate, and maintain Interstates to make them more resilient and less vulnerable to adverse effects of climate change.

Photo: U.S. National Archives

Photo: Minesweeper, Wikimedia

Left: Many Interstates, like I-5 in California, were built nearly five decades ago and designed for much less traffic. Right: Modern-day I-80 in Berkeley, California.

Photo: Washington State DOT

Photo: North Carolina DOT

Left: More than 5,000 traffic fatalities occur on Interstates each year. Addressing safety needs is paramount as traffic, construction, and technology increase. Right: Flooding damage from Hurricane Florence in North Carolina in 2018. Transportation agencies need to adjust how they construct and maintain infrastructure to increase resilience to weather events.

ERODING REVENUES FOR SYSTEM FUNDING

Increased vehicle fuel economy and the growing use of electric vehicles threaten a funding base that relies heavily on revenues from fuel taxes—a revenue source that has lagged spending needs. New funding mechanisms—equitable, efficient, and that do not divert resources from other highways and transportation modes—will be needed to pay for system reinvestments.

Investment Imperative

Limited planning and budgetary preparations have been made to fix the deterioration to the Interstate Highway System that has already occurred—and far fewer plans have been made to address the challenges that lie ahead. Recent combined state and federal capital spending on the Interstates have totaled approximately $20–$25 billion per year. The estimates in this study suggest this level of spending is too low. Over the next 20 years, $45–$70 billion annually is needed to embark on the long-deferred rebuilding of pavements and bridges and to accommodate and manage growing user demand.

This estimated capital investment is incomplete because it omits the spending that will be required to meet other challenges, such as boosting the system's resilience and expanding its geographic coverage. Although these investment needs could not be estimated even roughly for this study, billions—and perhaps tens of billions—of dollars in additional annual spending will be required.

Photo: MaxPixel

Increased use of electric vehicles has led to decreased revenue from fuel taxes.

Blueprint for Action

The original Interstate Highway Construction Program was underpinned by a long-term, collaborative commitment among the states and the federal government. A comparable partnership is needed to renew and modernize the system and ensure that it is resilient and responsive to the changing demands of users.

Photo: Famartin, Wikimedia

Tolling could offer revenue-raising options for states and help manage traffic demand.

Key Recommendations

- **Congress should legislate an Interstate Highway System Renewal and Modernization Program (RAMP).** This program should focus on reconstructing deteriorated pavements and their foundations, as well as bridge infrastructure; adding physical capacity and operations and demand management capabilities (such as tolling) where needed; and increasing the system's resilience. RAMP should be modeled after the original Interstate Highway System Construction Program; that is, a partnership in which the federal government establishes the national vision for the overall system, provides the bulk of the needed funding, and sets overall standards, and in which states prioritize and execute projects as owners, builders, operators, and maintainers of the system. The federal share of project spending should be comparable to 90 percent, the share of the original program.
- **In the near term, Congress should** 1) increase the federal fuel tax to a level commensurate with the federal share of the required RAMP investment, and 2) adjust the tax as needed to account for inflation and changes in vehicle fuel economy.
- To ensure that the federal government's long-term commitment to RAMP is not threatened by fuel tax revenues that decline as the vehicle fleet and its energy sources evolve, **Congress should prepare to employ new federal and state funding mechanisms**, such as tolls or per-mile charges for users of the Interstate Highway System.
- To offer more revenue-raising options for states and metropolitan areas to pay their share of RAMP investments and to manage traffic demand and operations of hard-to-expand Interstate segments, **Congress should lift the ban on tolling of existing general-purpose Interstates**. States should be required to assess the impact of tolls on current users and to offer alternative mobility options for those users significantly and disproportionately harmed by them.
- **Congress should direct the U.S. Department of Transportation and the Federal Highway Administration to develop criteria** for a rightsizing component of RAMP that would address current and emerging demands to extend the Interstate Highway System's length and scope of coverage and to remediate economic, social, and environmental disruptions caused by highway segments considered to be overly intrusive by communities and not deemed vital to network traffic. This system would use a consultative process involving states, local jurisdictions, highway users, and the general public.

Photo: Richard Klein, Flickr

Spalled concrete on I-495 bridge in Massachusetts.

Tried-and-True Approach

Implementation of these recommendations, as well as several other complementary recommendations called for in the report (see sidebar, below), would represent a fundamental shift away from a federal policy that has lost focus on the Interstate Highway System and the commitment to funding it adequately. These actions would restore the system's premier status among the nation's highways in a manner that is aggressive and ambitious, but by no means novel.

This approach would 1) rekindle a tried-and-true federal–state partnership; 2) reinforce the system's long-standing reliance on user fees to provide a fair, adequate, and reliable source of funding; and 3) reassert the forward-looking vision that was instrumental to the genesis of this crucial national asset more than 50 years ago. At that time, the nation's leaders endorsed a modern highway system that would confer large and lasting societal and economic benefits, a vision whose realization required a strong and continuing national commitment.

Today, the nation is experiencing—and can anticipate—new expectations for system performance, condition, and use. Meeting those expectations will require the same forward-looking outlook and commitment that informed the system's creation—a rededication to that original vision that reshapes and re-equips the system to serve generations to come.

For more information, visit interstate.trb.org.

Blueprint for Action

Other recommendations of *Special Report 329, Renewing the National Commitment to the Interstate Highway System: A Foundation for the Future*, include the following:

- **To better ascertain the spending levels required for RAMP investments, Congress should direct U.S. Department of Transportation (DOT) and Federal Highway Administration (FHWA) to join with the states to assess the foundational integrity of the system's pavements and bridges, and identify where full reconstruction is needed based on accepted life-cycle cost principles.**
- **To support renewal and modernization investment decisions, Congress should direct and fund U.S. DOT and FHWA in the development of modeling tools and databases that track the condition and reconstruction history of Interstate assets. These can be used to assess transportation options that can supplement or substitute for added highway capacity, monitor and model network-level traffic flows on the Interstate Highway System, and further understand the demand for long-distance and interregional passenger and freight travel.**
- **Congress should direct U.S. DOT and FHWA to work with states, industry, and independent technical experts to transition to more automated and connected vehicle operations, performing the needed research and updates to Interstate Highway System requirements and standards. Renewal and modernization projects should consider safety impacts—including the deployment of advanced design and operational features that have been demonstrated to effectively improve safety—and that cybersecurity protections are incorporated into the designs and upgrades of the Interstate highways and vehicles.**
- **Expanding upon earlier legislative directives, Congress should direct U.S. DOT and FHWA to substantiate that state Interstate highway renewal and modernization projects have fully accounted for the need for resilience, to assess the vulnerability of the Interstate Highway System to the effects of climate change and extreme weather, to develop standards for incorporating cost-effective resilience enhancements into projects, and to develop and maintain a database of cost-effective practices and resilience strategies.**
- **Congress should direct U.S. DOT and FHWA to ascertain the contribution of the Interstate Highway System to greenhouse gas emission levels and should recommend ways to reduce this contribution as well as emissions of other pollutants.**

Photo: Frank Schulenburg, Flickr

Traffic is rerouted from the original I-80 San Francisco–Oakland Bay Bridge span to the new eastern span replacement. The $6.5 billion replacement was engineered to withstand major earthquakes and to last for 150 years.

1 More than 225 poster sessions showcased research across all transportation modes and topics at the 2019 TRB Annual Meeting.

2 Tierra Bills (*left*), University of Michigan, Ann Arbor, participates in the first meeting of the Transportation Equity Joint Subcommittee.

Transportation for a Smart, Sustainable, and Equitable Future

Transportation research, policy, and innovations for efficiency, sustainability, and equity were the focus of the Transportation Research Board 98th Annual Meeting, January 13–17, 2019. Despite challenging winter weather and a U.S. federal government shutdown, the TRB Annual Meeting drew more than 13,000 researchers, policy makers, students, and transportation professionals to the Walter E. Washington Convention Center and the Marriott Marquis hotel in Washington, D.C.

U.S. Transportation Secretary Elaine L. Chao addressed transportation innovation, safety, and improved infrastructure at one of the meeting's nearly 800 sessions and workshops. Attendees also visited the large exhibit hall—which featured passenger rides on an autonomous transit vehicle—and participated in award sessions, committee meetings, and networking events.

More than 50 sessions and workshops focused on the meeting's theme, "Transportation for a Smart, Sustainable, and Equitable Future," and 170 sessions explored cross-cutting topics identified by the TRB Executive Committee: transformational technologies, transportation and public health, and resilience and sustainability.

Jon A. Epps, Texas A&M Transportation Institute, delivered the 2019 Thomas B. Deen Distinguished Lecture on "Innovative Asphalt Pavement Technology: Paving the Way for the World's Roadways." Norman R. Augustine and Norman Y. Mineta delivered the Chair's Luncheon address on the recently released Future Interstate Highway System report.

Annual Meeting photographs by Risdon Photography.

3 U.S. Transportation Secretary Elaine L. Chao.

Intersections

1 The Technical Activities Council coordinates the activities of TRB's volunteer standing committees and oversees the Annual Meeting program.

2 McKenzie Jones-Channel, Texas Southern University, discusses his research on the employment impacts of autonomous vehicles.

3 Adebola Adelakun (*right*), Georgia Department of Transportation (DOT), learns about Geotechnical Engineering Section activities with section chair Anand Puppala (*left*) and TRB staff representative Nancy Whiting.

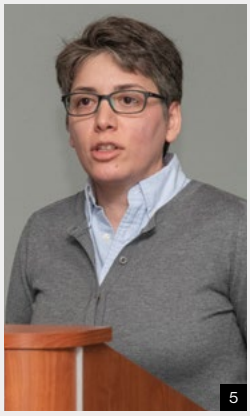
4 Shawn Turner (*right*), chair of the Pedestrian and Cycles Section, shares information about TRB committees at the New Attendee Orientation.

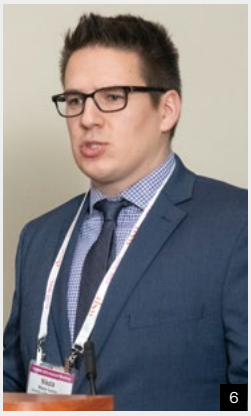
5 Jesus Barajas, University of Illinois Urbana–Champaign, offers the perspective of an alumnus of the TRB Minority Student Fellows Program, which had its 10th anniversary this year.

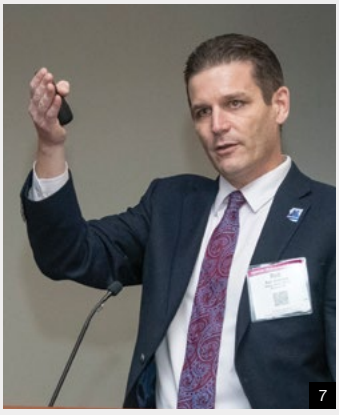
6 William W. Millar, past head of the American Public Transportation Association, remembers distinguished transit advocate Louis Gambaccini at a special session. Gambaccini died in 2018.

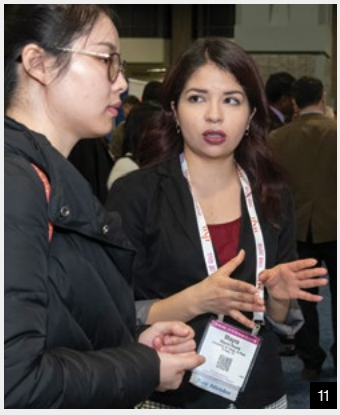
7 More than 1,200 attendees rode an autonomous shuttle, one of the many exhibits on display at the Annual Meeting.

1 2019 TRB Technical Activities Council: (*front row, left to right*) Joseph L. Schofer, Fred Wagner, Technical Activities Director Ann Brach, Council Chair Hyun-A Park, Coco A. Briseno, David Ballard, (*back row, left to right*) David Harkey, Mark Reno, C. James Kruse, William (Steve) Varnedoe, Nikola Ivanov, George Avery Grimes, Libby Rushley, and Brendon Hemily.









11 Mayra Reyna, University of Texas, El Paso, presents research on the role of aggregate type and properties on volumetric properties of asphalt concrete mixtures.

Sessions & Workshops

1 Chelsea Treboniak, Critical Ops, outlines a snow emergency and hazmat derailment scenario for participants of a transportation systems resilience workshop.

2 The popular "war games" workshop examined mobility as a service.

3 Barbara Lenz, German Aerospace Center, considers socioeconomic impacts of connected and automated vehicles in the United States and European Union.

4 Sophie Sabine Punte, Smart Freight Centre, addresses industry platforms for emissions accounting and reduction.

5 Anae Sobhani, Delft University of Technology, discusses a virtual reality application used to conduct research on pedestrian waiting times.

6 Nikola Ivanov, Young Members Council chair, welcomes Dwight D. Eisenhower Transportation Fellows to the Annual Meeting.

7 Rob Antoniak, Valley Metro RPTA, participates in a panel discussion on mobility on demand.

8 Qassim Abdullah, Woolpert, Inc., presides over a workshop on unmanned aircraft systems (UASs).

9 Basil Yap, North Carolina DOT, presents a user perspective on UASs.

10 Uma Shama, Bridgewater State University, shares research on UAS-based geospatial intelligence at a Transit Cooperative Research Program Innovations Deserving Exploratory Analysis (IDEA) session.

Sessions & Workshops

(continued)

1 Jaya Ghosh, U.S. Maritime Administration, presents her poster on freight data.

2 Nancy Dutta, University of Virginia, discusses assessing roadway safety risk.

3 Patricia Hu, Bureau of Transportation Statistics, shares information on U.S. DOT's safety data initiative.

4 G. P. Jayaprakash, TRB, imparts lessons on research and life at a session honoring leaders in the design and construction of transportation facilities.

5 Cosimo Leipold, Nuro, at a Freight Day session on autonomous vehicles in cities.

6 Paula Dowell, Cambridge Systematics, addresses zero-emissions freight corridors at a Freight Day session.

7 Brian Ness, Idaho Transportation Department, participates in a state DOT CEO roundtable.

8 Daniel Marquez, California State University, Los Angeles, offers insights on evaluating fiber reinforced self-consolidating concrete for transportation infrastructure applications.

9 Darshan Divakaran, North Carolina DOT, shares experience on using drones to conduct post-storm infrastructure assessments.

10 Andrea d'Amato, Massachusetts DOT, leads a session on strategic approaches to streamlining professional services procurement.

11 Jim Schoenduve pitches the RFNav system at the Six-Minute Pitch: A Transportation Startup Challenge.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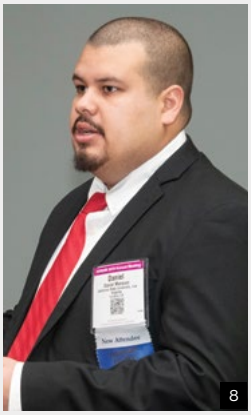
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1 (*Left to right:*) Claudia Bilotto, Public Involvement Committee chair; Libby Rushley, Planning and Environment Group chair; competition winners Joe Segale, Julia Gold, and Jared Fiel; and Terri Parker.

Sessions & Workshops

(continued)

1 The 12th annual John & Jane Q. Public competition, hosted by the Public Involvement Committee, honored best practices in communicating transportation system resiliency and sustainability in extreme weather conditions.

2 Elizabeth Yura, Bay Area Air Quality Management District, participates in a panel discussion on sustainable communities.

3 Daniel Reck, ETH Zurich, addresses equitable access to 21st-century mobility options.

4 Neha Rustagi, U.S. Department of Energy, presides over a session on fuel cell and electric vehicles.

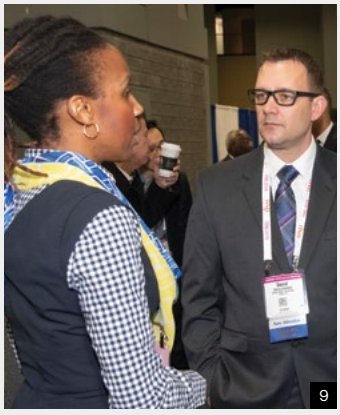
5 Anthony Howcroft, SWARM Engineering, discusses converging technologies that can affect port operations.

6 Roger Millar, Washington State DOT, examines workforce development innovations at a roundtable of state DOT CEOs.

7 Carl Slater, Navajo DOT, shares information on the Navajo Nation's airfields.

8 Duwan Morris, Morgan State University, examines the impact of work zone signage on driver speeding behavior in a driving simulator study.

9 Velvet Basemera-Fitzpatrick, TRB, discusses the Rail Safety IDEA Program with David Johnson, Boise State University.



Sessions & Workshops

(continued)

1 Beverly Byerts, Florida Department of Economic Opportunity, addresses economic resilience at a session on disaster logistics and business continuity.

2 Emmanuel James, Northern Arizona University, presents an analysis of factors affecting injury severity in traffic crashes on Arizona tribal lands.

3 Subeh Chowdhury, University of Auckland, addresses the role of gender in the ridership of public transportation routes involving transfers.

4 Cristian Camilo Alvarez Tuta, City College of New York, presents an investigation using open data of the New York City Clear Curbs Initiative.

5 Peiyong Yu, Econsult Solutions, outlines a property impact study of proposed bus rapid transit in Montgomery County, Maryland.

6 Steve Johnson, HNTB Corporation, explores regional cooperation and cybersecurity at a session on protecting critical transportation infrastructure and operations from cyber disruptions.

7 Monica Landgrave-Serrano, University of Arizona, shares research on the development of a toolkit for collecting qualitative pedestrian environment data.

8 Joshua DeFlorio discusses incorporating resiliency and sustainability into general operations at the Port Authority of New York and New Jersey.

9 Problems and solutions for large-scale transportation planning models were the topics of a multipart session.

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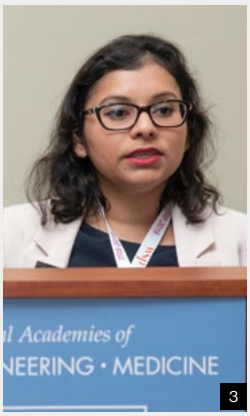

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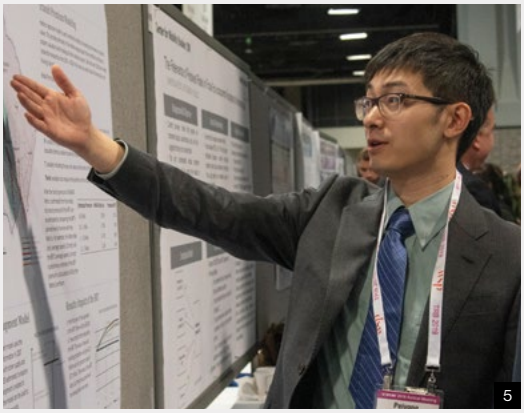
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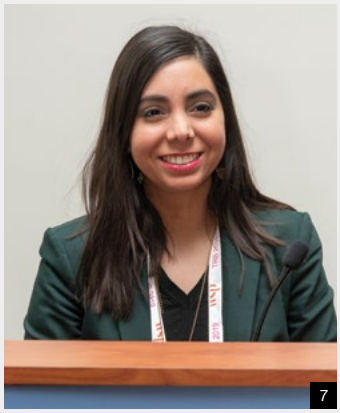
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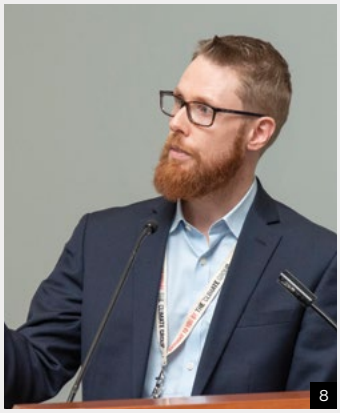
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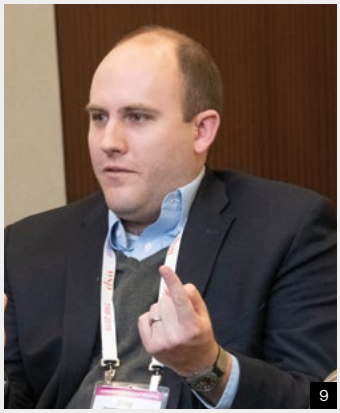
9 Presenters included Amit Ranjan Mondal, University of Connecticut; Siyu Chen, Massachusetts Institute of Technology; Thomas Hancock, University of Leeds; Taha Rashidi, University of New South Wales; Joshua Auld, Argonne National Laboratory; Hans Van Lint, Delft University of Technology; Sebastian Horl, ETH Zurich; and Rolf Moeckel, Technical University of Munich.



Committees

1 Geoffrey Gosling received the Aviation Group's Francis X. McKelvey Award in recognition of his exceptional service to the field of aviation.

2 Lisa Staes (*left*), University of South Florida Center for Urban Transportation Research, is chair of the Task Force on Transit Safety and Security.

3 Silas Nichols, Federal Highway Administration, shares the agency's initiatives and directions with the Foundations of Bridges and Other Structures Committee.

4 Incoming chair Mary Tinsman (*right*) helps outgoing chair Emily Pettis (*left*) guide a meeting of the Historic and Archeological Preservation in Transportation Committee.

5 Joan Walker leads a meeting of the Transportation Demand Forecasting Committee.

6 Debra L. Miller (*right*) presents a certificate of appreciation to Caroline Mays (*left*), outgoing Agriculture and Food Transportation Committee chair.

7 Erica Wygonik (*second from right*), RSG, participates in a meeting of the Urban Freight Transportation Committee.

8 Hyun-A Park (*left*) is a member of Organizational Management Joint Subcommittee, a collaborative effort between TRB and the American Association of State Highway and Transportation Officials.

9 Greg Macfarlane discusses membership initiatives at a meeting of the Young Members Council.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Representatives of TRB standing committees receiving Blue Ribbon Awards included:

1 Jerri Bohard (*left*) and Roger Bligh,

2 Charles Fuhs (*left*) and Casey Emoto,

3 Timothy Henkel (*left*) and Andrea d'Amato, and

4 William Eisele (*left*) and Knowles Tivendale.

Committees that Go Above and Beyond

The Technical Activities Council presented Blue Ribbon Awards to honor committees with exemplary best practices. These committees serve as role models, with chairs and members available to share their experiences with others:

- *Identifying and Advancing Ideas for Research:* Roadside Safety Design Committee, chaired by Roger Bligh, with an Honorable Mention to the Statewide Multimodal Transportation Planning Committee, chaired by Jerri Bohard;
- *Attracting and Preparing the Next Generation of Professionals and Scholars in TRB:* Managed Lanes Committee, cochaired by Casey Emoto and Charles Fuhs;
- *Moving Research Ideas into Transportation Practice:* Strategic Management Committee, chaired by Andrea d'Amato, with an Honorable Mention to the Transportation Asset Management Committee, chaired by Timothy Henkel; and
- *Contributing to Improving the Management and Operation of TRB Committees:* Public Transportation Planning and Development Committee, chaired by Joana Conklin, with Honorable Mentions to the Highway Traffic Monitoring Committee, chaired by Jonathan Regehr, and the Urban Freight Transportation Committee, chaired by William Eisele.

TRB Awards Emeritus Status to Longtime Volunteers

In recognition of their significant, long-term contributions and outstanding service to TRB's standing committees, the following individuals received emeritus membership at the 2019 Annual Meeting:

- Christopher P. L. Barkan, Rail Group;
- Werner Brilon, Highway Capacity and Quality of Service Committee;
- George K. Chang, Pavement Surface Properties and Vehicle Interaction Committee;
- Patricia Collette, Rural Public and Intercity Bus Transportation Committee;
- Thomas B. Deen, Transportation History Committee;
- Kay Fitzpatrick, Operational Effects of Geometrics Committee;
- Jerome Gluck, Access Management Committee;
- Ram Pendyala, Transportation Planning Analysis Methods Section;
- Brian Ray, Geometric Design Committee;
- Eric Schreffler, Transportation Demand Management Committee;
- Thomas H. Wakeman III, Transportation Systems Resilience Section;
- Kevin E. White, Subsurface Soil Structure Interaction Committee; and
- Kristine Williams, Access Management Committee.

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4 (*Left to right:*) Shiyan Yang, Steven E. Shladover, Xiao-Yun Lu, Aravind Kailas, and Hani Ramezani. Not pictured: Osman D. Altan.

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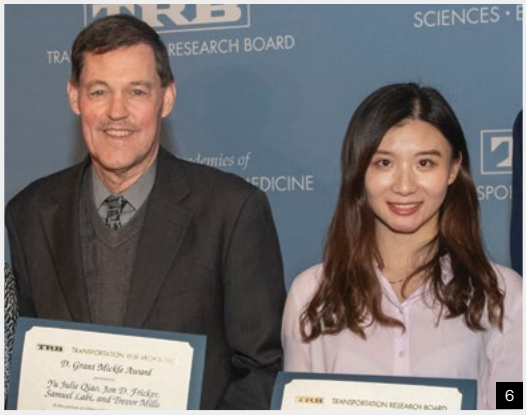

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Paper Awards

1-3 The Fred Burggraf Award is given to researchers under age 35.

1 Sara Ashley Wilkin's award-winning paper examined head-down time in single-pilot general aviation operations.

2 Matthew Laquidara was honored for an outstanding paper in the field of public transportation.

3 Nathan P. Belz (*left*) and Addison Yang (*right*) were recognized for their paper on the gaps at single-lane roundabouts.

4 The Patricia F. Waller Award honors an outstanding paper in the field of safety and systems users.

5 The Pyke Johnson Award for best paper in planning and the environment was presented to Taha Hossein Rashidi. Not pictured: Ali Najmi, Melissa Duell, Milad Ghasri, and S. Travis Waller.

6 Jon D. Fricker (*left*) and Yu Julie Qiao received the D. Grant Mickle Award. Not pictured: Samuel Labi and Trevor Mills.

7 The Charley V. Wootan Award went to Hamish Campbell.

8 The William W. Millar Award honors the best paper in the field of public transportation. (*Left to right:*) Christopher W. Southwick, Gabriel E. Sánchez-Martínez, Laurel Paget-Seekins, and Millar, past president of the American Public Transportation Association and award namesake. Not pictured: John P. Attanucci.

9 Scott Himes (*left*) and Kimberly Eccles received the K. B. Woods Award. Not pictured: R. J. Porter.

Major Awards

1 Daniel Sperling (*second from left*) received the 2018 Roy W. Crum Award for achievements in student mentorship and transportation research in the areas of energy, air quality, climate change, and policy. Presenting the award were (*left to right*) Victoria A. Arroyo, 2018 TRB Executive Committee Vice Chair; Katherine F. Turnbull, 2018 Executive Committee Chair; and Neil Pedersen, TRB Executive Director.

2 In recognition of her outstanding service to the National Academy of Sciences, Engineering, and Medicine; TRB; and the broader transportation research community, Susan Hanson (*second from left*) is the 2018 recipient of the W. N. Carey, Jr., Distinguished Service Award.

3 For her highly distinguished career in transportation—as director of the Arizona Department of Transportation, as Federal Highway Administrator, and as U.S. Secretary of Transportation—Mary E. Peters was awarded the 2019 Frank Turner Medal for Lifetime Achievement in Transportation.

4 Noted pavement expert Jon A. Epps delivered the 2019 Thomas B. Deen Distinguished Lecture.

5 Norman R. Augustine, former Lockheed Martin CEO and chair of the Future Interstate Highway System Study Committee, addressed the study's findings via video feed.

6 Norm Mineta, U.S. Transportation Secretary under the George W. Bush administration, delivered the joint Chair's Luncheon address on the report *Renewing the National Commitment to the Interstate Highway System: A Foundation for the Future.*

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New Executive Committee Leaders Step Up

Victoria A. Arroyo, Executive Director of the Georgetown Climate Center (GCC), Assistant Dean for Centers and Institutes, and Professor from Practice, Georgetown Law, is 2019 Chair of the TRB Executive Committee. She succeeds Katherine F. Turnbull, Executive Associate Director, Texas A&M Transportation Institute. Leslie S. Richards, Secretary for the Pennsylvania Department of Transportation, is the 2019 Vice Chair.

Arroyo oversees GCC's work on climate and energy policy, supervising staff and student work on climate mitigation and adaptation at the state and federal levels, and teaches courses in environmental law. She previously served as the Pew Center's Vice President for Domestic Policy and General Counsel, directing the Pew Center's policy analysis, science, adaptation, economics, and domestic policy programs. Before that, Arroyo practiced environmental law with Kilpatrick Stockton and other private firms and worked at the U.S. Environmental Protection Agency. From 1988 to 1991, she created and directed the Louisiana Department of Environmental Quality's policy office, briefly serving as Governor Buddy Roemer's environmental advisor.

Arroyo also has taught courses on environmental policy and climate change at Catholic University, George Mason University's graduate public policy program, and Tulane Law School. She holds a bachelor's degree in biology and philosophy from Emory University, a master's degree in public administration from Harvard University, and a J.D. from Georgetown Law.

Pennsylvania Transportation Secretary since 2015, Richards has extensive leadership experience in the management of transportation projects, both from two decades of private-sector work in planning and engineering and from work with local government. She is recognized in both the public and private sectors for her ability to build consensus to find solutions to problems. Richards has a bachelor's degree in economics and urban studies from Brown University and a master's degree in regional planning from the University of Pennsylvania.

Michael F. Ableson, General Motors; Nuria I. Fernandez, Santa Clara Valley Transportation Authority; Stephen W. Hargarten, Medical College of Wisconsin; Ashby Johnson, Capital Area Metropolitan Planning Organization; William (Bill) Kruger, UPS Freight; Michael R. McClellan, Norfolk Southern Corporation; Susan Shaheen, University of California, Berkeley; and Shawn Wilson, Louisiana Department of Transportation, are new members of the Executive Committee. Reappointed members include Susan Hanson, S. Jack Hu, Melinda McGrath, and Katherine F. Turnbull.

Executive Committee

(*Previous page*:) The TRB Executive Committee chooses a timely topic for their policy session each Annual Meeting. The 2019 policy session topic was rural transportation, with a panel of experts that included

7 Carri Kissel, National Association of Development Organization Research Foundation; and

8 Peter Schauer, Peter Schauer Associates.

9 Derek Kan, U.S. DOT Undersecretary for Policy, addresses the Executive Committee.

New and reappointed Executive Committee members include (*left to right*):

1 Ashby Johnson, Capital Area Metropolitan Planning Organization;

2 Nuria I. Fernandez, Santa Clara Valley Transportation Authority;

3 Michael R. McClellan, Norfolk Southern Corporation; and

4 Shawn Wilson, Louisiana Department of Transportation and Development.


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Executive Committee

(continued)

1 2018 Chair Katherine F. Turnbull guides the Executive Committee through its meeting agenda.

2 Victoria A. Arroyo was the 2018 Executive Committee Vice Chair.

3 TRB Executive Director Neil Pedersen offers updates on new Board initiatives.

4 Ann Brach, Technical Activities Director, briefs the Executive Committee on the activities of TRB's standing committees.

Also participating in Executive Committee deliberations were

5 Edward Comstock, Marine Board chair;

6 James M. Tien, University of Miami, Florida;

7 Leslie Richards, 2019 Executive Committee Vice Chair;

8 Raymond Martinez, Federal Motor Carrier Safety Administration; and

9 (*Left to right:*) Daniel Sperling, University of California (UC), Davis, and Susan Shaheen, UC Berkeley.

10 TRB Centennial Task Force chair Sandra Larson discusses plans for the commemoration of TRB's 100th anniversary in 2020.

11 Jim Tymon, American Association of State Highway and Transportation Officials, addresses state DOT research initiatives.

12 Michael F. Ableson, General Motors, is a new member of the Executive Committee.


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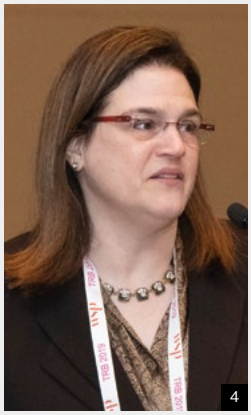
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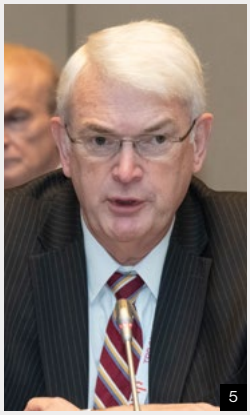
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FIVE YEARS OF REAL RESULTS

Ohio DOT Collaborates in Research Initiative

Photo: Mark K. Geneva, Flickr

RON POOLE

The author is Public Information Specialist, Ohio Department of Transportation, Columbus.

Above: The vast majority of Ohio road lane-miles are beyond the jurisdiction of the Ohio Department of Transportation (DOT). Because of this, Ohio DOT partnered with the Ohio Research Initiative for Locals (ORIL) and other academics and association representatives to address local roadway issues.

Whether they are native to the state or just passing through, drivers in Ohio are like drivers in most states: they tend not to think about the roadways they are using until those roads stop working. If drivers hit a pothole, get held up by work zones, or encounter slippery roads, they can get aggravated. If they are aggravated enough, they want to complain—but they do not always know where to take those complaints.

By Ohio law, different roadways are built and maintained by different public agencies, each having their own authority over their own system. County roads are maintained by the various county engineers' offices, each township is responsible for its own roads, and municipal roads are cared for by various cities and villages. All state and Interstate highways are maintained by the Ohio Department of Transportation (DOT).

Although Ohio DOT has a lot of ground to cover—literally—84 percent of the state's centerline miles fall under the jurisdiction of local counties, cities, villages, and townships. Ohio DOT is only responsible for 14,095 of the more than 44,000 bridges in Ohio—the rest are locally controlled. Even though Ohio DOT is not always responsible for roads and bridges, it still wants to help.

"Our local agencies are very important to us," observes Jim Barna, former assistant director of Ohio DOT and current executive director of DriveOhio. "Drivers often travel from Interstate highways to local roads and back again without even thinking about it. Their opinion is based on how they find driving the whole state. The department believes helping our local partners succeed helps us all succeed."

Ohio DOT always seeks ways to support and improve local transportation. The department has found that supporting research aimed at solving local agencies'

transportation problems makes a real difference in the system overall.

Program Beginnings

For years, Ohio DOT only accepted research ideas from Central Office staff; however, members of the DOT's research section saw a need to solicit ideas from Ohio DOT's various districts, county garages, and outposts across the state. The research ideas from people on the front lines of highway construction and maintenance produced more immediate results. This success led others within the section to consider how this front-lines approach could benefit roads not under the state's direct jurisdiction.

"Improving any part of the transportation system improves the whole," notes Vicky Fout, Ohio DOT's research program manager. "When we saw the success of involving Ohio DOT district offices, we felt we could apply the idea to the whole state by working with local agencies. We wanted to use research to find effective and affordable solutions."

It was from this opportunity that the Ohio's Research Initiative for Locals (ORIL) program was formed. Created in 2013, ORIL's focus was to use research to solve issues specific to the local transportation system. The program was developed with advice from the Iowa Highway Research Board and Minnesota's Local Road Research Board, the only other two transportation research programs in the country solely addressing local transportation.

On the ORIL board, academics and representatives from the County Engineers Association of Ohio, the Ohio Township Association, the Ohio Municipal League, the Ohio Division of the Federal Highway Administration, Ohio DOT, and the Ohio Local Technical Assistance Program (LTAP) Center all work collaboratively. Under the established charter, the county engineers and municipal league each nominate four members to the ORIL board. Ohio DOT contributes four additional members, and the township association contributes one representative. The two final positions are occupied by academics.

The members from the associations and Ohio DOT are chosen according to internal organization criteria and serve 4-year terms, with staggered reelections every 2 years. The exception to this is the

Photo: Robert Batina, Flickr

Road repair in Lancaster, Ohio. Counties and townships generally maintain their own roads in Ohio.

Photo courtesy ORIL

Founding members of the ORIL Board, 2013.

Photo courtesy ORIL

A meeting of the ORIL Board in Columbus, Ohio, in February 2018. The Board meets four times per year and communicates regularly by e-mail and phone on the progress on ORIL research projects.

academics, who are chosen by the board members. These advisors must be members of Ohio universities and must apply to the board on their own initiative. ORIL is staffed by Ohio DOT's Office of Statewide Planning and Research, and the board meets quarterly.

Project Selection

ORIL reaches out to local agencies all over the state and invites them to submit research ideas. These suggestions can come from anyone with authority over a construction and maintenance program for a county, city, village, or township. Local planning agencies and government associations are also welcome to submit ideas. The ideas must be submitted as research studies creating cost-effective solutions and identifying better practices and new technologies related to local transportation concerns. The study ideas must address one or more of three target areas: safety, renewal and infrastructure, or operations and business practices.

Qualifying ideas go through several more steps to refine them into requests for proposals that are bid competitively and eventually contracted as projects. The number of projects submitted varies from year to year; 18 ideas were submitted in 2015, half of which received funding. Ten ideas were submitted in 2018 and two selected for funding. Overall, over the past 5 years the board has received 51 submissions, of which 24 have received or will receive funding.

The ORIL program makes $500,000 available for use each year through Ohio DOT's research program. In 2015, the average budget of the projects undertaken was just under $96,000, with an average completion time of 27 months. Project budgets were at their highest peak in 2018, with an average budget of more than $143,500, and were completed after an average of 21 months. Although projects supported in 2015 and 2016 focused on structures, construction, environmental, hydraulics, and planning and policy, in the past 3 years the focus of the projects have shifted to maintenance, materials, planning, and safety.

ORIL accepts research proposals from anyone: public or private, universities from Ohio or from other states, and contractors and consultants. To date, about 84 percent of the ORIL projects have been awarded to universities. The testing and results of projects are publicly available via the ORIL website.[1]

Success Stories

"ORIL research focuses on creating practical results," comments Greg Butcher, Violet Township engineer and ORIL board chair. "Every agency faces the same challenges of doing all they can with their budgets, whether the projects are big or small—but not every agency shares the same priorities in serving their communities. The research serving local program goals covers areas that Ohio DOT would not usually consider. We have already begun to see the effects of having ORIL in place, and Ohio has been reaping the benefits of its research during the past 5 years."

Indeed, ORIL does have a few success stories to tell.

STRONG AND FLEXIBLE

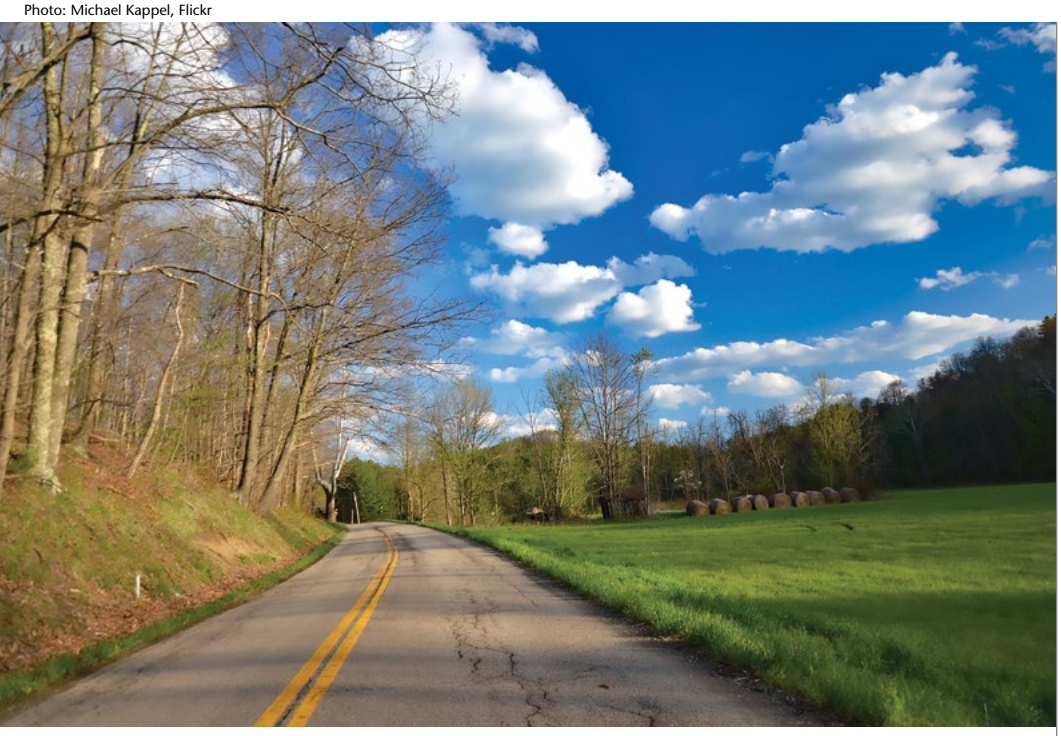
A common practice among local public agencies in Ohio is to reuse materials (e.g., asphalt and concrete) from some projects to widen existing roads. Repurposed materials can be combined with relatively inexpensive additions (e.g., fly ash, lime, and fabric) to create whole new roadway structures. Local officials can easily conduct cost-based comparisons of these methods, but not enough information is available to compare the overall effectiveness of these materials in terms of projected strength or relative load capacity.

"Ohio DOT has well-researched guidance on how to select conventional materials for the specific needs of highway construction," observes Warren Schlatter, Defiance County engineer and ORIL board member. "Department planners and engineers can consider the length of a high-capacity highway and the loads it will carry, then determine the right materials to be used and the method for applying them. But local agencies seeking to save money with mixes used for lower capacity roads had no such information; they needed a way to test their materials."

ORIL project researchers developed and verified a low-cost, repeatable, and

[1] http://oril.transportation.ohio.gov.

Photo: Michael Kappel, Flickr



A farm road through Zanesville, Ohio, in Muskingum County. County engineers researched new, lower-cost asphalt mix methods.

nondestructive method to characterize the load-carrying capacity of materials commonly used in road widening and construction. Newly acquired strength data from this research helped Defiance County engineers go forward with a full-depth reclamation project using portland cement as a base stabilizing material, paved with hot-mix asphalt. Muskingum County found that their method of mixing reclaimed materials with new stone was as strong as stone alone. Both methods lowered costs for their agencies, which can continue to test other materials in the future.

"Now the local agencies can move forward with more confidence, knowing their materials have the ability to maintain and possibly enhance pavement capacity while reducing total costs, all based on research," Schlatter notes.

Lean and Green

Old vehicle tires currently take up a lot of space in landfills. When processed, ground tire rubber (GTR) is a recycled product that can be used in place of polymers as an additive to asphalt mixtures. GTR also can be used to improve the durability, longevity, and performance of pavements and reduce the negative effects scrap tires have on the environment. Historically, however, the initial cost of using GTR in asphalt mixes was so high that many local agencies could not afford it. ORIL set out to determine if recent advances in technology have made the cost of using GTR more reasonable. This research assessed the true life-cycle cost of these mixes and identified opportunities for GTR to be more affordable while still matching traditional performance.

Researchers identified three GTR-modified binders with promising laboratory tests. These have been built into test sections in the cities of Columbus and Akron. The research team has conducted baseline testing and training has been provided to city personnel. The training will allow city engineers to continue collecting data that can be used for future analysis of the long-term performance of the GTR-modified binders.

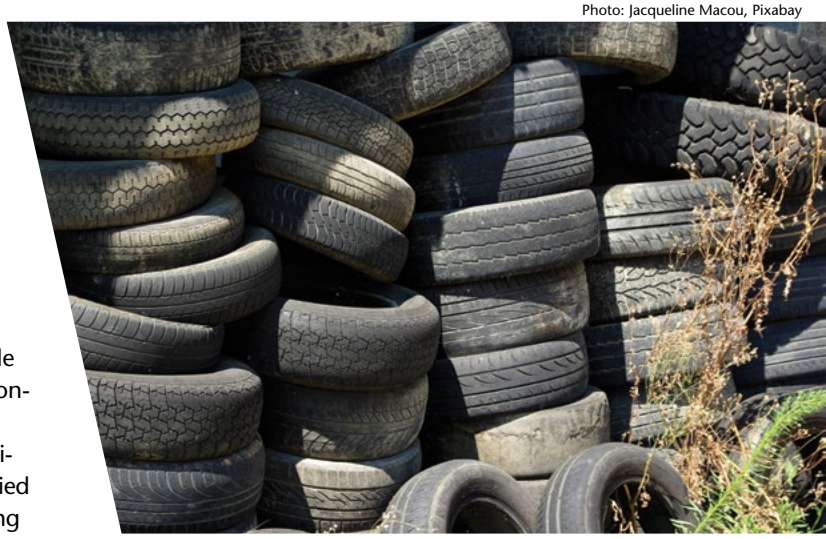
"Columbus is constantly trying new technology to create a more sustainable and cost-effective pavement," comments James Young, City Engineer for the City of Columbus and ORIL board member. "This process can help us reduce what we place in landfills, while still building strong, high-performing pavements. The exciting thing about ORIL is that it funds research that might have never been tried."

BRIDGE TO A NEW IDEA

Bridges on Ohio's local road system can feature many deck types. Because of the different deck options, the bridge rail is often mounted directly to the steel fascia beams of the bridge superstructure. The trouble is, however, that these connections have not been crash-tested and therefore are not eligible for federal-aid reimbursement on federal-aid projects.

"Bridge safety is the same for all bridges, whether they are the responsibility of Ohio DOT or a local agency," observes Tim Keller, Ohio DOT state bridge engineer. "But local bridges have different

Photo: Jacqueline Macou, Pixabay



ORIL research facilitated advances that have reduced the cost of using scrap tires—which tend to take up large amounts of landfill space—as an additive to asphalt mixtures.

Photo: Drainhook, Flickr

Amity Pike Bridge, Big Darby Creek. Low-volume bridges, like those in Ohio's townships and counties, can benefit from specially designed railing systems.

priorities and needs. The guardrail design for low-volume bridges is not less safe than the Ohio DOT standard—just different. The new system allows the railing to be attached to the beam rather than the concrete deck. Ohio DOT primarily uses concrete decks, so although the development of this type of railing system was not a high priority for our bridges, it is a high priority for local bridges."

ORIL researchers synthesized a combination of factors to propose a new kind of steel fascia beam design. In addition, researchers provided details for a transition system to connect the newly designed bridge rail to Ohio's existing guardrail system in other locations. This new fascia mount system provides the option to build steel bridges with lower-cost bridge decks and successfully meets federal criteria for crash safety, making it eligible for use on federal-aid reimbursement projects. Ohio DOT is capitalizing on this locally focused research by using the new design on a bridge deck replacement project on SR-273 in Logan County.

Working Together

ORIL continues to delve into interesting territory and encourage collaboration among transportation officials and, in some cases, system users. Recently, an idea submitted to ORIL by a county engineer echoed concerns that Ohio DOT was actively addressing on the state system. Recognizing an opportunity, ORIL joined forces with Ohio DOT to expand research on state route pavement repair from damage caused by horse-and-buggy traffic to include the local transportation system. Although the state conducts partial-depth repairs on its routes, these types of repairs may not be suitable for local county and township roads that see just as much—if not more—horse-and-buggy traffic.

The research study now accounts for not only pavement repairs, but for the use of GTR and potential new designs for horseshoes. ORIL, Ohio DOT, and the research team have actively engaged the Amish community, with input from various Amish farriers helping the research team to identify long-term, cost-effective solutions that will ensure the safety of Amish travelers.

Since its inception, ORIL has become a platform not just for innovative research and information sharing but for improving cost efficiency, creating best practices, and building stronger networks of connections among local agencies. More work remains before ORIL can provide its full benefits to the citizens of Ohio, however.

"Our biggest challenge is getting the word out to our local partners about ORIL and what it can do for them," comments Mike Fitch, a program manager with Ohio DOT's LTAP Center. "Looking to the future, I think this program will continue to provide a great opportunity for Ohio's local agencies to address a variety of transportation-related issues and challenges."

Photo: Shinya Suzuki, Flickr

Many rural areas of Ohio are home to Amish and Mennonite communities. ORIL worked with Ohio DOT to expand research on repairs to local road pavements from the damage caused by horse-and-buggy traffic.

Public-Private Partnerships

POLICY, PRACTICE, AND POPULARITY

Photo: Siddharth Patil, Wikimedia

MOHAMMAD S. KHAN

The author is Executive Vice President, High Performance Technologies, Inc., Bethesda, Maryland, and a member of the TRB Design and Construction Group.

Above: The new Goethals Bridge between Staten Island, New York, and New Jersey was delivered under a design–build–finance–maintain public–private partnership (P3).

A public–private partnership (P3) is a legal agreement between public and private institutions for some or all aspects of the project life cycle of a public asset, including design, build, finance, operate, and maintain. The traditional project delivery method is design–bid–build, in which public agencies separately contract the design and construction of their assets to private entities and only participate in the preliminary design, bidding, and the contractor oversight. A first step toward greater participation of the private sector, the design–build (DB) method involves a private company designing and building the asset. The ongoing Dulles Metrorail project in Virginia, totaling about $5.68 billion for its two phases combined, is a perfect example of DB.

P3 and Its Evolution

Initiated in 1987, the E-470 highway project in Denver, Colorado, established a basic framework that many future P3 projects followed. Project E-470 was not a P3 in true sense, but had all the characteristics of a P3 project. The state legislature created a new public entity, the E-470 Public Highway Authority, to design, build, finance, operate, and maintain the 47-mile segment of the highway. The initial segment of the project opened in June 1991 and the project was completed in January 2003. Toll revenues were the primary source of funding for the project. In a typical P3 project, a private entity would take the place of the E-470 Public Highway Authority.

In the United States, P3s began to take hold in the early 1990s. Between 1993 and 2017, 32 transportation P3 projects were completed, with a total cost of about $45 billion. This is a very small share of the nation's overall spending on transportation projects—according to a Congressional Research Service Report, P3s account for approximately 2% of public infrastructure (*1*).

Between 1985 and 2009, $996 billion of transportation P3 projects were planned and funded worldwide. Of these, 12.1% were in the United States, 2.8% were in Canada, 15.3% were in Latin America, 48% were in Europe, 2.3% were in Africa and the Middle East, and 19.5% were in Asia and the Far East (*2*, see Figure 1, below). These data show that P3s are more accepted and popular in Europe than in other regions of the world.

The Gordie Howe Bridge, linking Detroit, Michigan, in the United States and Windsor, Ontario, in Canada, is a recent major international P3 project. The selection of the project firm was announced in July 2018 and the P3 agreement signed in September. The $5.7 billion fixed-price contract includes the DB and operation, maintenance, and rehabilitation phases, and the project is scheduled to be completed by the end of 2024.

Legislative Authority

For public agencies to enter into a long-term legal agreement with a private entity, which typically lasts anywhere from 30 to 99 years, the agencies need to have legislative authority. Currently, 33 states, the District of Columbia, and Puerto Rico have legislative authority to enter into a P3 agreement.

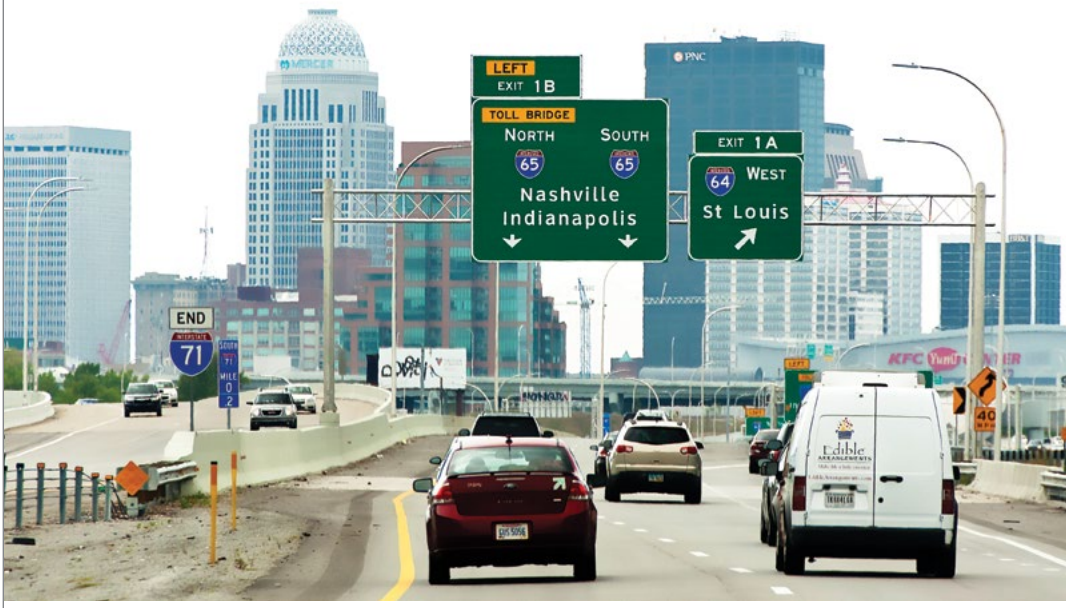


Photo: Sixflashphotos, Wikimedia

Kentucky and some other states allow tolls associated with P3 projects to be set and collected for only as long as revenue bonds are outstanding.

Though most states' legislations have enabled P3s, these laws vary widely in scope and limitation from state to state. For example, 25 states authorize all levels of government within the state to enter into a P3 agreement, and all types of infrastructure can be part of a P3 agreement. In other states, only the state is authorized to enter into a P3 agreement or a P3 can only be used for transportation projects. Some states have authorized DB projects, some have authorized P3s for existing and new facilities, some allow high-occupancy toll (HOT) lanes for congestion pricing, and some even allow for the conversion of existing roads to toll roads. On the other hand, some states have placed limits on the length of P3 agreements and some do not allow noncompete clauses in P3 agreements—that is, states can initiate projects in the vicinity of a P3, often in competition with the P3 project. Also, some states have instated annual caps on the number or cumulative dollar value of P3 projects (*3*).

Tolling of highways in general—and P3 projects in particular—has been a contentious issue. On transportation P3 projects, tolling generally is the primary source of funding; 29 states have addressed tolling and rate-setting authority via legislation. Some states specifically direct how and when the toll rates can be changed and in a few states, tolls must be removed after the initial construction debt is repaid. For example, Kentucky statute §54-3-104(c) allows tolls to be set and collected only as long as toll revenue bonds are outstanding (*3*).

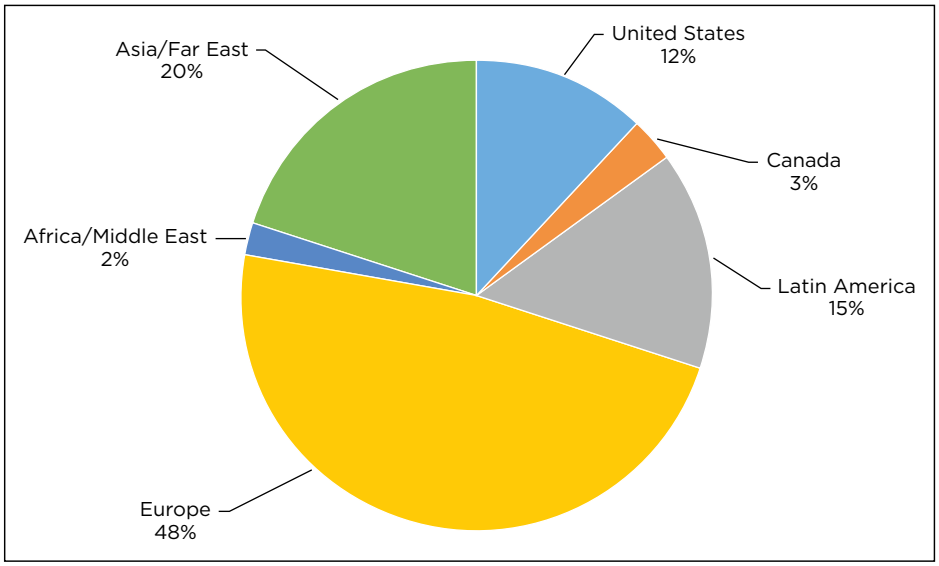


FIGURE 1 Percentages per region of the $996 billion total in transportation projects between 1985 and 2009 that were P3 projects.

Funding and Financing

In a P3 project, the public funds the project and public and private entities jointly finance the project. If public funds are sufficient to start, sustain, and complete a project, there probably is no need for a P3. But because of the challenges of limited state and local government budgets, the design, construction, operation, and maintenance of major transportation assets has become difficult. In P3 business models, a private entity shares project financing with a public agency in return for performing some or all components of the project and then sharing the revenues generated.

Collecting revenues (that is, funding), traditionally the function of public entities, can be delegated to the private entity in a P3 agreement. P3 projects generally are classified by how revenues are collected and how the private entity realizes its return on investment. The private entity can directly collect revenues (e.g., tolls and fares)—termed "revenue risk"—or the public agency can pay the private entity based on milestones and performance—termed "availability payment." In a revenue risk project, the private entity assumes a risk in that revenues can be higher or lower than forecast.

The Capital Beltway HOT Lanes project on I-495 in Fairfax County, Virginia, which was completed in November 2012, is an example of P3 funding and financing (see photo below). The funding source for the HOT lanes is tolls, which are collected by a private entity for a public asset. The shares of public and private entities in financing the $2.068 billion project were as follows: a 28.5% loan from the U.S. Department of Transportation (DOT) to the private entity under the Transportation Infrastructure Financing and Innovation (TIFIA) program; 28.5% in private activity bonds (PABs); a 24% contribution from the Commonwealth of Virginia; a 17% contribution from the private entity; and 2% from interest earnings.

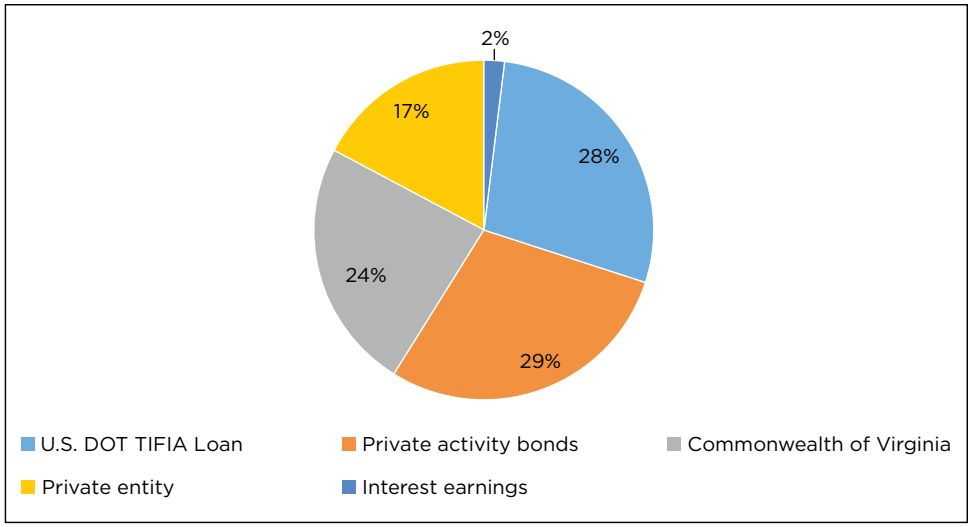
The financing share of the public and private entities is determined on a project-by-project basis. For example, on the subsequent $922.6 million I-95 HOT Lanes project in Virginia, completed in December 2014 and involving the same public and private entities, the corresponding financing share percentages were as follows: 33% from the U.S. DOT TIFIA program, 27% in PABs, 9% from Virginia, 30% from private equity, and 1% from interest earnings. The significant increase in private investment and decrease in public investment reflects the private partner's comfort with the success of the I-495 project (Figure 2, page 33).

U.S. DOT TIFIA LOANS

The borrower under the TIFIA program can be a state or local government, public authority, P3, or any other legal entity undertaking the project and authorized by the U.S. Transportation Secretary. The projects eligible for a TIFIA loan generally are at least $50 million, with a lower cost threshold of between $10 and $15 million for projects involving intelligent transportation systems, transit-oriented development, and rural or local infrastructure. Among other requirements, the borrower must establish their creditworthiness by achieving an investment-grade rating from at least one credible credit rating agency. On large P3 projects, the TIFIA loan is very attractive to a private entity because of low interest rates that otherwise would not

Photo: Virginia DOT

The Capital Beltway high-occupancy toll lanes project in Virginia. Funding for the project was provided in small part by public agencies and in larger measure by private entities, who collect tolls from noncarpooling drivers.



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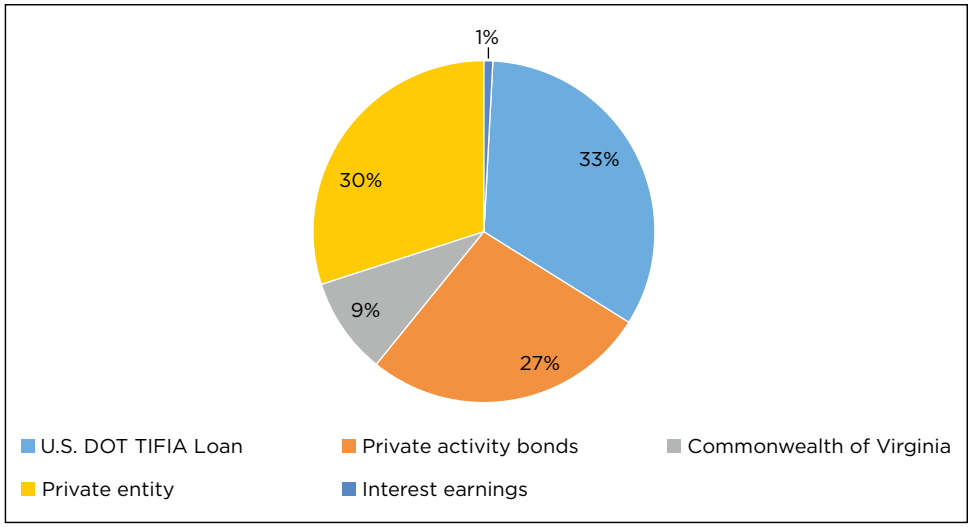


(b)

FIGURE 2 Financing share of project by source for (*a*) the $2.068 billion Capital Beltway HOT Lanes project and (*b*) the $922.6 million I-95 HOT Lanes project.

be available to them. TIFIA loan interest rates are fixed and are the same as the U.S. Treasury borrowing rate, with a term generally of 35 years from the date of substantial completion of the project. TIFIA loans can finance up to 49% of the project cost.

PRIVATE ACTIVITY BONDS

PABs are similar to municipal bonds but are administered by U.S. DOT, as authorized by Congress (*4*). Currently, the U.S. Transportation Secretary has the authority to issue $15 billion in PABs; as of November 27, 2018, approximately $11 billion in PABs have been issued or allocated in 28 transportation projects nationwide. The projects eligible to be financed via PABs include aviation, marine, rail, highway, and freight transfer facilities. PABs are attractive to regular citizens because they are tax exempt; the interest earned on these bonds generally is exempt from federal, state, and local taxes.

STATE CONTRIBUTIONS

State governments can make their contributions to P3 projects from federal highway funds apportioned for their state, state infrastructure banks (SIBs), or any other authorized sources. Thirty-two states and Puerto Rico have federally authorized SIBs (*5*). These SIBs can be capitalized on by using some of the state's share of federal surface transportation funds. Some states, such as California, Florida, Georgia, Kansas, Ohio, and Virginia, have established SIBs without any federal affiliation or assistance.

Legal Implications

P3s are long-term, complex legal agreements between a public entity and private entity; during the term of the agreement, lots of things can happen on either side that may not be conducive to an agreement already in place. Unresolved legal and regulatory issues and future laws and regulations can be problematic. The $1.4 billion P3 agreement for US-460 in Virginia is a recent example. The agreement was signed in December 2012, but the state

Photo: Dom Blevins, Wikimedia

Private activity bonds (PABs) funded Florida's Brightline expansion into Orlando. PABs are designed for private infrastructure that provides a public benefit.

suspended the work in early 2014 and canceled the agreement in early 2015. The main reason cited for the failed P3 agreement was that the project would not have been able to receive the environmental permits required for large swaths of wetlands along the 55-mile route. By the time the agreement was canceled, the state had already paid the private entity more than $250 million—including $125 million generated from bonds.

Another serious concern is the potential bankruptcy of a private entity during the lifetime of a P3 agreement. The private entity usually is a consortium of several different private organizations, including engineers, builders, and financial institutions, and the failure of one of these companies can bring the entire private partner down. A bankruptcy during the design and construction phase of the project—when most of the cost is incurred and few revenues are made—can be particularly damaging to a public partner.

TIFIA loans generally are subordinate debt; that is, payable after senior debt obligations are met. According to the TIFIA program's safeguard clause, however, a TIFIA loan becomes a senior debt in the case of bankruptcy. For example, for the Elizabeth River Tunnels P3 project in the Norfolk–Portsmouth area of Virginia, PABs comprise the project's senior debt. Loans from banks and other financial institutions on P3 projects generally are treated as senior debt as well. This hierarchy of senior and subordinate debts refers to their order of payment in cases both of healthy financing and of a defaulted project.

> Though most states' legislations have enabled P3s, these laws vary widely in scope and limitation from state to state.

A bankruptcy occurred in the $3.8 billion, 75-year P3 agreement between the Indiana Finance Authority (IFA) and a private entity for the operation and maintenance of the Indiana Toll Road (see photo below). The agreement was signed in April 2006 and the private entity filed bankruptcy in 2014. IFA entered into a new $5.7 billion, 66-year lease with another private entity in 2015. Aside from some uncertainty for a year or so, this bankruptcy was not too damaging to the state because it involved the operation and maintenance of an existing facility during a revenue-generating period.

Photo: Haydn Blackey, Flickr

When the private company operating the Indiana Toll Road declared bankruptcy, a new agreement was made with a different entity for the remainder of the operational and maintenance contract.

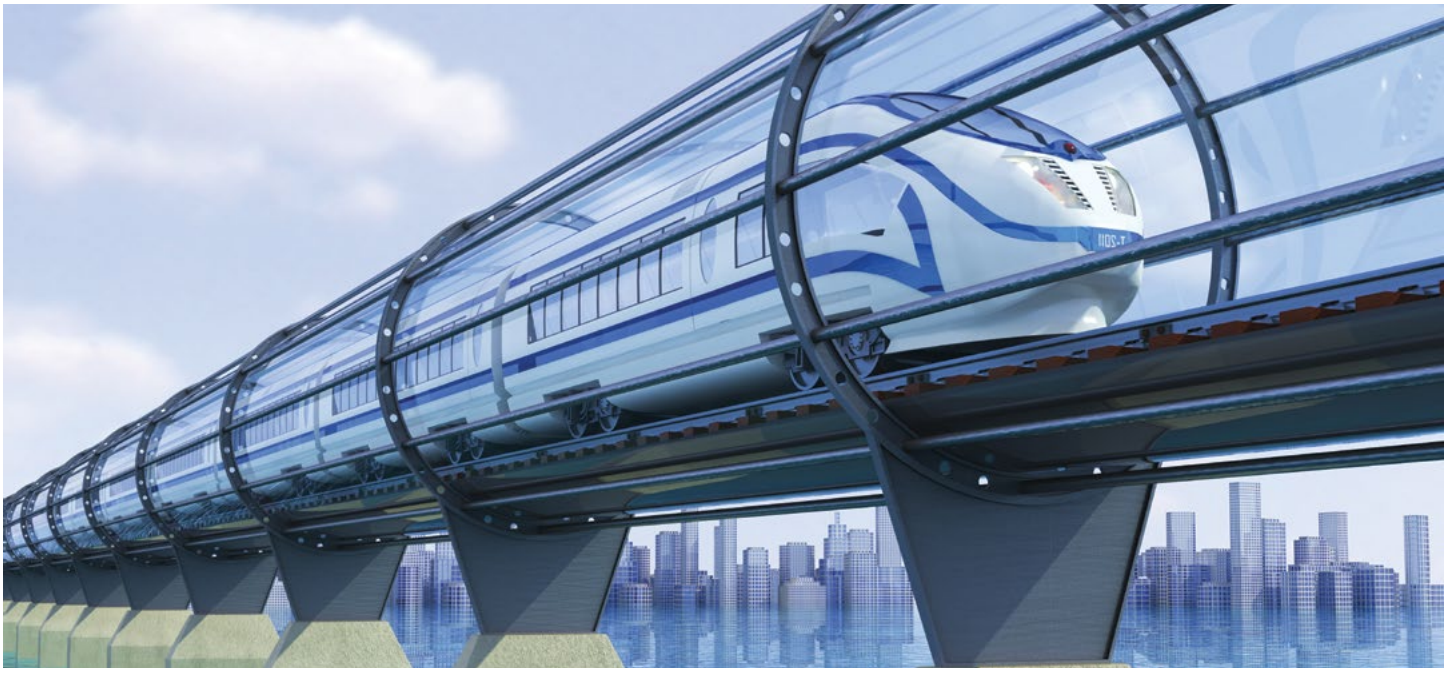
Innovative Solutions

Because of their nonprescriptive, performance-based, long-term nature, P3 projects provide an opportunity for innovative solutions—likely more than any other venue. The private entity is free to adopt and implement almost any innovation in design, construction, operation, and maintenance, as long as the performance standards established by the public agency in the agreement are met.

BUILDING INFORMATION MODELING

A technological advancement particularly well-suited for P3 projects is building information modeling (BIM). This technology has gained popularity in the building industry in the past two decades, but its acceptance in the transportation industry is still lacking. In BIM, the entire life cycle of a P3 project—including planning, surveying, design, construction, operation, and maintenance—can be created as a 3-D computer model that can be shared and modified digitally by participating team members. This model is improved and strengthened as more and more data become available and it essentially becomes a digital replica of the physical infrastructure, allowing people to visualize the infrastructure. Changes in project conditions can easily be entered and their effect on related parts of the project immediately noticed. Simulations can test different design options virtually under different loading configurations.

Cost information is part of BIM, facilitating timely procurements. BIM also can incorporate information about a project's surroundings, including underground wa-



ter mains and utilities, and thus any conflicts with surroundings can be resolved easily. The detailed models of transportation infrastructure created through BIM also can assist connected and automated vehicle technology, which relies on accurate data and information.

OTHER TECHNOLOGIES

P3s present opportunities for adoption and implementation of other technologies, such as advanced sensors for monitoring and asset management and even futuristic design and construction technologies like 3-D printing (*6*–*7*). The significance and magnitude of transportation P3 projects is such that they generally are part of the nation's critical infrastructure. A transportation infrastructure element embedded with monitoring sensors can add to its safety and security. A variety of sensors are at different stages of development, including piezoelectric sensors, fiber-optic sensors, and eddy current sensors.

CHICAGO HYPERLOOP

In June 2018, a P3 agreement was announced to design, build, finance, operate, and maintain a high-speed transportation system between Chicago's downtown area and O'Hare International Airport. Using hyperloop technology, high-powered automated vehicles in a tunnel will transport passengers between these two congested locations in about 12 minutes at a speed of 150 mph (see illustration above). The trip usually takes at least 40 minutes by transit or car.

A unique feature of this agreement is that no public financing will be used—the entire $1 billion project cost will be financed by a private entity. In this hyperloop transportation system, a magnetic levitation environment, often a vacuum, allows automated vehicles to accelerate from zero to 192 mph and decelerate back to a complete stop in less than 0.31 mi (*8*). Considering the relatively short distance on the Chicago project, no vacuum will be used.

The significance and magnitude of transportation P3 projects is such that they generally are part of the nation's critical infrastructure.

Moving Forward with P3

Although it has been 30 years since P3 projects first emerged in the United States, and many projects have been completed using this business model, the acceptance, popularity, and market share of P3s are still low. About 30% of states still do not have P3-enabling legislation, and tolling—the primary source of funding for transportation P3 projects—still is a contentious issue and lacks public support. A common public perception is that the nation's public assets are being taken over by large private institutions, both of domestic and foreign origins, primarily for the sake of profit-making and without contributing much to local communities.

To some extent, it is true that private entities are assuming control of public assets for as long as 75 or 99 years without an equitable investment in these assets. With a few exceptions, the share of private equity on transportation P3 projects is much less than 50%. Public sources

People, Planet, and Profit

A common perception of public–private partnerships (P3s) is that they do not add to the goal of sustainability. For P3s to be more acceptable and popular, it is important that they align with another P3: people, planet, and profit, also referred to as the "triple bottom line." These two P3s have one common element—profit—but people and planet are not as obvious in P3s. Transportation projects established with a goal of achieving both of these P3s can be much more popular.

The $2.9 billion I-4 Ultimate P3 Improvement project in Florida, expected to be completed by 2020, is an example of a project in which sustainability benefits are well highlighted. This project received Envision Platinum recognition from the Institute for Sustainable Infrastructure on the basis of its positive contributions to social, economic, and environmental impacts on a community.

Some of the attributes of a sustainable P3 project include

- Profitable and thriving businesses of all types and sizes;
- High employment opportunities and low unemployment rates;
- Training and workforce development opportunities;
- Higher income per capita;
- Investment and reinvestment of businesses in communities;
- Safe and secure communities;
- Better accessibility to educational, health, shopping, sports, and recreational facilities;
- Affordable cost of living;
- Lower commute time;
- Easy accessibility to other modes of transportation, such as transit, rail, airport, and ports;
- Safe drinking water and air;
- Control of environmental contamination of land, air, and water;
- Protection of wetlands, wildlife, and natural habitats;
- Recycling of construction materials from existing facilities;
- Reduction of carbon and greenhouse gas emissions; and
- Long service life—100 years or more—for transportation facilities.

of financing, like TIFIA loans and tax exempt PABs, all are subsidized to varying degrees, at public cost. Furthermore, in cases of failed P3s and bankruptcies, the responsibilities of the asset fall back on the shoulders of public agencies. Thus, in order to be a true P3, the share of the private equity should be at least 50% and as much as 100%. At this level of maturity of transportation P3 projects, the following share of investment is reasonable: 20% TIFIA loans, 20% PABs, 10% state contributions, and 50% private equity.

To encourage participation from smaller private entities, P3s of less than $1 billion in present value should be considered more favorably. Megaprojects may be divided into parts or phases. Also, limiting concession periods to 50 years would allow public agencies to better manage future unknowns and opportunities.

Only $4 billion is left of the $15 billion authorized limit for PABs; it would be wise to consider increasing this ceiling to $30 billion. Also worthy of consideration is increasing the availability of TIFIA loans—from 2016 to 2020, the average is about $285 million per year—to at least $500 million per year.

For states that are reluctant to facilitate the wider use of P3s, adopting policies friendly to DB projects is a step in the direction of P3s. Design–build projects are a form of P3 that preserve more control and risk for the public agency. Innovative and sustainable solutions should be the cornerstone of P3 projects, embedded in the process at the time these projects are created. Finally, communities should be educated about P3s.

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Photo courtesy Metropolitan Airports Commission

Guidebook for Airport Terminal Restroom Planning and Design

JENS VANGE AND
ALAN HOWELL

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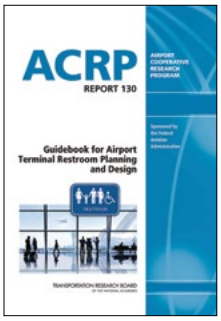
Above: When the restrooms at Minneapolis–Saint Paul International Airport (MSP) became the top complaint among passengers, the airport created a new approach to improving their restroom facilities. This successful initiative led to an Airport Cooperative Research Program (ACRP) guidebook for other airports.

When Minneapolis–Saint Paul International Airport (MSP) set out to upgrade its restrooms in 2010, the team leading the initiative knew that a mere facelift would not solve the facilities' growing issues. Renovations had been done and redone; new restrooms, with minor tweaks to the finishes and amenities, had been added in various expansion projects; and some of the original 1960s vintage facilities remained. Across the two terminals at MSP, 100 sets, or pairs, of restrooms served the public and employees. Although paper-towel dispensers had been updated and basic retrofits had been conducted to conform with Americans with Disabilities Act of 1990 (ADA) guidelines, and even as hold rooms, concessions, and wayfinding facilities received upgrades, the restroom program had not. In fact, restrooms had become *the* problem at MSP—they were a top complaint on traveler surveys and an ongoing operational challenge. It was clear that a new approach was required.

In 2015, the Airport Cooperative Research Program (ACRP) released *ACRP Research Report 130: Guidebook for Airport Terminal Restroom Planning and Design*. Inspired by MSP's initiative, the report compiles input from nine case studies at airports across the United States and from various local stakeholder groups. The research team was directed to bring this guidance to the aviation industry because every airport was facing similar issues:



For more information on *ACRP Research Report 130: Guidebook for Airport Terminal Restroom Planning and Design*, visit www.trb.org/Publications/Blurbs/172507.aspx.

inadequate fixture counts and the resulting long lines, especially at the women's restrooms; failing plumbing fixtures, dispensers, and disposals; tired finishes that were difficult to maintain and clean; and, most significantly, travelers who vastly preferred to keep all their belongings within reach, making the building-code-minimum–sized toilet stalls even more cramped than before the tightening of security measures across the industry.

To ensure the guidebook's ease of use, the printed content was kept to 75 pages with color graphics and images. The remaining 244 pages of supporting appendices (research data, charts, forms, and more) are provided on a CD as well as PDFs on the ACRP website.

As MSP's Restroom Team (see sidebar, page 42) conducted its research, a guiding principle surfaced: "Airport restrooms are often the first and last impression travelers have of an airport." The restroom should be memorable—in a positive way.

Project Beginnings

ACRP Research Report 130 describes the process of initiating a restroom project through completion and beyond. The first chapter focuses on planning—the process the Restroom Team used to begin their program development. Several concurrent tasks were initiated to determine what the facilities had, which was a critical step before determining a direction for the program.

The design team surveyed each restroom using a series of matrices. These addressed the quantities and types of fixtures in each restroom set, finishes, ADA compliance, construction year, and more. As this mundane—but critical—effort progressed, the team weekly conducted equally important discussions about the drivers and goals for the restroom program.

This process went on for several months before the first design ideas were drawn. Internal and external stakeholders, such as MSP's voluntary Travelers with Disabilities Advisory Committee, aired their priorities, which often conflicted with the priorities of others. These misalignments were debated and worked through until consensus was reached. The design chapter of *ACRP Research Report 130* contains a form to help facilitate decision making on which priorities should top the airport's list.

Master Plan Required

Another piece of the puzzle was to develop a long-term master plan. Inadequate fixture counts cannot be remedied if there are no goals targeted, and it became evident early on that building code minimums are inadequate from a customer-service perspective. The planning chapter of *ACRP Research Report 130* offers equations to help determine fixture counts based on aircraft size, peak periods, level of service, and other variables. Also included is guidance for determining the fixture-count ratio for facilities for males and females by accounting for various factors and airport priorities; one of the appendices also suggests considerations for all-gender restrooms.

Recognizing that additional space was needed to provide not only the desired number of fixtures but also extra space within the restrooms—especially in the stalls, to accommodate luggage and maneuvering, and for travelers with differing mobilities—the MSP Restroom Team developed a prototype to test the viability of their new goals. Now, a decade later, the prototype continues to be tweaked in response to traveler and employee feedback, product innovations, new code requirements, and shared best practices from other airports.

Photo courtesy Metropolitan Airports Commission

A chapter of *ACRP Research Report 130* addresses determining priorities not just for visual spaces but also for plumbing, electrical, and ventilation systems.

Photo courtesy Metropolitan Airports Commission

The MSP restroom design overhaul included technology to increase cleanliness and decrease odors, offer space to address passenger needs, and provide lighting and outlets to energize travelers.

Photo courtesy Metropolitan Airports Commission

A high priority of MSP and *ACRP Research Report 130* was addressing compliance with Americans with Disabilities Act of 1990 guidelines.

ACRP Research Report 130 navigates the development of the prototype by breaking the restroom into spatial nodes such as the entry, sink area, and toilet stalls. The desired components are situated within these nodes, including plumbing fixtures, dispensers, and more. The nodes then are arranged in one or more layout modules that can adapt to various sizes and configurations (Figure 1, at left).

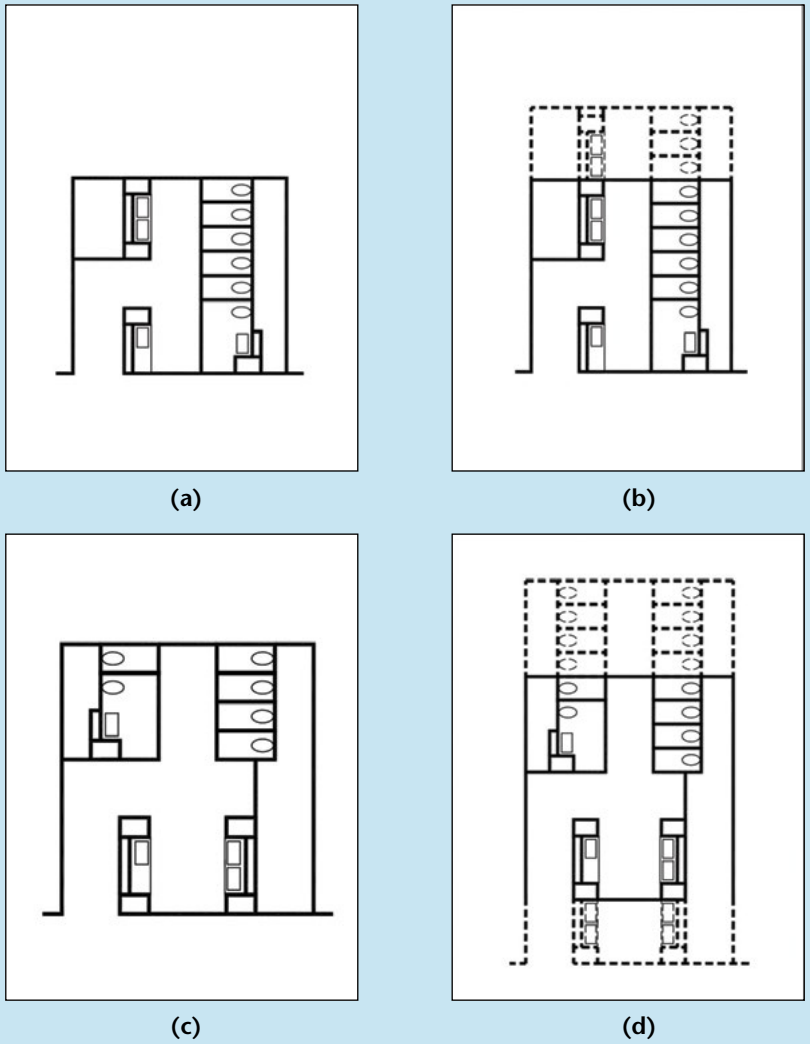


FIGURE 1 Room and galley prototypes are shown with the preferred minimum restroom size and gender mix of fixtures: (*a*) basic galley prototype, (*b*) expanded galley prototype, (*c*) basic room prototype, and (*d*) expanded room prototype.

A section on master planning provides guidance on the ideal placement of these prototypes within the airport based on traveler catchment zones; that is, specific gates or support areas served by each set of restrooms, such as ticketing, baggage claim, or mall areas. Often, it turned out that the ideal placement of a restroom set was not in its current location at MSP. With customer service a primary consideration, concessions were shuffled around and restrooms muscled in between gates to provide facilities where they were needed—rather than using them to fill in leftover space, as had been done previously.

Also highlighted in the guidebook are the positives and negatives of renovating existing restrooms versus creating new sets.

Prototype Design

The third chapter focuses on the design of the prototype. Addressing each component, such as signage, surfaces, and heating and air conditioning, *ACRP Research Report 130* offers guidance on maintenance, sustainability, and universal design. Also included is a discussion about standardizing layouts, products, and finishes.

Airports must balance competitive bidding against generic bulk stock from the likes of multiple faucet or carpet manufacturers. At MSP, the Restroom Team determined that the cost percentage of the non-infrastructure-related components (finishes, fixtures, and the like) was small enough that most of the project's

Photo courtesy Metropolitan Airports Commission

Photo courtesy Metropolitan Airports Commission

(At left:) Surfaces, finishes, and fixtures should be selected with consideration of their durability, ease of cleaning, and timeless appeal. (At right:) Each restroom at MSP has technology to facilitate efficient and frequent cleanings.

scope could maintain an open specification and still remain competitive on the remaining project products via supplier competition.

FIXTURES AND SURFACES

Surfaces within restrooms require careful consideration, since they require significant cleaning and repair and tend to be subjective in terms of their aesthetic appeal and the whims of taste. MSP collectively chose a timeless color palette, using materials with no or minimal joints to clean or repair and that are resistant to wear and abuse. Lighting is calming and task-oriented, designed to energize travelers fresh off long flights. Air movement is facilitated strategically to dry wet floors at the sinks and to exhaust odors above the stalls. Convenience outlets at the sinks are provided for shaving and hair drying.

To aid in the selection of finishes, plumbing fixtures, paper towel dispensers, and other elements, an appendix to *ACRP Research Report 130* features a matrix listing product types (e.g., toilet partition materials) with comparison keys for the range of durability and cost.

MSP continually fine-tunes its restroom designs as feedback is collected from travelers and employees, maintenance and cleaning crews, and other members of the Restroom Team.

EMBRACING TECHNOLOGY

Technology is playing an increasing role in the operation and maintenance of airport restrooms. A high level of customer service is demanded. Manufacturers offer sensors to notify janitorial staff if dispensers are out of paper or if a trash receptacle is full. Indicator lights show which stalls are unoccupied. Music often is provided to temper the din in the hard-surfaced spaces as well as to provide an element of calm in the traveler's often hectic and tiring journey. Speakers provide general terminal paging, which is required by ADA to be augmented by visual paging for hearing-impaired travelers. To further dampen the live surfaces within the restroom, a perforated metal ceiling with acoustic bags above absorbs 90% of the sound. Since the entrance areas to the restroom are open, often adjacent to hold rooms, minimizing the sound of hand dryers and flushing toilets is essential.

MSP has embraced technology, primarily through a custom restroom-management system that utilizes a direct interface with the airport's overall facility-management system. A screen is incorporated into the lighted room sign at the entry to each restroom. With the swipe of a cleaner's badge, this screen indicates the distance in each direction to the next-nearest restroom for customers approaching the bathroom. The badge swipe also doubles the exhaust level to extract cleaning-chemical smells and speed up the drying of wet surfaces. A thermal sensor in the entry ceiling tracks the number of people entering and leaving the restroom to help gauge cleaning needs.

RELATED AMENITIES

The design chapter also addresses a variety of restroom-related amenities: baby changing, grooming, and incorporating

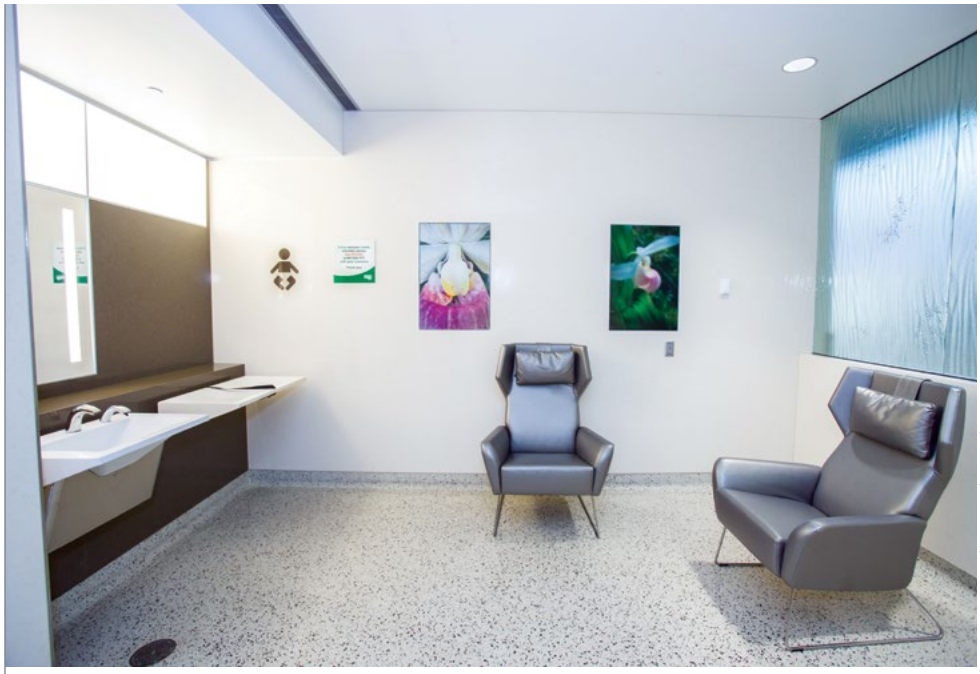


Photo courtesy Metropolitan Airports Commission

MSP has incorporated lactation rooms for nursing mothers. These and other amenities will be addressed in a follow-up project to *ACRP Research Report 130*.

art within and outside the restroom.

The same research team that developed *ACRP Research Report 130* is working on a follow-up report, expected to be completed later in 2019. This report will provide similar guidance for other special amenities: lactation rooms, service animal relief areas, changing table restrooms, sensory rooms, and several other spaces. This guidebook will build upon the content of the restroom book. Some amenity prototypes developed by MSP's Restroom Team will be the basis for the added content.

The design chapter concludes with a discussion on cost-estimating strategies during the planning and design phases, with the recommendation to follow the typical industry practice of conducting estimations at the completion of the schematic design and design development phases, along with a final 90% cost check.

Implementation

The fourth and final chapter of *ACRP Research Report 130* focuses on implementation of the restroom design process. Since most restroom projects in airports take place within existing facilities, phasing is an important consideration. Not only is construction disruptive in terms of noise, dust, and odors—all of which need to be carefully planned for and managed—but during renovations, one or more restroom sets are out of service for a period of months.

Prefabricated restrooms offer a potential solution to expedite the construction process. This technique is used in healthcare facilities, in which an entire headwall assembly can be brought in and installed in a few hours. Prefabricated restrooms are most practical in new construction, and bringing in wet-wall assemblies for toilets and sinks, for example, could go a long way to shorten the disruption.

The final—and very important—aspect of the process is post-occupancy evaluation. As noted in the beginning of the article, MSP continually fine-tunes its restroom designs as feedback is collected from travelers and employees, maintenance and cleaning crews, and other members of the Restroom Team, such as the Travelers with Disabilities Advisory Committee. In existing facilities, restroom sets frequently are renovated one or two at a time, so the post-occupancy evaluation is an opportunity to correct inefficient layout issues, change products that are not performing as expected, and make other modifications.

In the first few iterations of the MSP prototype, the Restroom Team periodically reviewed all these aspects and made some significant changes:

- The custom stall door hardware was replaced with a more durable, easy-to-replace, off-the-shelf hardware.
- The location of the accessible stall in the prototype plan was relocated within the restroom block, netting an additional standard stall.
- A darker wall base was integrated into the monolithic quartz wall panels to hide the mop line from cleaning.

Each set of restrooms at MSP is a bit better than the last—although stained terrazzo flooring under the urinals remains an ongoing battle for MSP and for most of the other airports surveyed.

Related ACRP Titles

ACRP Research Report 109: Improving Terminal Design to Increase Revenue Generation Related to Customer Satisfaction, www.trb.org/Publications/Blurbs/170867.aspx

ACRP Research Report 175: Improving Intelligibility of Airport Terminal Public Address Systems, www.trb.org/Main/Blurbs/176329.aspx

ACRP Impacts on Practice: Improving Customer Experience at Airport Restroom Facilities, www.trb.org/Main/Blurbs/175363.aspx

ACRP Web Resource 2: Airport Passenger Terminal Design Library, www.trb.org/Main/Blurbs/176507.aspx

During construction of the first two prototypes at MSP, the construction management firm's foreman remarked, "These restrooms are like a Swiss watch!" Indeed they are. Many elements are thoughtfully packed into the new restrooms. Travelers feel they should be pampered a little for the cost of their travels, often are lugging extra bags, and are running on too little time and feeling anxious or tired.

The input of the MSP Restroom Team comfortably and intuitively accommodated all the issues, desires, and requirements related to airport restrooms—as well as helped to make a traveler's brief stop at the airport a memorable one. These small moments are vital to an airport—especially in cities or regions that have other, competing transportation options. First and last impressions do count.

Minneapolis–Saint Paul Airport Restroom Team

Vital to the success of any restroom project, whether constructing several sets in a new concourse or in a minor renovation, is the formation of a Restroom Team. Every manager at an airport with a stake in the planning, implementation, and maintenance of the restrooms should be included. This involves representatives, as relevant, from the following groups:

- **Facilities–planning;**
- **Customer service;**
- **Carpentry trades;**
- **Heating, ventilation, and air conditioning trades;**
- **Plumbing trades;**
- **Electrical trades;**
- **Information systems;**
- **Cleaners;**
- **Airport police; and**
- **Special-interest committee liaisons from such groups as Travelers with Disabilities, Arts Foundation, and others.**

Consulting experts should include the following:

- **Aviation planner,**
- **Architect,**
- **Interior designer,**
- **Wayfinding designer,**
- **Customer experience consultant,**
- **Mechanical engineer,**
- **Electric engineer,**
- **Technology systems designer, and**
- **Construction manager.**

A core group of these representatives should meet regularly from the project's outset to at least its conclusion. Ideally, meetings would continue after completion, as restrooms require ongoing attention regarding maintenance issues, product performance evaluation, usage monitoring, and customer complaints. In larger airports, by the time the last restroom is updated, it likely is time to start all over again on the first. Ongoing assessment also streamlines the next startup process significantly.

MSP's research team addressed less-obvious traveler needs, such as pet relief areas for service animals and traveling pets. Representatives from a variety of special-interest groups can broaden the services an airport provides.

Airport leadership support of the Restroom Team is essential. Participants should be encouraged to expand their expertise by attending conferences, visiting other airports, and monitoring product and system innovations. Restroom Team members need to be resilient and as open to compromise as they are tenacious about their needs and goals. A good sense of humor to weather the bumps and grinds—and the inevitable bathroom jokes—doesn't hurt either.

—Jens Vange
Senior Associate Architect, Alliance, Minneapolis

Photo: Kanaka Rastamon, Flickr

Understanding Demographics, Preferences, and Locations Influencing the Future of Public Transportation

MULTIDISCIPLINARY STUDY OF FACTORS THAT AFFECT THE MARKETS FOR TRANSIT

MATTHEW A. COOGAN

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Above: The Transit Cooperative Research Program explored why different demographic groups respond differently to transportation options.

Although the tools for understanding travel demand, which focus on relative travel times and relative travel costs, provide a sound basis for supporting near-term policy issues, they prove inadequate to support longer-term examination—such as the future of public transportation over the next decade.

When society wants to explore such large and complex issues, simply analyzing the implications of travel times and costs is not enough, because transportation behavior is strongly influenced by a set of underlying factors that cannot be expressed in these terms alone.

Simply put, different demographic groups respond differently to common sets of transportation options. For example, a recent study for the National Cooperative Rail Research Program concluded that, when faced with exactly the same set of services, younger millennial women were three times as likely to choose an intercity curbside bus than were older, postmillennial men (*1*). Again, the times and costs of the competing services were the same for everyone, and it was an individual's demographic category—more than the traditional factors of times and costs—that best explained mode choice (Figure 1, page 44).

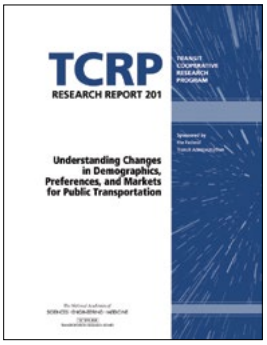
Although variation in demographic category is important in predicting travel behavior, variations in preferences, values, and attitudes also are significant. Some people in society value moving their residence to a more urban setting; some do not value such urban characteristics and defend the suburban settings they have worked hard to attain. As a second-order impact, those with urban preferences are more likely to settle in dense, transit-rich neighborhoods, and populations in such locations will use transit at higher rates.

Challenge of Interdisciplinary Research

When directed to analyze key aspects of the future of public transportation in American

Photo: NACTO

Young millennial women are three times as likely to choose curbside transit as postmillennial men.



addition to relative times and relative costs of the supply side of the equation.

How to incorporate key underlying factors posed a challenge from the very beginning of the study. Researchers in the field of social psychology have accepted methods to relate attitudes and values to choices in behavior, more and more applying Icek Ajzen's theory of planned behavior to transportation (*2*). In parallel, research literature is rich with studies of how characteristics of land use are related to transportation behavior and mode choice. Finally, advanced tools of market segmentation increasingly are used in market research to cluster groupings of travelers by commonality of attitude rather than by traditional demographic categories (*3*). The challenge, then, is how to undertake a truly multidisciplinary research project; that is, using separate tools that may or may not come together in their conclusions.

For the authors of *TCRP Research Report 201*, the answer was to apply a wide variety of the appropriate research techniques; indeed, to develop a new set of methods that attempt to integrate several factors into one mathematical structure.

society, research team managers assembled to produce *TCRP Research Report 201: Understanding Changes in Demographics, Preferences, and Markets for Public Transportation*. The researchers realized that one comprehensive research plan would have to cover values, attitudes, preferences, and location—by demographic category—in

NEW MODELS AND METHODS

The project created a somewhat unusual mix of research methods. For interpretations of how attitudes and values interact to influence travel behavior, a structural equations model was created, incorporating some of the concepts utilized in the theory of planned behavior. Advanced procedures in market research were applied to create several attitude-based market segments, and new multinomial logit travel demand models were created to facilitate a better understanding of classic supply-side factors.

To deal with the effect of location on transit, sample populations from two surveys—one from 2014 with 11,000 respondents and one from 2016 with 3,500 respondents[1]—were assigned to five neighborhood types in terms of the transit orientation of the neighborhood. Formulas developed using the U.S. Environmental Protection Agency's Smart Location Database program allowed the researchers to categorize geographic zones for all 14,500 respondents of the two surveys into the five levels of transit orientation, defined by the ratio of their transit accessibility to jobs divided by highway accessibility to the same jobs.

To better understand how key underlying factors are related to preferences, attitudes, and values, an ambitious analytic framework was created. Using the 3,500-person sample designed for this purpose, researchers examined behaviors, attitudes, and values three times: once in terms of five age categories, once in terms of five neighborhood types, and once in terms of four attitude-based market segments. This format produced a multidisciplinary view both of attitudes and behaviors. For any given proposition, the reader can observe the extent of variation associated with age, location, and market preferences.

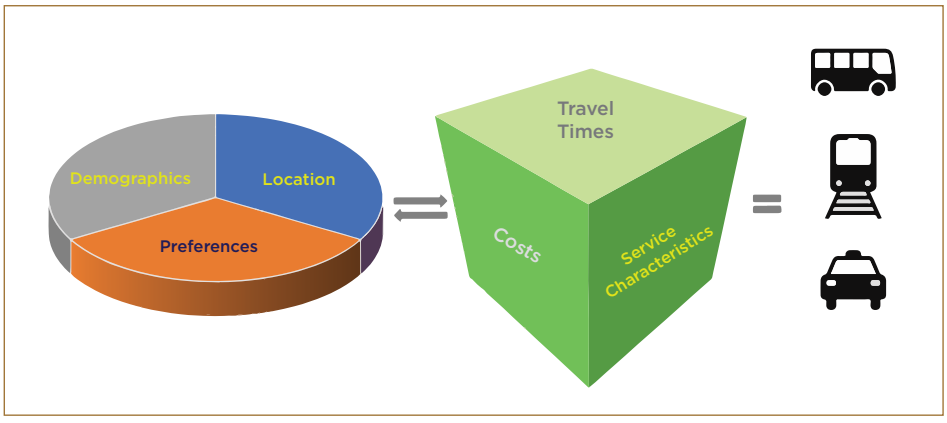


FIGURE 1 Although all the factors noted here affect public transportation ridership levels, the TCRP study focused on the underlying factors illustrated in the pie chart (*left*).

[1] The survey of 11,000 respondents in 2014 was conducted by RSG, Inc., in support of *Who's On Board,* a 2016 TransitCenter, Inc., report.

INTEGRATED CHOICE LATENT VARIABLE

The most ambitious new method created was a single mathematical model that incorporated attitudes and preferences, demographic categories, and locational characteristics to augment travel times and costs. The model, known as an integrated choice latent variable model, combines established procedures used in social psychology with established procedures in travel demand forecasting to facilitate the simultaneous, integrated examination of hard and soft variables when explaining travel behavior.

Results

As part of its research objective to look at future transportation markets, *TCRP Research Report 201* focused strongly on the role of age. A key question concerns how a given cohort group will behave when they are, for example, 10 years older than today, and this leads to an examination of the impact of age on transportation behavior.

To establish the setting, researchers examined the role of age in generating vehicle miles traveled (VMT), a measure of the use of private automobiles (*4*). In Figure 2 (below), which shows the role of age in VMT per driver, the overall amount of car use can be divided into three phases (see arrows). The phase between ages 16 and 30 is characterized by increasing auto use during a period of high level of lifestyle volatility; that is, people tend to change locations, and to form and disband household living arrangements, more frequently in their 20s than later in life (*5*). The number of cars owned increases. Around age 30, people tend to reach their maximum auto use and VMT plateaus. A strong pattern revealed in Figure 2 is the lack of change in transportation patterns between the ages of 30 and 50. Around age 50, some of the travel to far-flung suburban soccer games is transferred to the younger generation, who begin to drive themselves. Later still, retirement patterns reduce VMT in the oldest age categories.

AGE AND TRANSIT USE

According to national aggregate statistics, the life phase between the ages of 16 and 30 includes the prime years for transit use. As shown in Figure 2, the competitive role of the automobile is not firmly established in this time period; by contrast, the intense reliance on cars takes over around age 30. In fact, the TCRP study found that a traveler's age is the one of the most powerful determinants of transit ridership—in general, the older people get, the less they use transit. This pattern can be seen in Figure 3 (page 46), in which the relationship between age and number of transit trips per capita has been averaged using the four most recent National Household Travel Surveys.

Photo: State Farm

The use of automobiles sharply increases—and the use of transit decreases—in the decade between the ages of 20 and 30.

To some extent, the number of transit trips by age group reflects an inverse relationship with the use of its principal competitor, the automobile. The prime auto usage at around 30 years of age generally reflects the same life changes as the decline in transit trips shown in Figure 3. For various reasons, the decade between the approximate ages of 30 and 40 shows a sharp drop in the use of transit per capita.

Researchers found that the distance to the nearest bus stop increases consistently by age group, and the distance to the nearest commercial or village center increases similarly. Additionally, the study's analysis has demonstrated that age is a dominant explanatory factor—not only by acting through the intermediate variable of location. For example, the study's analysis revealed that, for any given level of neighborhood transit accessibility, the younger traveler will choose transit more often than the older traveler.

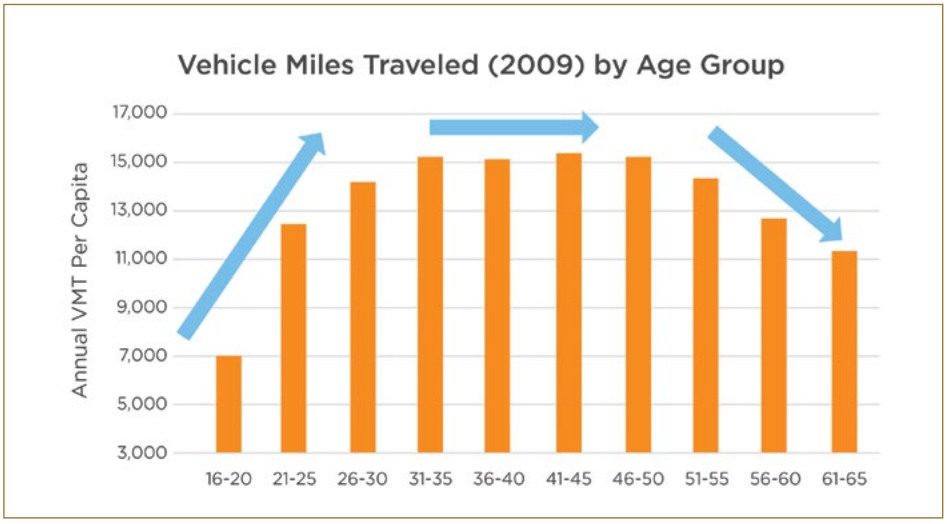


FIGURE 2 The number of VMT per driver can be seen in three phases, denoted by the blue arrows. (Source: National Household Travel Survey of 2009.)

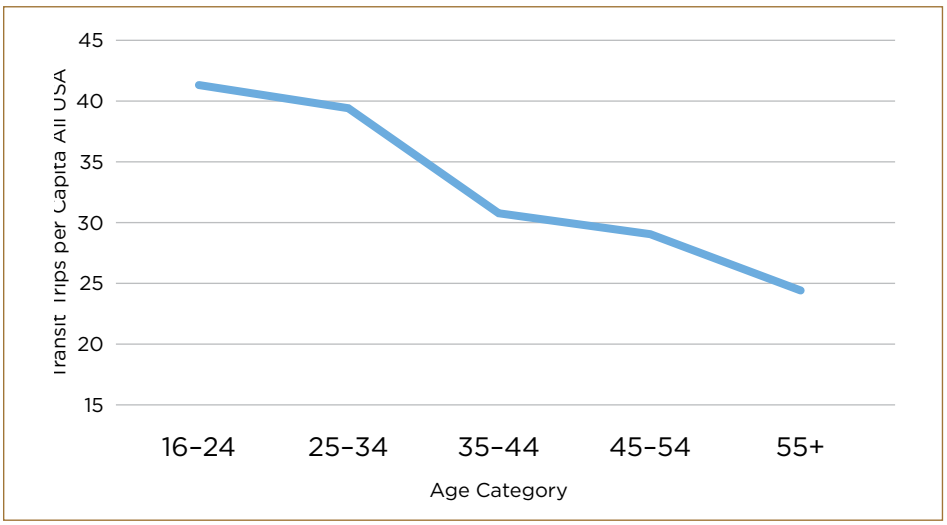


FIGURE 3 Effect of age on number of transit trips per capita. (Source: Nancy McGuckin, Analysis of National Household Travel Surveys of 2017, 2009, 2001, and 1995.)

MILLENNIAL GENERATION

The study concluded that the next decade could see some difficult times for the public transportation market. Using the multidisciplinary techniques noted above, the study merged information about attitudes with information about demographics and location. The results raise some issues of concern.

Recently, the Pew Research Center defined the millennial generation as those between 22 and 37 years of age in 2018 (*6*). If the millennial generation is divided into three cohort groups of 5 years each, the oldest of these groups now is between 32 and 37, and solidly within the age category with the greatest decline in transit, shown in Figure 3. People between the ages of 26 and 31 will move into this older age category in the coming years; importantly, this 5-year cohort currently is the single largest cohort category in U.S. population. The cohort of Americans ages 26–31 is larger than any 5-year segment of the Baby Boomer generation, which previously boasted the largest cohorts in the U.S. population.

The youngest 5-year age cohort—ages 22–26—is somewhat smaller than the middle group, and the following 5-year cohort group is smaller still. This means that the size of the key 20–30 age category for pro-transit behavior is shrinking demonstrably over time when viewed through the lens of national demographic data. At the same time, the largest cohort soon will be passing through the lower-transit-use age category of between 30 and 40.

What Will Happen Next?

The research conducted for *TCRP Research Report 201* included extensive consideration of the values, preferences, and attitudes for each relevant age category; this allows additional understanding of what may happen to millennials' transit use as they proceed through the life cycle. An analysis of attitudes shows that this group has positive views of urbanism and are more open-minded about automobile alternatives. As they age, however, millennials may find that loyalty to transit becomes more difficult.

The expected shift away from transit has been flagged not only in terms of demographics, but is reported by millennial survey participants themselves in the TCRP study. Although the study has found that millennials proceed through the stages of the life cycle more slowly than previous generations (getting married and buying homes later), millennial survey respondents reported that they fully expect to move to less-dense locations as their families mature.

Millennials also expect to take transit less often and drive more often in future

Photo: Shawna L. Keyes, U.S. Air Force

More than half of survey participants ages 25–34 responded that they wanted to settle in a house and neighborhood that reminded them of their parents' home.

Photo: Ian Fisher, Flickr

Long-term values—for example, living in a diverse community—influence a preference for urban living and can lead to higher transit use.

years, according to the survey. In addition, in no age group did a majority of respondents report that they wanted to replace auto ownership with various short-term strategies to share, borrow, or rent cars. Of all age groups, it was the 25–34 age group who agreed most strongly that they "love the feeling of freedom and independence that owning several cars provides for my household." Approximately 56% of that key age group also agreed with the following statement: "As I get older, I think I will eventually want to settle in the kind of house and neighborhood that my parents had."

How Does It All Fit Together?

Keeping in mind the goal of integrating preferences and demographics to understand markets better, the research team created an analytical framework separating preferences into two categories: 1) longer-term values that influence location selection and 2) nearer-term attitudes about travel services and options. Preferences about desired residential location influence travel, both directly and through the mediating influence of the choice of residence. Similarly, the details of the environment at any location affect travel directly as well as via the mediating influence of near-term attitudes. Finally, near-term attitudes reflect perceptions of available options, highly influenced by comparative times and costs. As noted by the arrows stemming from the top of the diagram in Figure 4 (below), demographic categories must be taken into consideration at all phases of the process.

Results from the project's structural equation modeling (included in *TCRP Research Report 201* and documented in its technical appendices) show the cumulative importance of many factors. For example, a latent factor is created to reflect value placed on urbanism, derived from responses to such statements as the following: "I would value living in a community with a mix of people with different backgrounds." The model shows the impact of this underlying value on the selection of neighborhood type (e.g., density of intersections per square mile) and reveals the impact of the neighborhood type latent factor on amount of transit taken. The model allows the reader to see the cumulative effects of the longer-term preferences for the urban setting and the indirect influence through subsequent mediating factors. For example, the model shows that a 10% increase in the latent factor "Values Urban" is associated with a 3.5% increase in transit ridership—a strong impact.[2]

> The TCRP study found that a traveler's age is the one of the most powerful determinants of transit ridership.

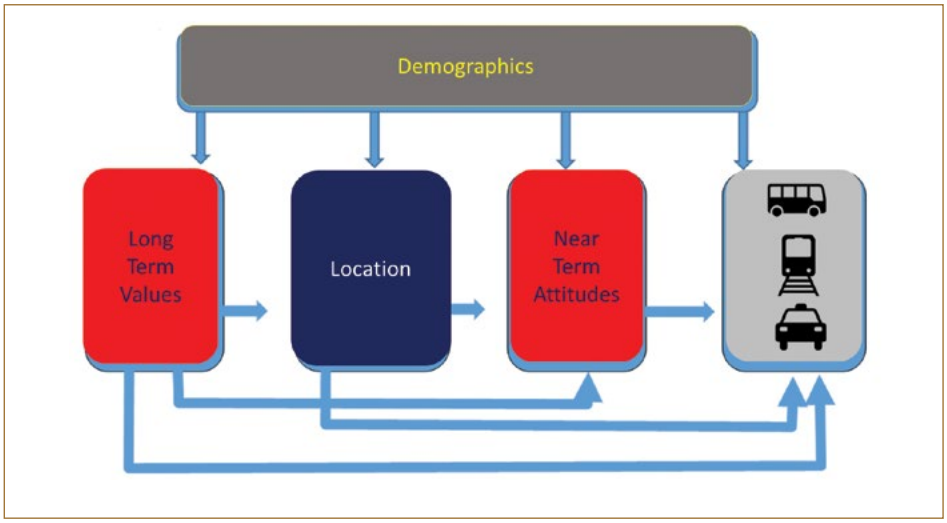


FIGURE 4 The relationship between demographics, long-term values, location, near-term attitudes, and travel behavior.

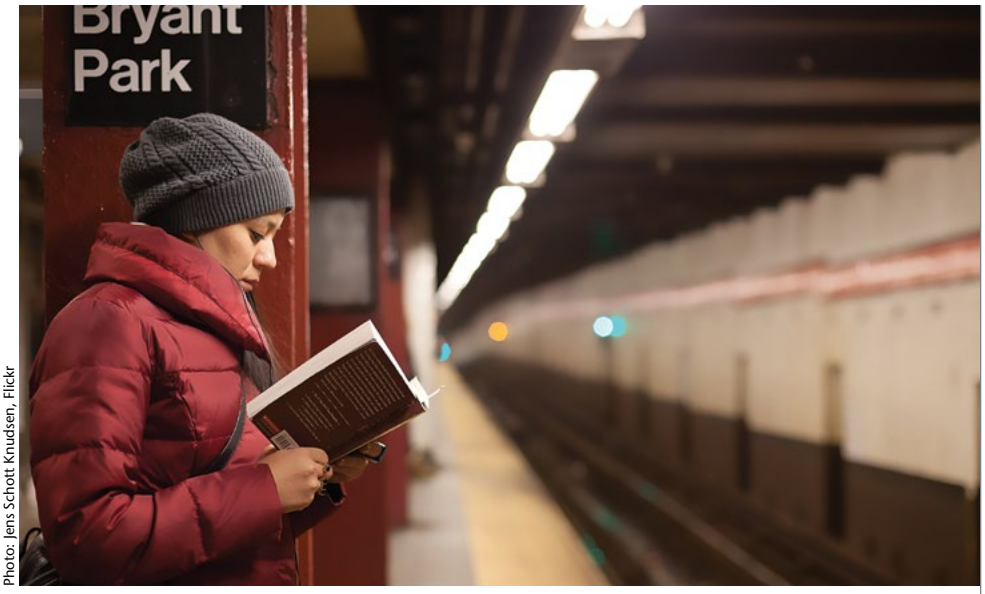


Photo: Jens Schott Knudsen, Flickr

Travelers under the age of 30 and with higher levels of education are more likely to choose transit.

TCRP Research Report 201 also reports the results of the integrated choice latent factor model developed in the project. This innovative effort to incorporate both preferences and service characteristics into one forecasting model showed that, in the hypothetical case in which all age categories adopted the attitudes of those under 30, transit ridership would increase by 5%.

A similar scenario, in which all groups adopted the attitudes of those with the highest levels of education, showed an 8% increase in transit ridership. A combined scenario, in which all participants had the attitudes of both the highest-education and under-30 groups, produced a combined ridership increase of 13%.

The same model then was used in a parametric exercise to explore possible futures assuming improved levels of transit times and costs and worsening times and costs of competing modes. In this exercise, transit ridership increased by 35%.[3] This experience in scenario testing allowed *TCRP Research Report 201* to conclude that the future of transit will be influenced far more by the competitive quality of its services than by cultural changes about attitudes and values. Hypothetical futures with more supportive attitudes toward transit pushed the needle up by 13% and hypothetical futures with more competitive transit travel times and costs are associated with growth of more than 30%.

The future of transit will be influenced far more by the competitive quality of its services than by cultural changes about attitudes and values.

The transit industry must face the challenge, however, of fewer people in the key 20–30 age categories. If this loyal—and large—population cohort reduces its present transit use as they reach the ages of 30–40, a new generation of transit services may be required that attempt to retain key positive market segments even as they migrate out of transit-rich locations into lower-density geographic settings. *TCRP Research Report 201* concludes that, in the meantime, further research is needed to better understand the Generation Z cohort—now firmly in its prime transit-consuming years.

[2] This measure, called "standardized total effect," is documented in detail in the technical appendix to *TCRP Research Report 201*.

[3] In the same set of model runs, a scenario with worsened transit services and improved competing mode services showed transit use to fall by 32%.

Acknowledgments

The study described in this article was the work of large research team, which included Tom Adler, Greg Spitz, Stephane Hess, and Mark Bradley, on travel behavior; Nancy McGuckin on demographics; Rich Kuzmyak on land use; and Karla Karash on transit services. Coogan served as principal investigator. The research team is indebted to the TCRP project panel and TCRP Senior Program Officer Dianne Schwager.

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Development of National Specifications for Accelerated Bridge Construction

Photo: Petty Officer 1st Class Steven Smith

MICHAEL P. CULMO

The author is Chief Technology Officer, CME Associates, Inc., East Hartford, Connecticut.

Above: A self-propelled modular transporter (SPMT) moves a tied-arch bridge into place. The accelerated bridge construction (ABC) process allows traffic to be diverted for hours rather than months. With new processes and technology come a need for new design and construction specifications.

Accelerated bridge construction (ABC) technologies have been in development for more than 15 years. These technologies have fundamentally changed the way bridges are built, with construction times reduced from years to weeks—even days. The benefits of ABC are far-reaching and have led to significant increases in road user satisfaction, as demonstrated in user survey polls. This has raised an inevitable question from travelers: "Why can't we build every bridge using ABC?"

The widespread use of ABC technology has been hampered by the lack of an ABC-specific national design and construction specification, one similar to the American Association of State Highway and Transportation Officials' (AASHTO's) *Load and Resistance Factor Design* (LRFD) *Bridge Design Specifications*. Without a national specification, owners must use their own engineering judgment and must refer to various research results to design and build bridges using ABC. This has discouraged many agencies from adopting these practices.

The TRB General Structures Committee coordinated with the AASHTO Bridge Technical Committee on Construction, or the AASHTO T-4 Committee, to formulate a research needs statement (RNS) for the development of a national ABC design and construction specification.[1] The committees also developed RNSs for two particular ABC-related issues that needed further research.

This effort led to two National Cooperative Highway Research Program (NCHRP) research projects: NCHRP Project 12-102, which developed a national ABC design and construction specification, and NCHRP Project 12-98, which studied tolerances in prefabricat-

[1] The TRB Research Needs database can be found at http://rns.trb.org.

ed elements and the dynamic effects of moving entire bridges from prefabrication staging areas to the actual bridge sites (a common ABC technology). Both projects were awarded to CME Associates, Inc., of East Hartford, Connecticut, a firm that has been at the forefront of ABC research and practice since the early 2000s. Having one research team leading both projects was beneficial since the two subjects were so closely integrated.

NCHRP 12-98 Research

NCHRP 12-98 was, essentially, two unrelated research topics combined into one. The first topic addressed a need for a national specification for tolerances of prefabricated elements. Proper management of tolerances plays a major role in the success of a prefabricated bridge project; many of the problems in recent projects can be attributed to a lack of tolerance control. The second topic addressed owner agency concerns with the dynamic effects of moving entire bridges using self-propelled modular transporters (SPMTs) or lateral slide technologies. The goal of NCHRP 12-98 was to develop national guidelines for these two subjects that could be referenced in design and construction specifications.

SYNTHESIS PROCESS

Initially, a literature search and synthesis were conducted. The research for the dynamics of bridge moves was limited to a few investigations by owner agencies and several guidelines published by owner agencies and the Federal Highway Administration. These documents had dynamic recommendations that were based on rules of thumb, not on actual research. The research team also contacted international heavy move companies and found the same results. The only significant literature on tolerances was two guidelines published by the Precast/Prestressed Concrete Institute (PCI) and the American Concrete Institute (ACI).

These publications on precast element tolerances were a helpful start in the development of a national guideline. The project team met with the PCI Tolerance Committee, which oversees the publication of the PCI document, and discussed the basis for the specified tolerances. It was found that the various PCI committees had set recommended tolerances based on a history of plant fabrication and what was reasonable to be achieved on a regular basis—not on hard data analysis.

TOLERANCE RESEARCH FOR PREFABRICATED ELEMENTS

The research team developed a basic statistical data analysis process in which results from actual plant fabrication could be used to develop a reasonable tolerance limit for various dimensional aspects of the elements. The team tried to obtain significant data for analysis; however, little information was available in plant records as these typically only indicate tolerance quality as a pass–fail score. Large volumes of actual dimensional variation data were not available. In the end, however, the tolerances used by PCI were found to represent a reasonable starting point for a national guideline.

In the future, if data become available, the statistical methods developed in the NCHRP project research can be used to verify the suggested tolerances. Recommended tolerances were developed for all commonly used bridge elements (see Figure 1, page 51).

In element tolerances, specifications for joint width tolerances are a major knowledge gap. The width of joints between individual prefabricated elements can be affected by erection tolerance and up to six different element tolerances. A conservative approach that assumes

Photo: Massachusetts DOT

Photo: FHWA

Left: A new bridge superstructure is lifted into place by an SPMT in a Massachusetts DOT ABC project to replace River Street Bridge in Boston. Right: Traditionally, reasonable tolerance limits of bridge elements have been based on a history of plant fabrication. An NCHRP project developed statistical methods to recommend tolerances.

all maximum tolerances occur at any one joint would lead to very wide joints. The research team used Monte Carlo simulations to determine recommended joint widths based on the probability of occurrence of each tolerance. This resulted in reasonably wide joints that would accommodate all tolerances with a 95% probability.

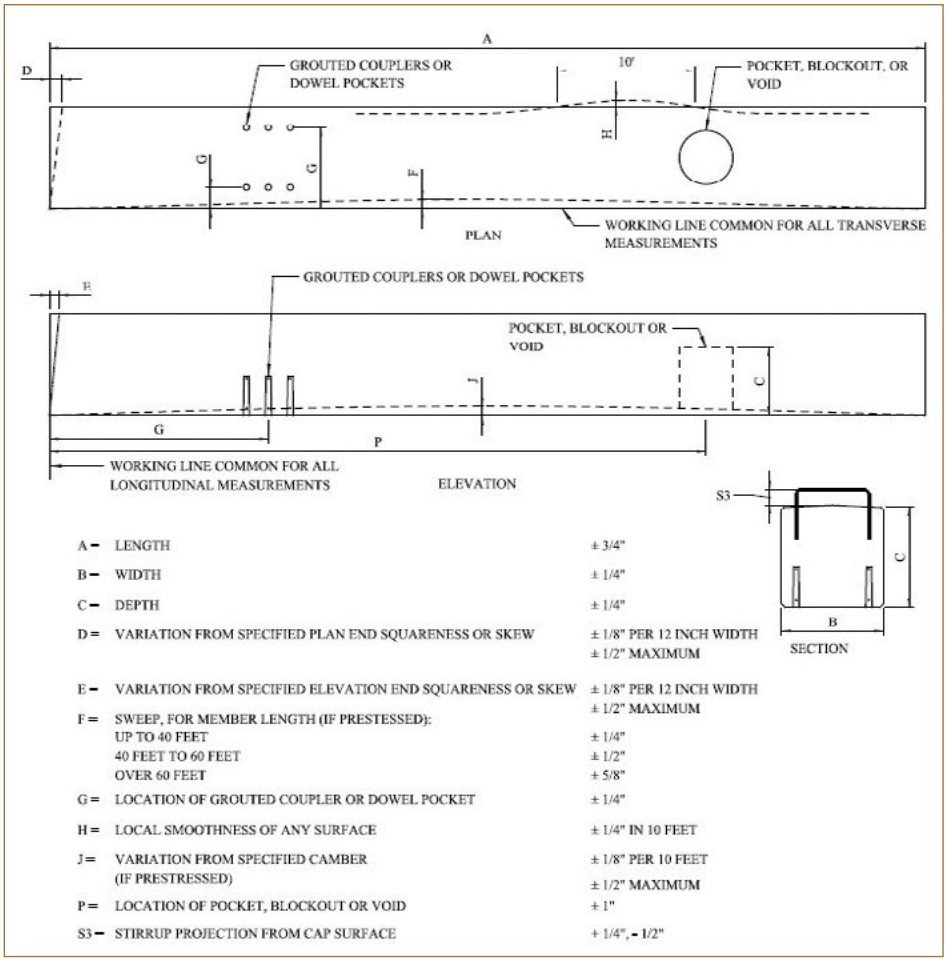
DYNAMIC RESEARCH FOR BRIDGE MOVES

The dynamics of bridge moves are important to bridge owners. Concerns include the forces imparted on the bridge during a move, which can lead to damage, as well as the forces acting on the falsework supporting the bridge. The research team hypothesized that a bridge move is akin to a man-made earthquake—the SPMT generates horizontal and vertical accelerations that are similar to ground motions during seismic events, and the falsework and bridge are similar to structures exposed to seismic ground motions. A structure's stiffness would affect the level of forces borne during the move.

The research team studied this theory by measuring base accelerations on a loaded SPMT unit. Several loads were applied to the SPMT to identify any variations in accelerations with different loads. The SPMT then was moved using a preset series of typical maneuvers used during bridge moves and was operated at the highest possible speed to establish an upper bound on the dynamic effects. The photo on page 52 shows a typical test setup.

The results of the testing were used to develop response spectra for both horizontal and vertical motions as well as load combinations and factors. The team also developed an analysis method for bridge dynamics that is similar to seismic design of bridges.

Additional research was conducted as part of NCHRP 12-98 to study the friction of bridge sliding systems. The results of this research led to recommended design values for lateral slide bridge installations.



A =	LENGTH	± 3/4"
B =	WIDTH	± 1/4"
C =	DEPTH	± 1/4"
D =	VARIATION FROM SPECIFIED PLAN END SQUARENESS OR SKEW	± 1/8" PER 12 INCH WIDTH ± 1/2" MAXIMUM
E =	VARIATION FROM SPECIFIED ELEVATION END SQUARENESS OR SKEW	± 1/8" PER 12 INCH WIDTH ± 1/2" MAXIMUM
F =	SWEEP, FOR MEMBER LENGTH (IF PRESTESSED): UP TO 40 FEET 40 FEET TO 60 FEET OVER 60 FEET	 ± 1/4" ± 1/2" ± 5/8"
G =	LOCATION OF GROUTED COUPLER OR DOWEL POCKET	± 1/4"
H =	LOCAL SMOOTHNESS OF ANY SURFACE	± 1/4" IN 10 FEET
J =	VARIATION FROM SPECIFIED CAMBER (IF PRESTRESSED)	± 1/8" PER 10 FEET ± 1/2" MAXIMUM
P =	LOCATION OF POCKET, BLOCKOUT OR VOID	± 1"
S3 =	STIRRUP PROJECTION FROM CAP SURFACE	+ 1/4", - 1/2"

FIGURE 1 Example of a tolerance specification for a precast concrete pier cap.

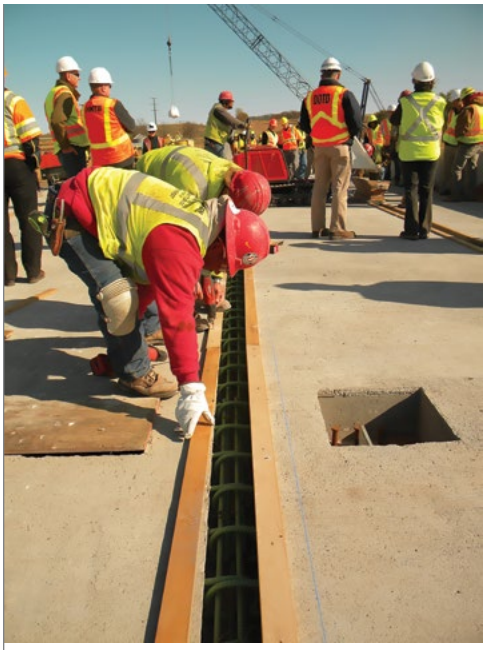


Photo: FHWA

Workers prepare to fill the deck joint between two precast modular deck units. An NCHRP project addresses specifications for joint width tolerances, a need particular to prefabricated elements.

GUIDELINES

Using the research data, the team developed two specification-style documents that can be used by designers of ABC projects, published as *NCHRP Web-Only Document 243: Recommended Guidelines for Prefabricated Bridge Elements and Systems Tolerances and Recommended Guidelines for Dynamic Effects for Bridge Systems.*

The guidelines are written in AASHTO specification format with guidelines and commentary. With these documents, designers and contractors now can design and detail prefabricated elements with reasonable tolerances and design bridges and falsework for bridge systems.

Photo courtesy Michael Culmo

Typical SPMT testing setup.

NCHRP 12-102 Research

The goal of NCHRP 12-102 was to develop a national guide specification for all forms of ABC. A significant body of past research was available, but there was no single source of design and construction guidance. No new research or testing would be completed as part of this work, although the team was charged with identifying knowledge gaps in the research that could lead to future studies. The team also queried bridge owners to determine which ABC technologies are in use.

An extensive literature search identified the state of knowledge regarding ABC. As anticipated, ABC is the subject of a substantial body of work. The research team collaborated with the NCHRP project panel to develop a technology readiness evaluation process. Each major ABC technology was evaluated using the following weighted scoring process:

- Level of testing and completeness of research: 25%
- Presence of recommended specifications: 15%
- Level of implementation of the technology on actual projects: 30%
- Long-term durability of the technology: 30%

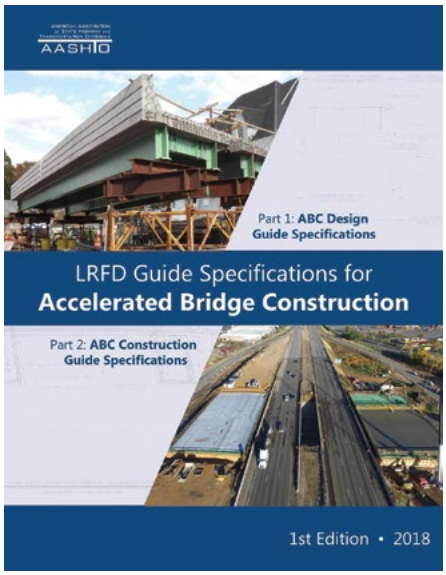
The weights for each criterion were recommended by the research team and coordinated with several state bridge engineers participating on the project panel. The goal of this approach was to gain widespread acceptance of the proposed guide by owner agencies. Each ABC technology was scored, and a threshold value was set for inclusion in the guide. Technologies that met the threshold would be included in the guide, and others would be included in the project report.

The culmination of the project was the development of a complete ABC design and construction guide specification, titled AASHTO *LRFD Guide Specifications for Accelerated Bridge Construction*. All forms of ABC are covered in the specification, as well as both seismic and non-seismic provisions, making it a go-to document for ABC projects.

The NCHRP 12-102 project team carefully developed the guide to be consistent with AASHTO design and construction specifications, including notation, definitions, and references. Each provision has specification language on the left side of the page, and commentary on the right

Photo: Vermont Agency of Transportation

A lateral bridge slide on I-91 in Hartford, Vermont. The study of friction in bridge sliding systems led to recommended design values for lateral slide bridge installations.



For details on the AASHTO *LRFD Guide Specifications for Accelerated Bridge Construction*, visit https://store.transportation.org/Item/PublicationDetail?ID=4134.

side. The document was carefully written to dovetail with the work completed under NCHRP 12-98, and the guidelines developed under that project are referenced where appropriate.

Moving Research into Practice

The deliverables for the two NCHRP projects included two guidelines and one guide specification. Guidelines are informational documents that provide guidance to designers. Specifications differ from guidelines, however. In AASHTO publications, specifications—for example, the *LRFD Bridge Design Specifications*—are considered to contain mandatory design requirements unless superseded by an owner agency. Though written in a similar format, guide specifications are considered optional. The ultimate goal of NCHRP 12-102 was to develop an AASHTO guide specification.

Special care was taken to develop a document that not only looked like an AASHTO specification but that included the same level of detail and approach. The grammar used for specifications is important—words such as "shall," "should," "may," and "recommended" all have particular, distinct meanings:

- The term "shall" indicates a requirement for compliance with the specifications.
- The term "should" indicates a strong preference for a given criterion.
- The term "may" indicates a criterion that is usable—but other local and suitably documented, verified, and approved criterion may also be used in a manner consistent with the LRFD approach to bridge design.
- The term "recommended" is used to give guidance based on past experiences.

These distinctions are very important, therefore every provision must be weighed for the proper wording to convey the intent of the provisions.

Upon completion of NCHRP 12-102, the research team worked closely with the AASHTO T-4 Committee on the process of securing the guide specification's adoption as an AASHTO publication. This process involved a review of the entire document by all voting members. All 50 states were asked to review the document in detail. The result was hundreds of comments that needed to be resolved. The majority of the comments were editorial; however, some significant comments also needed to be addressed. Through many meetings, the project team worked with the AASHTO T-4 Committee to resolve the comments. The work was complicated and arduous, but well worth the effort; the document improved as a result.

> The dynamics of bridge moves are important to bridge owners. Concerns include the forces imparted on the bridge during a move, which can lead to damage.

Photo: Arizona DOT

Using ABC techniques, Arizona DOT partnered with other agencies to build a bridge over Oatman Highway in 96 hours.

In June 2017, a ballot item on the adoption of the guide specification was put forth to the AASHTO Subcommittee on Bridges and Structures. Further comments were offered during the balloting process and changes were made up to the last minute. In the end, the ballot item passed, and the document technically became an AASHTO publication.

After the ballot process, several states still had reservations on some articles in the document. AASHTO and the T-4 Committee took an unusual course of action: the final publication of the document would be postponed for one year while these issues were worked out.

What followed was more meetings and revisions. At the 2018 annual meeting of the newly renamed AASHTO Committee on Bridges and Structures, the guide specification was reballoted and adopted a second time. In November, AASHTO formally published the *2018 AASHTO LRFD Guide Specifications for Accelerated Bridge Construction*. The AASHTO T-4 Committee decided to use the guidelines developed under NCHRP 12-98 as references to the guide specification, as noted in several applicable provisions.

Through the dedicated work of the AASHTO T-4 Committee and the project team, the deliverables have moved to the forefront of the ABC industry.

The following people were involved in the research for these two NCHRP Projects:

NCHRP Project 12-98

Michael P. Culmo, CME Associates, Inc., *principal investigator*
Jennifer Pixley, CME Associates, Inc.
Marvin W. Halling, Utah State University
Marc Maquire, Utah State University
Paul Barr, Utah State University
Kris Johnson, Utah State University
Dennis Mertz

NCHRP Project 12-102

Michael P. Culmo, CME Associates, Inc., and Lee Marsh, Berger ABAM, *principal investigators*
Stuart Bennion, Berger ABAM
Paul Smith, Berger ABAM
John Stanton, University of Washington
Dennis Mertz

The implementation process did not end after the guide specification's adoption. The project team has delivered several presentations on the document at conferences and webinars. Florida International University's ABC University Transportation Center hosted several webinars on both NCHRP 12-98 and 12-102, with an estimated attendance of more than 3,000 people. The research team and NCHRP also seek to develop more in-depth training for the implementation of the guide specification.

Conclusion

NCHRP Projects 12-98 and 12-102 are prime examples of how research can be moved into practice. Too often, research is completed and placed on a shelf or in a library. Through the dedicated work of the AASHTO T-4 Committee and the project team, the deliverables have moved to the forefront of the ABC industry.

"The guide specifications developed under NCHRP 12-102 and 12-98 fill a knowledge gap in the bridge engineering community that will help to facilitate the implementation of ABC across the country," notes Carmen Swanwick, Utah Department of Transportation (DOT), and Chair of the AASHTO Committee on Bridges and Structures.

The *AASHTO LRFD Guide Specifications for Accelerated Bridge Construction* now represent the national standard for ABC and can be used by all owner agencies and designers. The document will bring uniformity of design to all ABC projects—a uniformity that is based on sound research.

Acknowledgments

The project team acknowledges the significant efforts of Carmen Swanwick, Region Two Deputy Director, Utah DOT, and Chair, AASHTO Committee on Bridges and Structures, and Waseem Dekelbab, Senior Program Officer, Transportation Research Board.

Mark E. Felag

Rhode Island Department of Transportation

For nearly 35 years, **Mark E. Felag** has worked for the Rhode Island Department of Transportation (DOT) as an engineer. He joined the agency in 1984 as an entry-level engineer and in 1987 became acting materials engineer. For most of the past 30 years he has served in a management capacity, supervising up to 70 employees.

"A highlight of my career is that I have had the privilege of working with many outstanding, dedicated people. I have worked on the entire Rhode Island statewide network—and indirectly on almost all state facilities across the country—in my standards and research work over the years," Felag notes.

In 1988, the original Strategic Highway Research Program was initiated. "I was the state coordinator and helped implement Superpave™ and other products," Felag comments. "We were the first state to implement independent testing on a system basis; all other states used a project-based approach. This made us more efficient and we set up one of the nation's first comparison check of results with tolerances." Rhode Island also was one of the first states to use self-compacting concrete for structural applications and to use thin-lift pavements for Interstate construction.

In 2016, Felag joined the planning office to work on bicycle planning and, in 2018, the transit office. In this role he works closely with cities and towns on subrecipient projects, and on an asset management program for shared-use bike paths.

"In my work, I find it is very important to talk to people and learn from them. I learned about this in high school, from a teacher who stated that even the lowest salaried worker will know more things about something than someone higher up in an organization," Felag muses. "Although we can get by on conference calls, we still need to talk face-to-face at times. By talking directly, you can delve deeper into ideas and thoughts. Diverse backgrounds also will produce greater ideas and opportunities for improvements."

Felag takes pride in his 30 years serving on TRB committees. "I heard about the good works of TRB and began going to the Annual Meeting in 1987," he notes, adding that he has not missed a year since. "I have learned so much from TRB meetings and have been able to implement so many items that it is hard to track." Felag has served as chair of the Concrete Materials and Placement Techniques Committee for 6 years, and is a member of the Concrete Materials Section.

"Diverse backgrounds will produce greater ideas and opportunities for improvements."

Felag served as a longtime member of the Executive Board of the American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Materials. "For AASHTO, implementing and following through with the AASHTO–ASTM Harmonization Task Force has been a huge success with national significance," Felag comments. Historically, he explains, manufacturers of cement produced two different products for normal cement usage—an AASHTO version and ASTM version. The task force, working with National Cooperative Highway Research Program Project D18-11, aligned these two major cement specifications.

"At the onset, I stated the harmonization task would only work if we remove our biases and truly look at both organizations' specifications in a new light," Felag recalls. "The research on this worked because it answered a question that was very much needed and produced a product that could be implemented. Isn't that what research should be?"

Felag's membership on TRB and AASHTO committees helped pave the way for research implementation. "In our Concrete Materials meetings, we would talk and discuss our most pressing issue that to be addressed," he notes. "A statement was written up and then forwarded to AASHTO. Since I was an AASHTO chair, I would be able to promote it and make others see the need for it. This helped us get many projects approved over the last 5 years."

At national meetings, Felag may recite a poem or sing a song he has written. "I do this to lighten the meetings up a bit and deliver a message. My poems or songs reflect a position, present an overview of the meeting, recognize someone, or give thanks to those on the committee for their work," he comments. In 2014, he compiled a collection of the songs in a document called "Standards in a Spec Book: A Collection of Songs and Poems." He also conducts outreach to students to promote engineering and safety, visiting classrooms as the character P.E. Pothole.

Convening Events to Address Pressing Issues Facing Airports

KAREN FEBEY

The author is Senior Report Review Officer, Transportation Research Board, National Academies of Sciences, Engineering, and Medicine, Washington, D.C.

The Airport Cooperative Research Program (ACRP) is an industry-driven, applied research program that develops near-term, practical solutions to problems faced by airport operators. ACRP is managed by TRB and is sponsored by the Federal Aviation Administration (FAA). ACRP's research topics are selected by an independent governing board, appointed by the U.S. Secretary of Transportation, that includes individuals from airports, universities, FAA, and the aviation industry.

In 2015, ACRP determined that the airport industry would benefit from a deeper understanding and dialogue on certain challenges, even if an immediate solution is not practical. This led to the development of Insight Events, which convened airport industry leaders and subject-matter experts in various fields to encourage discussion and promote broader insight on topics of significance to airport operators. These events create a communal environment that fosters dialogue across sectors, institutions, and industries.

So far, three Insight Events have taken place, with more planned for the future. Descriptions of these three events are provided below, along with highlights of a few of the presentations and discussions that took place at each event. Information on accessing these reports can be found below, and more information about the Insight Series can be found at www.trb.org/ACRP/ACRP-Insight-Events.aspx. Links to each of the three reports highlighted below can be found on page 58 (see box).

AIRPORT ROLES IN DISEASE PREVENTION

The first Insight Event, titled "Airport Roles in Reducing Transmission of Communicable Diseases," took place March 6–7, 2018, in Washington, D.C. The event covered a wide range of issues, including different diseases and transmission modes, preparedness and response actions, legal issues, and airports' public relations approaches to addressing community perception of risk. Public health agencies, law enforcement, and other stakeholders all may respond to communicable disease outbreaks involving airports; however, this event focused on strategies, best practices, and suggestions that pertain to airports.

Communicable disease outbreaks have the potential to affect air travel and public health interests. Concerns about travel and spread of communicable disease are not new, as documented outbreaks of cholera, yellow fever, and other diseases associated with marine travel date back hundreds of years. What has changed in recent decades is how transportation modes—especially air travel—make the world tremendously interconnected today: in 2016, the total distance traveled worldwide by commercial flights was 6.7 trillion kilometers, with half of that travel accounted for by flights originating in just 10 countries.

Martin Cetron, Centers for Disease Control and Prevention (CDC), noted that travelers can now move from isolated rural villages to virtually any major city worldwide in less than 36 hours. So a contagious traveler from an area with a disease outbreak can quickly spread disease, as demonstrated by localized transmission of ebola in Nigeria or severe acute respiratory syndrome (SARS) in Toronto. In these cases, transmission was traced back to a single passenger infected with the disease who arrived on an international flight from an affected country.

As the threat of communicable disease transmission has grown, however, so have prevention, preparedness, and response efforts among air travel interests and the

(*Left to right:*) Marci Greenberger, TRB; Julie Morita, Chicago Department of Public Health; Martin Cetron, CDC; and Ansa Jordaan, International Civil Aviation Organization, at the first-ever ACRP Insight Event on airports and the transmission of communicable diseases, March 6, 2018.

Kelly Moulton (*far right*), Sacramento County Department of Airports, participates in a panel discussion at the April 2018 ACRP Insight Event on airport land use strategies.

public health community. At the national level, CDC works to prevent the introduction, transmission, and spread of communicable diseases through regulation, research, preparedness, and response. The agency's Division of Global Migration and Quarantine focuses on preventing importation and spread of communicable diseases in part by building systems and programs to prevent, detect, and respond to disease transmission among immigrants, refugees, travelers, expatriates, and other globally mobile populations.

Throughout the Insight Event, invited speakers from airports and public health agencies considered the following four topics that relate to airports' actions reducing transmission of communicable diseases: risk management, stakeholders, communication, and infrastructure.

Discussions about airport risk management emphasized the importance of developing, testing, reevaluating, and revising communicable disease response plans. If used effectively, the plans can help prevent or minimize the consequences of the introduction and spread of communicable diseases via air travel. Examples of communicable disease concerns ranged from localized disease transmission occurrences (e.g., tuberculosis transmission on domestic flights) to regional and international transmission facilitated by air travel (e.g., SARS, pandemic influenza).

Engaging stakeholders is key to addressing communicable disease risks through coordination among experts from various disciplines. Doing so requires multisector, multipartner collaboration; sharing information and best practices; and regularly scheduled meetings and joint exercises.

Airports' communication strategies among stakeholder groups ideally would address internal communications with external parties, health education messages from medical authorities, and information and data sharing with public health agencies. Speakers discussed challenges such as the need to dispel myths, address public perception of risk, and issue clear and consistent messaging, especially during disease outbreaks. Airport infrastructure—and the practices used to operate and maintain the built environment—can affect potential communicable disease transmission in various ways, such as ensuring ample space for passenger evaluation and isolation and implementing effective infection control measures.

Throughout the Insight Event, speakers referred to the resources available to airports and other stakeholders to enhance their communicable disease response efforts. These resources, which are listed in the report, include those from ACRP, CDC, the Code of Federal Regulations, the Department of Homeland Security, the Government Accountability Office, and the World Health Organization. This list is not comprehensive but does represent the broad array of resources that can be used to address airports' communicable disease response and prevention efforts.

LAND USE STRATEGIES AT AIRPORTS

The second Insight Event, titled "Challenges to Implementing Successful Land Use Strategies at Airports" took place April 10–11, 2018, in Washington, D.C. Discussions focused on how airports operate within the larger context of their communities, how development affects and is affected by a nearby airport. Land use planning around airports typically is managed by local governments, with nearby municipalities often having no connection to airport management. Airport operators and local jurisdictions have much to gain from collaboration, however. This Insight Event sought to encourage airport and community planners to work together in a mutually beneficial manner.

Jackie Sweatt-Essick, FAA, spoke in one session about the role of her agency and airport operators in land use planning. She noted that FAA has been revising its Advisory Circular on height zoning around airports, in part by working with the American Planning Association and metropolitan planning organizations that have a role in land use planning around airports.

Janet Bednarek, University of Dayton, provided a historical perspective of how land use evolved around airports. She noted that during the 1920s and 1930s, planners were interested in airports and the need to integrate them into the region. Cities were focused primarily on urban and residential

zoning at the time, however, and by the 1930s, most cities defunded city planning and courts were hostile to airport zoning. The lack of zoning created significant airport encroachment following the growth in suburbs after World War II. By the 1970s and 1980s, airport operators learned that the best solution was ownership of airport land and surrounding property.

In recent years, the concept of an aerotropolis—an urban form in which the airport acts as the center of a city with multimodal connections to an urban core—has become a key consideration for airport and urban planners. One attendee remarked that John Kasarda, a lead advocate for the aerotropolis concept, believes that the concept has not been as successful in the United States because airports are too small and do not have enough land to support the broader development needed to realize full potential of the concept. One audience member thought that another issue is that the aerotropolis concept also embraces residential development, which airport operators currently discourage or prevent from close proximity to airports.

One issue discussed was whether general aviation (GA) airports have less economic value. Some panel members noted that, from an economic impact perspective, their dollar value may be less, but some GA airports are relievers whose presence enables major air carrier airports to provide the economic benefits that they do. Steven Rother, Essex County Improvement Authority, New Jersey, noted that some private GA airports have 9,000-ft runways and serve an important aviation function. He said further that there are development pressures on smaller airports in New Jersey as the land is so valuable.

SUSTAINABILITY AT AIRPORTS

"Economic and Social Sustainability at Airports" took place May 7–8, 2018 in Washington, D.C. This topic grew from the acknowledgment that airports should understand and actively work toward solutions focused on both the environmental aspect of sustainability as well as the economic and social aspects of sustainability. Airport practitioners discussed how domestic and international airports frame planning that accomplishes social and economic sustainability goals, identify innovation for those goals, and develop innovative practices for use in economic and social sustainability.

In the opening discussion, Steve Nakana, Social Equity Manager, Port of Portland, talked about the port's social equity program which largely operates out of its Administrative and Equity Division. Its policy defines social equity as "fair and equitable inclusion, and the creation of conditions where all people can participate, prosper, and achieve equitable outcomes with respect to the Port's employment, business, and services." In outlining the Port of Portland approach to social equity, Nakana said that it includes jobs, wellness, business ethics, security, diversity, community outreach, and labor relations.

In another discussion, Davina Durgana, Global Slavery Index, Walk Free Foundation, and Nancy Rivard, Airline Ambassadors International, discussed human trafficking and modern slavery. Rivard noted that Airline Ambassadors has an internationally recognized program to educate people on human trafficking and toolkits to assist airports. They have found that each airport has a different way of addressing this issue, and if staff suspect trafficking, they do not always know whom to ask or how to report it.

Durgana and Rivard said that signs a person could be in a trafficking situation include fearful and submissive behavior; often, the person being trafficked will defer to someone else to answer questions. They may not know where they are traveling to, may have overt branding on their person such as clothes or tattoos, and may have conspicuously little luggage. Victims of trafficking may also be intimated by authority figures, such as police and border protection agents.

In the event's keynote address, Stephen Van Beek, Steer Group, delivered a presentation titled "The Erosion of 'Public' Airports." He noted that current capacity issues are associated with terminals and the surrounding land, not on the airfields, but policy to guide funding for terminal and landside improvements is lacking. As a result, airports are beginning to consider private equity and public–private partnerships. He noted that an airport's primary value to the community is its socioeconomic benefits (e.g., jobs, payroll, and regional economic contribution).

Van Beek noted that the 30 largest airports in the United States accommodate 72% of the activity. Enplanements are up 15.5% between 1999 and 2017, but aircraft operations were only up 4.1%—reflecting a large increase in load factors. This increase in passengers is placing a strain on the terminal and landside. Transportation network companies have had a large effect on parking at airports and the revenue available to the airport operator, according to Van Beek.

ACRP Insight Series Publications

Airport Roles in Reducing Transmission of Communicable Diseases, www.trb.org/Publications/Blurbs/178666.aspx

Challenges to Implementing Successful Land Use Strategies at Airports, www.trb.org/Publications/Blurbs/178843.aspx

Economic and Social Sustainability at Airports, www.trb.org/Publications/Blurbs/178871.aspx

Ridesharing Services Increase Urban Traffic

New data show that transportation network companies (TNCs) like Lyft and Uber and their ridesharing services have increased urban vehicle miles traveled by 160%. In his 2018 report, *The New Automobility: Lyft, Uber and the Future of American Cities*, urban transportation expert Bruce Schaller combines recently published research and newly available data, including information from the National Household Travel Survey, to create a profile of TNC ridership and usage and examine how TNCs are affecting urban transportation.

Along with highlighting the added mileage TNCs create in urban areas—where the services operate most heavily—the report finds that 60% of TNC users would otherwise have walked, biked, or ridden transit. Also addressed in the report are public policies like congestion pricing, traffic-signal timing, and limits on low-occupancy vehicles that may help TNC congestion.

To view the report, visit www.schallerconsult.com/rideservices/automobility.htm.

Better Bus Stops Improve Ridership

Bus stop improvements like shelters, seating, and sidewalks are inexpensive but effective ways to increase transit ridership and decrease demand for paratransit services, according to research by the Utah Transit Authority (UTA).

In a 2018 study, UTA researchers analyzed the impact of bus stop improvements on ridership and paratransit demand. Through literature review and a comparison of rider use before and after the improvements at 30 statewide stops, analysts found a 92% increase in ridership and a 94% decrease in paratransit demand over a 3-year period at the treated stops.

Photo: Oregon Department of Transportation

Basic, low-cost bus stop improvements increase ridership and accessibility for travelers with disabilities.

The inclusion of sidewalk connections and concrete pads in particular were noted as significant contributors to mobility and accessibility.

To read the report, visit www.udot.utah.gov/main/uconowner.gf?n=42420111425367128.

Predictive Technology to Balance Road Safety

Transportation agencies in Nevada and the analytics firm Waycare recently concluded a yearlong road safety pilot program. The Waycare system combined data from connected cars, road cameras, and crowdsourcing apps like Waze with predictive analytics to identify, in real time, areas of roads at high risk for incidents. This information then was passed on to traffic agencies to facilitate preventative action.

The Regional Transportation Commission of Southern Nevada delivered warning via dynamic message boards, and the Nevada Highway Patrol (NHP) positioned its vehicles in high-visibility mode. These proactive measures resulted in the reduction of primary crashes by 17 percent along a key corridor in Las Vegas—without the need for additional resources.

In the areas in which risks were identified and measures deployed, 91% of drivers reduced their speeds to below 65 mph. The predictive data also allowed NHP to get ahead of crashes, to identify crashes 12 minutes faster, and to restore normal traffic flow more quickly.

Similar pilot programs are under way in Florida and Colorado.

To find out more, visit www.zdnet.com/article/waze-fed-ai-platform-helps-las-vegas-cut-car-crashes-by-almost-20.

E-Bikes Rising in Popularity

According to a 2018 study from the National Institute for Transportation and Communities (NITC), more North Americans are buying electric bikes, or e-bikes, and reducing car use. In a survey of nearly 1,800 e-bike users, researchers found that 28% specifically purchased e-bikes to replace their cars. Without the bikes, 78% of the trips would have been made by car.

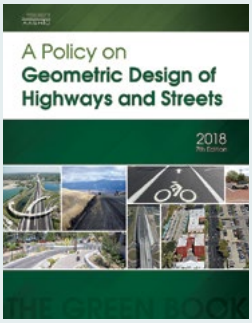
Photo: Dean Groom

Electric bikes remove some of the impediments to regular cycling, such as hills or long distances.

NITC surveyed both men and women about their primary and secondary reasons for e-bike purchases, along with their transportation behavior and experiences. Notably, e-bikes overcame obstacles common to traditional cycling—for example, hills and lengthy distances to a travel destination. E-bikes also make bicycling possible for travelers otherwise restricted by physical limitations.

Although survey respondents acknowledged that e-bikes alleviated travel concerns about parking, safe biking infrastructure still remains a barrier for some, according to researchers.

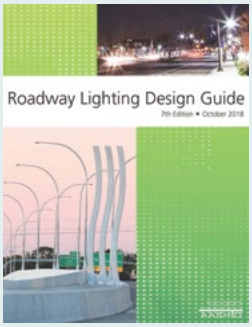
For more information, visit https://cyclingindustry.news/electric-bikes-purchases-pulling-people-from-private-cars-finds-nitc-study.



A Policy on Geometric Design of Highways and Streets, 7th Edition

American Association of State Highway and Transportation Officials (AASHTO), 2018; 1,047 pp.; paperback: AASHTO members, $288; nonmembers, $388; 978-1-56051-676-7.

Commonly referred to as the AASHTO Green Book, A Policy on Geometric Design of Highways and Streets contains the current design research and practices for highway and street geometric design. This revised 7th edition presents a more flexible, multimodal, performance-based framework for geometric design than past editions, with expanded context classifications.



Roadway Lighting Design Guide, 7th Edition

AASHTO, 2018; 89 pp.; PDF download: AASHTO members, $45; nonmembers, $61; 978-1-56051-725-2.

The revised guide provides a general overview of lighting systems from the point of view of state transportation departments and recommends minimum design parameters. It has been updated to reflect current practices and may be used to inform agency policy including lighting equipment and technology, calculation preferences, and maintenance issues.

These titles are not TRB publications. To order, contact the publisher listed.

TRB PUBLICATIONS

Socioeconomic, Sustainability, and Human Factors in Transit 2018
Transportation Research Record 2672, Issue 6

Topics explored in this issue include reducing rural car ownership, a comparative study of rail and bus travel by low-income households, and the impact of built environment on first- and last-mile travel mode choices.

2018; 51 pp. For more information, visit http://journals.sagepub.com/home/trr.

Transportation Policy
Transportation Research Record 2672, Issue 7

Authors present research on autonomous transportation, the impact of app-based ride share systems, bicycle lanes and business success, parking occupancy detection, and transportation on Indian reservations.

2018; 81 pp. For more information, visit http://journals.sagepub.com/home/trr.

Freight Systems
Transportation Research Record 2672, Issue 9

The 24 articles in this issue explore global freight system research, including evolving supply chains and freight flow; joint deployment of quay cranes and yard cranes in container terminals; scheduling of cranes, trucks, and stackers in railway operations areas; woody biomass logistics for co-firing in coal power plants; and the impact of weigh stations on truck time travel reliability.

2018; 272 pp. For more information, visit http://journals.sagepub.com/home/trr.

Articles for Issues 1–3 of *TRR* Volume 2673 (2019) are now online. Beginning this year, *TRR* will publish one interdisciplinary issue monthly. Individual articles will be released as available and compiled into the issue at the end of the month. Readers will be able to choose to access either the complete issue or individual articles. For more information, visit http://journals.sagepub.com/home/trr.

Railroads
Transportation Research Record 2672, Issue 10

Topics included in this issue are modeling the probability of hazardous materials release in crashes at highway–rail grade crossings, examining the injury severity of truck drivers in highway–rail grade crossing crashes, and investigating the relationship between train speed and bolted rail joint fatigue life, among others.

2018; 288 pp. For more information, visit http://journals.sagepub.com/home/trr.

Marine Transportation and International Trade
Transportation Research Record 2672, Issue 11

Assessing Canada's transportation system under the comprehensive economic and trade agreement, leveraging the value of land and landside access to fund port infrastructure in Texas, and determining minimum distance to obstacle avoidance in the Singapore Strait are a few of the topics included in this issue.

2018; 80 pp. For more information, visit http://journals.sagepub.com/home/trr.

Maintenance and Operations, Parts 1 and 2
Transportation Research Record 2672, Issue 12

This extensive issue explores topics on maintenance, preservation, and operation of infrastructure surfaces, including chip seal performance, the measurement of water infiltration in asphalt, procedures for the analysis of agency and user costs of bridge repair, and the effects of additives on the ice-melting capacity of sodium chloride.

2018; 242 pp. For more information, visit http://journals.sagepub.com/home/trr.

Research and Education
Transportation Research Record 2672, Issue 13

The evaluation of TRB's Minority Student Fellowship Program, a historical perspective on AASHTO's Guide for the Development of Bicycle Facilities and the Impact of the Vehicular Cycling Movement, and the implications of public parking in Washington, D.C., are subjects explored in this issue.

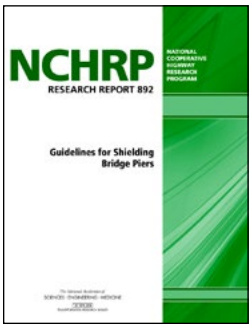
2018; 59 pp. For more information, visit http://journals.sagepub.com/home/trr.

Freeway Operations; Regional Systems Management and Operations; Managed Lanes 2018
Transportation Research Record 2672, Issue 14

Authors present research on toll lane access violations, the safety of cross-sectional elements of freeway managed lanes, estimating incident clearance duration, and wrong-way driving crash risk reductions, among other managed lanes concerns.

2018; 116 pp. For more information, visit http://journals.sagepub.com/home/trr.

SAGE is now the publisher of the Transportation Research Record: Journal of the Transportation Research Board (TRR) series. To search for TRR articles, visit http://journals.sagepub.com/home/trr. To subscribe to the TRR, visit https://us.sagepub.com/en-us/nam/transportation-research-record/journal203503#subscribe.



Guidelines for Shielding Bridge Piers
NCHRP Research Report 892

Proposed load and resistance factor design (LRFD) bridge design pier protection specifications and proposed occupant protection guidelines are offered in this report.

2018; 116 pp.; TRB affiliates, $55.50; nonaffiliates, $74. Subscriber categories: bridges and other structures, design.

Systemic Pedestrian Safety Analysis
NCHRP Research Report 893

This report offers a safety analysis method that can be used to proactively identify sites for potential safety improvements based on specific risk factors for pedestrians.

2018; 110 pp.; TRB affiliates, $55.50; nonaffiliates, $74. Subscriber categories: pedestrians and bicyclists, planning and forecasting, safety and human factors.

Performance of Longitudinal Barriers on Curved, Superelevated Roadway Sections
NCHRP Research Report 894

Guidance is provided for designing, selecting, and installing longitudinal traffic barriers for curved, superelevated roadways for possible incorporation into AASHTO's Roadside Design Guide. Five appendices detailing DOT surveys, vehicle simulations, and crash testing results are included.

2019; 138 pp.; TRB affiliates, $60; nonaffiliates, $80. Subscriber categories: construction, design, safety and human factors.

Simplified Full-Depth Precast Concrete Deck Panel Systems
NCHRP Research Report 895

New connections between full-depth precast concrete deck panels and beams are described in this report.

2018; 156 pp.; TRB affiliates, $62.25; nonaffiliates, $83. Subscriber categories: bridges and other structues.

Updating Regional Transportation Planning and Modeling Tools to Address Impacts of Connected and Automated Vehicles, Volumes 1–2
NCHRP Research Report 896

Volume 1 of this report summarizes guidelines to help agencies update their modeling and forecasting tools to address the impacts of connected and automated vehicles. Volume 2 provides detailed guidelines for these tools. A PowerPoint presentation that can be adapted for agency decision makers accompanies these volumes.

2018; Volume 1: 126 pp.; TRB affiliates, $58.50; nonaffiliates, $78; Volume 2: 126 pp.; TRB affiliates, $58.50; nonaffiliates, $78. Subscriber categories: highways, operations and traffic management, planning and forecasting.

Tools to Facilitate Implementation of Effective Metropolitan Freight Transportation Strategies
NCHRP Research Report 897

Offered in this report are 30 strategies for implementing effective metropolitan freight strategies, tailored to specific circumstances in local areas, along with 16 factors that affect implementation.

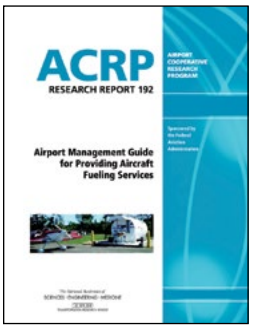
2018; 116 pp.; TRB affiliates, $55.50; nonaffiliates, $74. Subscriber categories: freight transportation, operations and traffic, planning and forecasting.

A Guide to Developing Financial Plans and Performance Measures for Transportation Asset Management
NCHRP Research Report 898

Addressed in this report are fiscal and programmatic constraints associated with legislation, methodologies for valuing assets, forecasting resources, and practical concerns related to financial markets

and accounting requirements for state departments of transportation and other agencies conducting financial analyses and developing financial plans to manage transportation assets.

2019; 112 pp.; TRB affiliates, $57; nonaffiliates, $76. Subscriber categories: finance, planning and forecasting, policy.



Airport Management Guide for Providing Aircraft Fueling Services
ACRP Research Report 192

This report is designed to assist airports that are considering or currently are self-providing fuel services. Addressed are feasibility for fueling facilities, fuel pricing strategies, and the components of an airport fueling system. A sample request for proposal to solicit bids from suppliers is included.

2019; 244 pp.; TRB affiliates, $71.25; nonaffiliates, $95; Subscriber categories: aviation, operations and traffic management.

Best Practices for Airport Obstruction Management Guidebook
ACRP Research Report 195

Guidance is offered to airport operators in developing and implementing an obstruction management program to protect airport airspace from the encroachment by tall objects. A methodology for creating composite maps is included.

2019; 129 pp.; TRB affiliates, $60; nonaffiliates, $80; Subscriber categories: aviation, planning and forecasting.

Guidebook for Integrating Collaborative Partnering into Traditional Airport Practices
ACRP Research Report 196

This report provides guidance on bringing airport owners, designers, and construction teams together for airport construction projects.

2019; 108 pp.; TRB affiliates, $57; nonaffiliates, $76; Subscriber category: aviation.

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.

In the printed July–August 2018 edition of TR News, a theme issue on alternative contracting methods research, captions for three photos on Washington State Department of Transportation projects contained inaccurate information. The captions have been corrected and reposted at www.trb.org/Publications/Blurbs/177989.aspx.

TRB STANDING COMMITTEES

April

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

June

2–5 17th National Transportation Planning Applications Conference
Portland, Oregon

12–14 7th International Conference on Bituminous Mixtures and Pavements*
Thessaloniki, Greece

25–27 17th Biennial National Harbor Safety Committee Conference
Houston, Texas

August

4–7 9th International Conference on Structural Health Monitoring of Intelligent Infrastructure*
St. Louis, Missouri

September

10–13 6th International Conference on Women's Issues in Transportation
Irvine, California

12–18 12th International Conference on Low-Volume Roads
Kalispell, Montana

15–19 Conference on Performance and Data in Transportation Decision Making
Atlanta, Georgia

29–Oct. 2 3rd International Conference on Information Technology in Geo-Engineering*
Guimaraes, Portugal

October

6–10 PIARC 26th World Road Congress
Abu Dhabi, United Arab Emirates

21 TRB Workshop at the 69th Highway Geology Symposium*
Portland, Oregon

23–24 Air & Waste Management Association Conference on Freight and Environment: Ports of Entry*
Newark, New Jersey

UPCOMING WEBINARS

May

1 Understanding Disadvantaged Business Enterprise Interstate Certification

8 Priming the Pump: Cleaner Approaches to Airport Ground Transportation

13 Dialysis Transportation: The Intersection of Transportation and Healthcare

15 Guide to Snow and Ice Performance Measures: Key Findings and Recommendations

21 Evolution of Intellectual Property and Research in the Transportation World

22 The Making of a Smart Airport: Preparing for the Internet of Things

30 Continuous Deflection for Comprehensive Pavement Assessments

For more information, contact Elaine Ferrell, TRB, at 202-334-2399 or eferrell@nas.edu.

CONSENSUS AND ADVISORY STUDIES

May

20–21 U.S. Coast Guard Vessel Stability Regulations Study Committee 3rd Meeting
Irvine, California

29–30 Research and Technology Coordinating Committee Meeting
Woods Hole, Massachusetts

July

14–15 Forum on Preparing for Automated Vehicles and Shared Mobility
Orlando, Florida

August

4 Federal Highway Administration Emerging Trends Symposium
Washington, D.C.

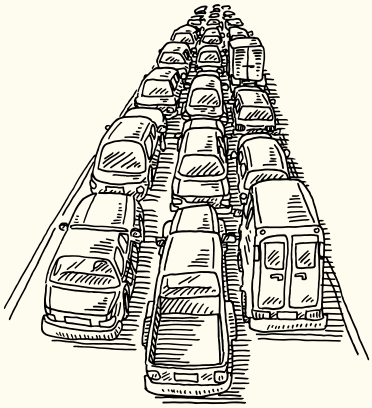
For more information on these events, e-mail Michael Covington, TRB, at mcovington@nas.edu.

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

To subscribe to the TRB E-Newsletter and keep up to date on upcoming activities, go to www.trb.org/Publications/PubsTRBENewsletter.aspx and click on "Subscribe."

* TRB is cosponsor of the meeting.

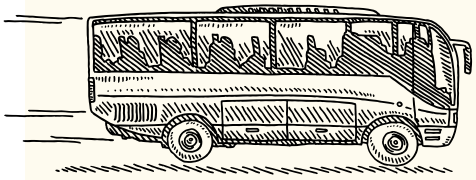
COOPERATIVE RESEARCH PROGRAMS



The National Cooperative Highway Research Program FY 2020 program announcement and request for panel nominations will be issued by **Wednesday, May 15**.

For more information, visit www.trb.org/NCHRP/NCHRPOverview.aspx.

New NCHRP Synthesis projects also will be announced **May 15**, along with a request for panel nominations and letters of interest.



Solicitations for proposals for the Transit Innovations Deserving Exploratory Analysis (IDEA) program were released **January 2019**. Proposals are due **Wednesday, May 1**.

For more information, visit www.trb.org/IDEAProgram/IDEATransit.aspx.

Applications for the Airport Cooperative Research Program Graduate Research Awards for Applied Research in Public-Sector Airport-Related Aviation Issues are due **Wednesday, May 15**. Ten (10) one-year awards of $12,000 each are available.

For information about application requirements, eligibility, and more, visit vsgc.odu.edu/acrpgraduateresearchawards or e-mail the Virginia Space Grant Consortium at ACRP@odu.edu.

NASEM EVENTS

May

16–17 Health-Focused Public–Private Partnerships in the Urban Context
National Academy of Sciences Building, 2101 Constitution Ave. NW, Washington, D.C.

For more information, contact Claire Moerder at cmoerder@nas.edu or 202-334-3264.

21–22 Workshop on Forced Migration Research: From Theory to Practice in Promoting Migrant Well-Being
National Academy of Sciences Building, 2101 Constitution Ave. NW, Washington, D.C.

For more information, contact Jillian Kaufman at jkaufman@nas.edu or 202-334-3465.

22–23 Committee on Urban Air Mobility Research and Technology
Keck Center, 500 Fifth St. NW, Washington, D.C.

For more information, contact Gaybrielle Holbrook at gholbrook@nas.edu or 202-334-3477.

INFORMATION FOR CONTRIBUTORS TO

TR NEWS

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

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

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

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

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

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

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

SUBMISSION REQUIREMENTS: Manuscripts submitted for possible publication in *TR News* and any correspondence on editorial matters should be sent to the *TR News* Editor, Publications Office, Transportation Research Board, 500 Fifth Street, NW, Washington, DC 20001, telephone 202-334-2986, or e-mail lcamarda@nas.edu.

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

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

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

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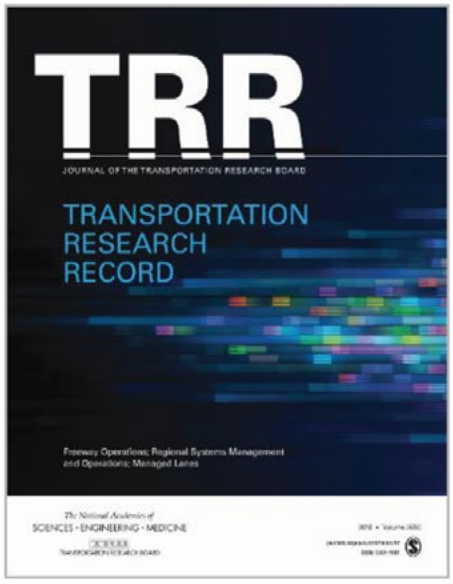

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