TR NEWS
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INTEGRATED FLOOD PREDICTION SYSTEM

Know When the Waters Are Coming and How to Respond

PLUS

Decision Support for Wildlife Crossing Programs

Maintaining the Global Vaccine Supply Chain

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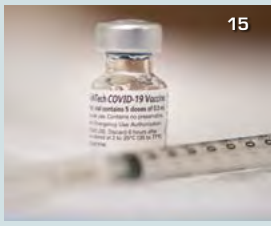

3 **Getting Safely to the Other Side: Decision Support for Wildlife Crossing Programs**
Fraser Shilling, Glen Kalisz, and Andrew Runk
When wildlife and traffic collide, the end result can range from property damage to injury and death of drivers, as well as wildlife, with the latter also negatively affecting the overall health of wildlife populations. The authors describe how science supports the decisions made to construct wildlife crossings that keep traffic flowing and animals out of harm's way.

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How do transportation authorities measure the effectiveness of public engagement efforts? This NCHRP project implemented a first-of-its-kind toolkit to measure public involvement effectiveness. Several state DOTs used the toolkit, shared their lessons learned, and helped fine-tune the kit's contents. A major takeaway: Hands-on practice is key.

COVER Battered homes, bent trees, and broken impassable streets leave scars on a Florida coastal community following Hurricane Ian's flooding and high winds in late September. To stay ahead of such catastrophes, state departments of transportation and other state and local agencies are working with integrated flood warning and response systems that predict the extent and severity of flooding. (Florida Fish and Wildlife, Flickr, CC BY-NC-ND 2.0)

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TRB COVID-19 Resources

Agencies and organizations can use TRB publications and online resources for useful and timely information to help address issues related to the COVID-19 pandemic. To read about TRB's current research and activities, and for a list of relevant publications, visit www.nationalacademies.org/trb/blog/transportation-in-the-face-of-communicable-disease.

Coming Next Issue

The January–February 2023 issue of *TR News* features a compelling mix of articles. Authors examine transportation's environmental, health, and social effects on Native American tribes and communities; how transit agencies make effective use of social media; and the factors to be considered when installing lighting at isolated rural intersections.

J. Stephen Conn, Flickr, CC BY-NC 2.0

Wildflowers and wild grasses line a road leading into White Earth Indian Reservation, home to the White Earth band of the Chippewa tribe in northwest Minnesota. Throughout the United States, tribal transportation issues intersect with environmental justice concerns, such as the risks associated with transporting mining resources and hazardous materials through Indian Country and the need for adequate infrastructure to access health care and other basic requirements. Successfully addressing these and other matters hinge on understanding Native American communities and the complex jurisdictions under which they function—and that's just the beginning.

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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Getting Safely to the Other Side

Decision Support for Wildlife Crossing Programs

Washington State DOT

FRASER SHILLING, GLEN KALISZ, AND ANDREW RUNK

Shilling is director of the Road Ecology Center at the Institute of Transportation Studies in Davis, California, and a senior scientist at Dudek, Inc., in Portland, Oregon; Kalisz is the habitat connectivity biologist at the Washington State Department of Transportation in Olympia; and Runk is a regional bridge consultant at Contech Engineered Solutions (California Region) in Costa Mesa, California.

Mimicking the smooth curve of forested hills, the Keechelus Wildlife Overpass is part of the larger Snoqualmie Pass East Project in Washington's Central Cascade Mountains. Based on scientific research that includes topography, light conditions, and wildlife behavior, the project will ultimately improve a 15-mile stretch of I-90, addressing safety and capacity needs as it reconnects habitats and wildlife fragmented by the highway.

Wildlife and ecosystems are directly and indirectly affected by transportation systems and other linear infrastructure. Roads and traffic are primary causes of habitat and genetic fragmentation, wildlife mortality, and reduced resilience to climate change. Wildlife–vehicle collisions can result in property damage, injury and death to drivers, and also wildlife mortality with potential negative effects on the overall health of wildlife populations. Increasingly, transportation agencies and their scientific partners are proposing approaches to reduce these effects and even restore broken connections. This approach has received new support in the Infrastructure Investment and Jobs Act of 2021. One of the best known and most effective methods to reduce such effects has been to build wildlife crossing structures, which are either existing bridges or culverts enhanced to encourage wildlife movement, or bridges or culverts built specifically for wildlife—usually in combination with fencing (*1*). Recently, ecologists and wildlife biologists have been studying the complex responses wildlife have to linear infrastructure and traffic. Some of these responses can be generalized into the following four main types:

- Wildlife–vehicle collision affecting driver or animal safety, or both;
- Safe wildlife passage across road surface;
- Wildlife aversion from highways; and
- Wildlife attraction to roadside.

This complexity requires creativity and good information to make sure mitigation approaches are likely to be successful.

This article updates earlier discussions of wildlife crossing structures (*2*, *3*) and examines how to make economic, engineering, and ecological decisions to implement and evaluate their effectiveness. It focuses on existing and innovative approaches that state departments of transportation (DOTs), their partner

Road Ecology Center and Caltrans

Caught in midsprint, a gray fox traverses a wildlife crossing culvert under CA-299. Caltrans, District 2, built the culvert as mitigation for nearby road reconstruction and partnered with the Road Ecology Center to set up monitoring.

agencies, and consultants are taking to use these structures to reduce environmental effects and improve road–highway safety. The various decisions involved in developing wildlife crossings are placed in the context of recent science and an overall decision-making process and workflow. The proposed workflow includes the following steps:

1. Determining placement of wildlife crossing structures,
2. Deciding on the kinds of fencing and passage structures needed,
3. Determining the economic and ecological benefits of wildlife crossing structures,
4. Designing wildlife crossing structures around wildlife behavior,
5. Building a replicable system of structures, and
6. Assessing whether they worked.

Where Should Structures Be Placed or Enhanced to Reduce Effects?

Key questions to consider when reducing infrastructure effects on wildlife is where a wildlife crossing action should take place, and whether it is mitigation associated with an improvement project or a standalone project. Typically, the answer is to use habitat connectivity modeling, locations of wildlife–vehicle collision hotspots, and known barrier effects of highways. Because new crossing structures are geographically committed once they are built, getting the location right is important. Another approach is enhancement of existing structures, requiring a lower investment for a particular site and allowing a greater number of—and more flexibility in—sites to be treated.

HABITAT CONNECTIVITY MODELS

Over the past two decades, large-area models have been developed in geographic information systems to predict where wildlife movement and connectivity were more likely to occur (*4*, *5*). Most of these models result in maps of hypothetical areas of habitat core areas (i.e., important, undisturbed habitat) and linkage areas (i.e., areas connecting core areas). Generally, these models are not based on evidence of wildlife occurrence, and model validations with wildlife data have given mixed results. For example, the Road Ecology Center at the University of California, Davis, evaluated five recent linkage models—four statewide and one regional—and found that the linkage areas were not important predictors for occurrence for most species or for wildlife–vehicle collisions on roads.[1] This suggests that until they are improved, or scientifically validated, these models should not be used to plan wildlife crossing structures but could be used to trigger field research.

INFRASTRUCTURE AS BARRIERS TO MOVEMENT

Restoring permeability within human-dominated areas is critical to biodiversity conservation. California's Wallis Annenberg Wildlife Crossing over US-101—the result of a collaborative proposal between the California DOT (Caltrans) and the National Wildlife Federation—is one of the best contemporary examples of using wildlife crossing structures to resolve barriers to wildlife population connectivity from an extremely busy highway in a habitat area. In this case, genetic separations for carnivore populations—such as coyote, bobcats, and mountain lions—had been identified across US-101 and were used to justify building the crossing (*6*).

WILDLIFE–VEHICLE COLLISIONS

Locations and annual rates (number per mile) of collisions with particular species, large mammals, or all wildlife can be used to support locating wildlife crossing structures (Figure 1). When wildlife–vehicle collision data collection results in mitigation, it can lead to demonstrably successful reductions in wildlife–vehicle collisions and improved safety (*7*). The Infrastructure Investment and Jobs Act of 2021 includes a recommendation for federal support of statewide wildlife–vehicle collision reporting systems. State agencies in Idaho, Maine, Nevada, Ohio, and Washington have deployed successful systems for collecting wildlife–vehicle

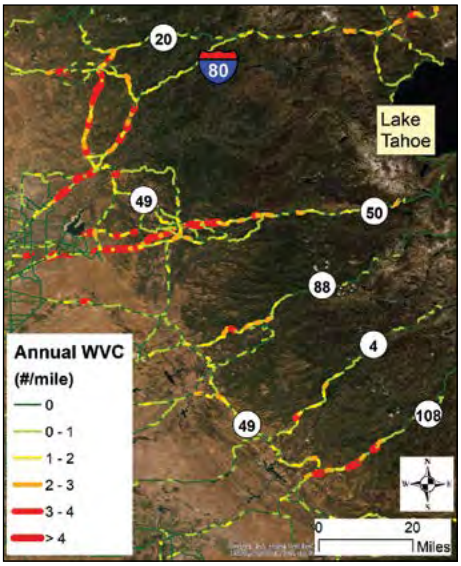

FIGURE 1 Rates (number/mile-year) of wildlife–vehicle collisions with large mammals along highways on the western slope of the Sierra Nevada in California. (WVC = wildlife–vehicle collisions.) (Source: California Roadkill Observation System.)

[1] Discover the research underway at the Road Ecology Center at https://roadecology.ucdavis.edu/.

collision data, primarily for larger mammals. In California, the longest-running and largest system in the United States is operated by the Road Ecology Center.[2]

What Kind of Fencing and Passage Structures Are Needed?

The most common approach to thinking about wildlife crossing structure projects is to build a crossing structure combined with fencing to funnel wildlife to the structure (*2*, *3*). One important caveat to this is that there is little evidence that wildlife respond to fencing by going toward a crossing structure (the funneling effect), especially if animals have not been there before or cannot see the crossing structure from where they encounter the fence. That is not to say that fencing is not important. Teixiera, Rytwinski, and Fahrig reviewed the scientific literature and revealed an important bias in interpretation against fencing: They suggest that the mortality reduction from fencing alone may be as important to wildlife populations as connectivity (*8*).

Although there are no examples in the peer-reviewed literature of systematic ways to determine what kind of wildlife crossing structure to build for a specific passage need, there are useful reviews of effective wildlife crossing structures and other mitigation approaches, especially Rytwinski, Soanes, Jaeger, Fahrig, Findlay, Houlahan, Van Der Ree, and van der Grift (*1*). The following are useful and standard rules for deciding what kind of wildlife crossing structure to build:

- Overcrossings are generally better than undercrossings for more species, except for those species wary of wide open spaces. The best situation would be paired over- and undercrossings to suit as many species as possible.
- Larger crossings are generally better but not necessarily at the expense of more frequent small crossings (*9*). Deciding which approach to take is likely to end up at a solution involving both large and small wildlife crossing structures.
- Multifunction passages are likely to be best (*2*), providing for wide ranges of species sizes and types, terrestrial and aquatic passage, and natural processes such as sediment transport.

Economic and Ecological Benefits of Wildlife Crossings

States generally lack consistent mechanisms for evaluating the economic and societal benefits of reducing wildlife–vehicle collisions relative to the costs of mitigating such collisions. With support from the Pew Charitable Trusts, the Road Ecology Center developed a web-based tool to assist decision making related to wildlife–vehicle collision mitigation, based on economic benefits and costs associated with mitigation.[3] The Center collaborated with transportation and wildlife staff from Arizona, Idaho, Montana, Oregon, and Wyoming to elucidate goals for such a decision-support tool, develop wildlife values, estimate crash costs, and calculate costs for different types of mitigation. The tool estimates the total costs per road segment (wildlife cost plus crash cost) of wildlife–vehicle collision events. The user can then compare the benefit of avoiding the costs of wildlife–vehicle collisions with potential long-term costs of mitigation.

Figure 2 shows an example of an economic analysis of wildlife–vehicle collisions in California, including incidents with

[2] Access California's wildlife–vehicle collision reporting system at the Road Ecology Center at https://wildlifecrossing.net/California.

[3] Learn more about the Wildlife Crossing Calculator at https://wildlifecrossingcalculator.org.

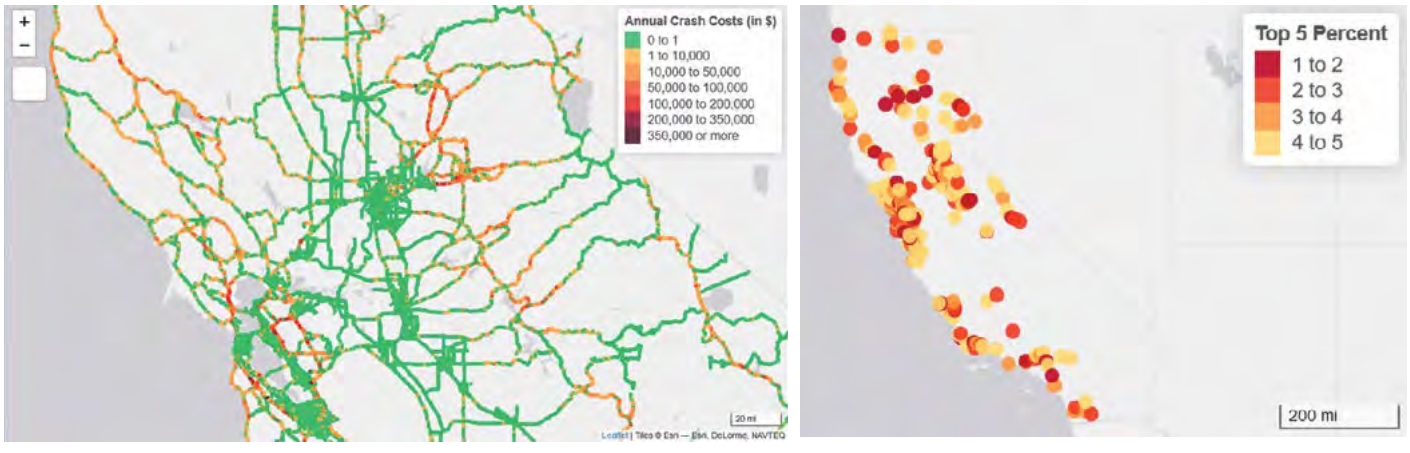

FIGURE 2 A map of (*a*) a portion of California—including the Central Valley to Lake Tahoe—shows an analysis of annual crash costs per one-mile segment of wildlife–vehicle collisions involving large mammals between 2016 and 2020. Another map shows (*b*) the state's top 5 percent of annual crash costs per mile. The darker the red, the higher the wildlife–vehicle collision cost and lower the percentage value.

mule deer, black bears, mountain lions, wild pigs, bighorn sheep, coyotes, pronghorns, and elk. Annual costs ranged from $0 per mile-year for highway segments with no recorded wildlife–vehicle collisions to $2,759,409 per mile-year for segments with high rates of collisions, including human-injury or human-fatality crashes, or both. These data can be used to develop regional or statewide prioritization maps to inform policy and funding decisions at larger extents.

Designing Crossings Around Wildlife Behavior

Several criteria are key for the success of wildlife crossing structures, but getting wildlife to approach the structures is probably the most important. Traffic noise and light can change animal presence and behavior (*10*, *11*) and potentially deter wildlife from approaching roadways, except in areas and for structures where noise and light are less disturbing due to traffic volumes, topography, and vegetation. Lighting intensities and types—including fixed-position and vehicle-based lighting—are increasingly recognized as an important source of disturbance for wildlife in the vicinity of transportation (*12*). Wildlife crossing structures often are designed to optimize wildlife use, but existing guidance in the field of wildlife crossing design does not inform designers, engineers, architects and habitat designers of the structural and vegetation elements that could reduce disturbance.

One solution to this problem is to use wildlife behavior and field measurements and modeling of light and noise produced by traffic to inform and test wildlife crossing design (*13*–*15*). The Road Ecology Center developed and tested three 3-D wildlife-responsive designs—noise/glare barriers, noise/glare barriers plus berm, and noise/glare barriers plus multiple berms—based on field measurements of traffic noise and light at the site of the proposed Wallis Annenberg Wildlife Crossing. The center found that a combination of berms and noise/glare barriers could be used to decrease disturbance in the crossing structure approach zones and create dark and quiet paths to increase the wildlife responsiveness of the designs (Figure 3).

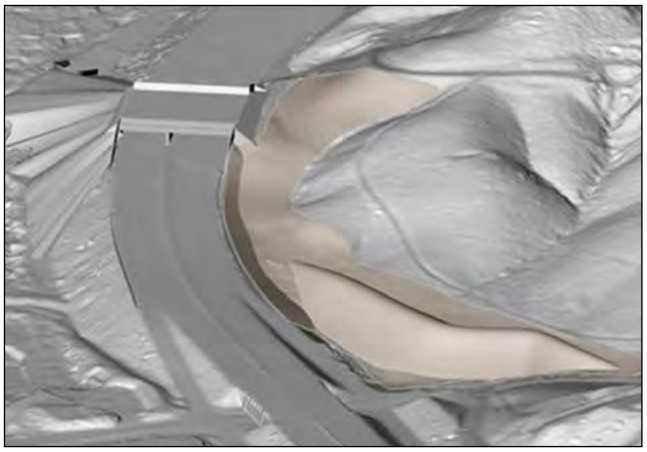

FIGURE 3 A 3-D model design of the approach zone to the Wallis Annenberg Wildlife Crossing over US-101. Tan areas were modified through virtual excavation and fill to create a quiet, dark path within the crossing structure.

Building a Replicable System of Structures

For wildlife crossing structures to become a standard and programmatic part of state DOT activities, the wildlife connectivity field must develop and endorse systematic and replicable approaches. The use of prefabricated bridge elements and systems (PBESs) offers solutions that provide significantly reduced on-site construction time, safety advantages, and convenience for human and wildlife travel, while minimizing environmental effects. PBESs address many constructability and financial challenges, often resulting in lower cost infrastructure and enabling more projects to be funded and constructed.

Prefabricated solutions are not a one-size-fits-all option but, rather, include elements that are fully engineered and fabricated to the specifics of each project application (Figure 4). Tailoring a standardized prefabricated solution—such as a bridge structure—to meet the needs of a specific project and location (or type of project) reduces design and construction

FIGURE 4 Installing a prefabricated wildlife overpass along I-90 Snoqualmie Pass East in Washington. (Source: Contech Engineered Solutions.)

costs. The use of prefabricated structural solutions results in accelerated construction time versus conventional solutions and efficient cost-effective long-term solutions. The implementation of PBESs provides turnkey solutions with the least material per waterway or environmental area versus conventional construction practices, while contributing to the goal of balancing wildlife connectivity and civil infrastructure.

Most Importantly, Did It Work?

Groups of wildlife crossing experts have published key guidance for determining whether wildlife crossing structures and other mitigations were effective (*16*). They propose using before–after control–impact study designs for the two stages in the road/mitigation project where researchers may become involved: at the beginning of a road/mitigation project and after the mitigation has been constructed, highlighting real case examples when they are available. These experts pose a number of questions that should be considered with regard to the location, size and type of structure, role of fencing, and relationship between the wildlife crossing structure and adjacent environment. Early involvement by scientists means that wildlife crossing designers can measure mitigation impacts more effectively, which will support future decision making.

A good current example of effectiveness monitoring is Washington State DOT's I-90 Snoqualmie Pass East Project.[4] As of fall 2022, the department had constructed the first half of the project, including 11 large wildlife crossing structures, 30 acres of restored habitats, and fencing to keep wildlife off the highway. The second half is well underway. A combination of trail cameras and live thermal and high-definition color video cameras continuously evaluate the efficacy of crossings, jump-outs (i.e., ramps allowing wildlife to escape from inside the fence), and fence-ends (i.e., where the fence line eventually stops). Academic researchers and students conduct systematic surveys to detect species often missed by cameras, including small mammals, amphibians, reptiles, fish, and bats. Across all monitored years, elk, deer, moose, black bears, cougars, bobcats, coyotes, and other common species—and a handful of rare ones like American martens and fishers—have been recorded using the structures (Figure 5). Furthermore, small mammal surveys revealed pika and flying squirrel use, snorkel surveys encountered giant salamanders and threatened bull trout crossing beneath new bridges, and radio-tagged western toads ventured across the overpass. The unusually intensive monitoring at completed structures and preconstruction sites is being used to inform future construction within the project area and beyond.

FIGURE 5 Captured on thermal video camera, a cougar uses the Snoqualmie Pass East underpass to cross beneath I-90.

Conclusion and Next Steps

Systematically approaching decision support for individual wildlife crossing structures and their programs is not only likely to speed up the rate of wildlife crossing structure implementation but also to provide the necessary economic, ecological, and engineering information to prove effectiveness in these domains. Planning and building individual wildlife crossing structures is similar to any transportation project, taking into account site-specific effects, needs, and conditions. Making the process of developing networks of wildlife crossing structures more systematic does not change this site specificity; however, it is likely to reduce delays, costs, and the effort required for each structure. Besides removing roads and traffic, wildlife crossing structures and fencing are among the most efficient strategies to improve safety and wildlife connectivity.

Acknowledgments

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[4] Take a look at the I-90 Snoqualmie Pass East Project at https://wsdot.wa.gov/construction-planning/major-projects/i-90-snoqualmie-pass-east-project.

Six Important Takeaways

1. Enhancement of existing structures for wildlife passage, or building of new structures, should be informed by data about wildlife–vehicle collisions, infrastructural barriers to wildlife movement, or evidence of wildlife occurrence and movement.
2. Building what is needed to solve the problem is critical and begins with "what is the problem?" Some common perceptions about crossings are misconceptions, but revisiting the objectives of a project can help.
3. Hotspots of wildlife conflicts with traffic can indicate where a well-designed structure can be placed to reduce mortality, restore connectivity, or both.
4. Wildlife are often sensitive to infrastructure and traffic. Designing crossings to respond to this sensitivity is an obvious way to make sure crossings are cost-effective and ecologically successful.
5. One barrier to the expansion of systematic programs of building wildlife crossing structures is the lack of standard and replicable approaches to building the structures. Prefabricated structures—refined to specific sites—could expedite wildlife crossing structure construction.
6. One of the most important aspects of decision making for wildlife crossing structures is choosing systems that work. One way to do that is to monitor the ecological and safety outcomes of wildlife crossing structure projects. Ecological outcomes go beyond just counting deer and elk and include consideration of a broad range of species, ecosystem functioning, and genetic connectivity.

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More to Explore

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VOLUNTEER VOICES

"The first time I attended the TRB Annual Meeting, I was lost in a sea of people! Once I visited the Standing Committee on Pavement Surface Properties and Vehicle Interaction, I found a home to anchor myself. During the following three decades, TRB greatly influenced my professional life. I started as a volunteer and committee friend. Since then, I have actively participated in reviewing papers, recording meeting minutes, writing research needs statements, forming task groups, running the committee as a chairperson, and promoting TRB around the world. My TRB experiences helped me grow professionally and network with world experts in pavement surface characteristics. Now, I am an emeritus member, with lifelong friends in the industry. Thank you, TRB!

—GEORGE K. CHANG
Director of Research
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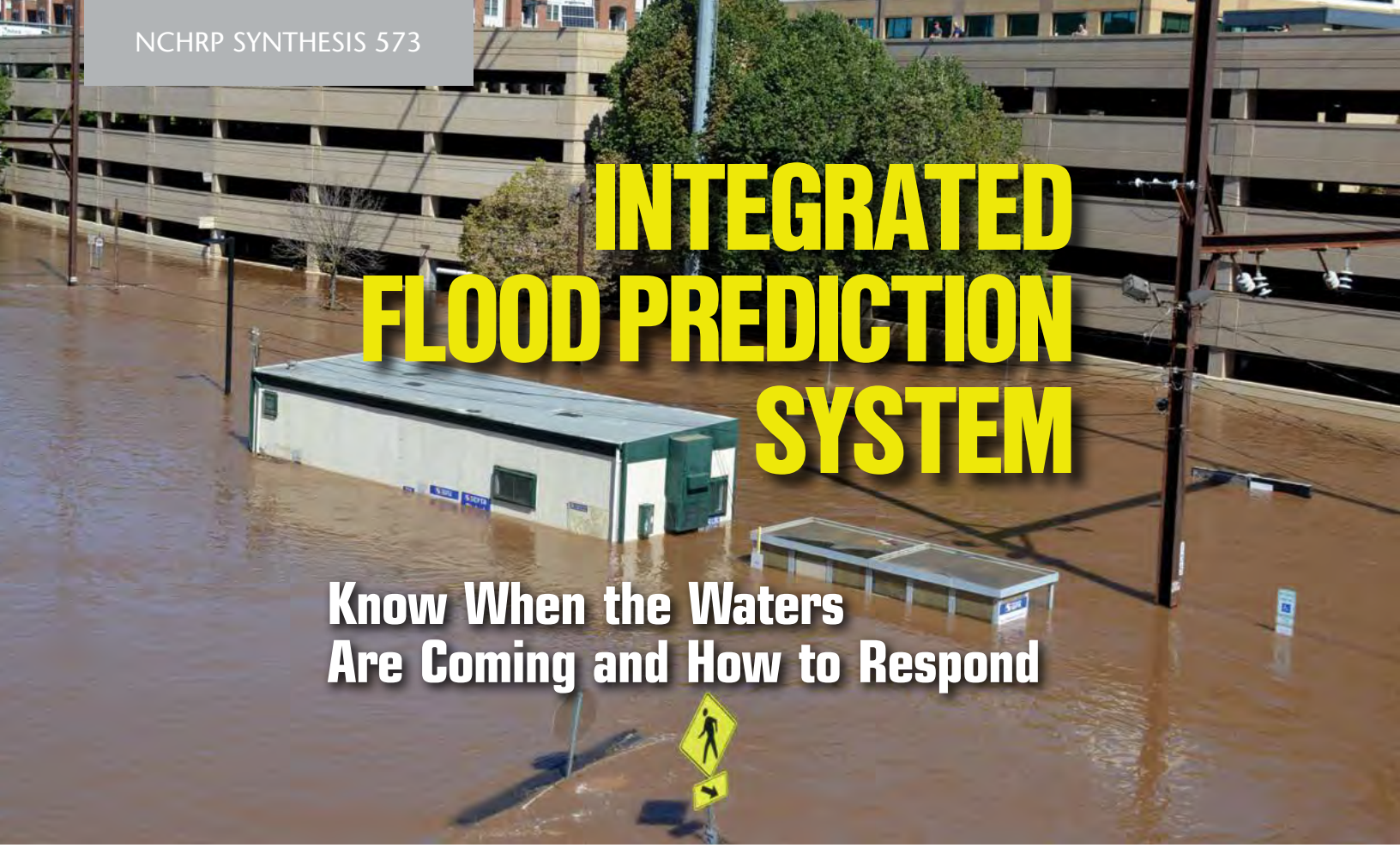
INTEGRATED FLOOD PREDICTION SYSTEM

Know When the Waters Are Coming and How to Respond



Michael M. Stokes, Wikimedia Commons, CC BY 2.0

SERI PARK

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Murky—and catastrophic—floodwaters inundated the streets of Conshohocken, Pennsylvania, brought on by the remnants of Hurricane Ida in 2021. Across the country, state departments of transportation and other state and local agencies are employing integrated flood warning and response systems. Their hope is that predicting the extent and severity of flooding will lessen economic—and human—losses.

As manifested during the Category 4 Hurricane Ida storm event in the summer of 2021, a critical issue facing state departments of transportation (DOTs) across the United States is to efficiently and precisely predict and respond to flooding. Recognizing that roadway and bridge flooding have significant economic effects, state DOTs and other state and local agencies have implemented integrated flood warning and response systems to mitigate those negative effects. In addition, accurately predicting the extent and severity of flood inundation; providing proper and timely alerts to the public about affected areas; and protecting the public from these hazards became major tasks for state DOTs and public agencies. *NCHRP Synthesis 573: Practices for Integrated Flood Prediction and Response Systems* focuses on identifying successfully implemented strategies and practices in managing critical flooding cases through a literature review, a nationwide survey sent to state DOTs, and in-depth interviews.

Literature Review Findings

A comprehensive literature review identified several issues, including data gaps in stream networks without monitoring gages, challenges in river modeling for backwater and coastal zones, and flood prediction difficulties stemming from the dynamic nature of intense runoff events increasing in frequency due to urbanization and land development.

Survey Findings

With a 94 percent survey response rate, the research team was able to identify various aspects of the approaches state DOTs are taking to address flood prediction and response systems. The survey covered the following five topic areas:

1. Current status of flood event management,
2. Flood monitoring,
3. Flood prediction,
4. Flood warning systems, and
5. Flood response systems.

The following sections present key findings in each topic area.

CURRENT STATUS OF FLOOD EVENT MANAGEMENT

Many states indicated that river flooding (e.g., overtopping banks) and surface overland flooding (e.g., due to poor drainage) are the two major types of flooding they experience. Heavy rain, storm surge, snowmelt, and sea-level rise were identified as flooding causes. Based on responses from 25 state DOT offices, overall safety enhancement (such as a reduction in death toll attributable to flood events and decreased crash frequency during heavy rain season), streamlined and collaborative interagency communication, and improved and reliable relationships were observed benefits of their successfully integrated systems.

Sharing the lessons learned from successful state DOT practices is essential for effective integration of flood prediction and response systems. In the survey, the team asked state DOTs for the top three lessons learned from their state's flooding over the past 15 years. Common responses to this question included making sure a plan is in place and being prepared for a flood event. Other common responses were ensuring good communication between agencies and being proactive, rather than reactive.

FLOOD MONITORING

When asked about the methods and practices state DOTs use for flood monitoring, the U.S. Geological Survey's National Water Information System was the most widely used. Based on responses from 30 state DOTs, improved emergency response and understanding of maintenance needs are ranked as top observed benefits of state DOT flood monitoring systems. According to 47 state DOT responses, the most common method they employed to determine the extent and severity of flooding is visual inspection. Other identified methods for assessing the extent and severity of flooding on infrastructure include public reporting, external agency reporting, and application of sonar sensor and drone footage.

Sgt. Devon Bistarkey, U.S. Army National Guard, Flickr, CC BY-ND 2.0

In Ida's wake, aviators from U.S. Army National Guard North Carolina Detachment 1 Bravo Company, 2nd 151st Aviation Regiment conducted aerial search missions. As they scanned for individuals in distress in homes—such as this one, engulfed in flood waters—and other structures, they witnessed the extensive flooding along North Carolina's Cape Fear River near New Bern, Wilmington, and Lumberton.

FLOOD PREDICTION

A hydrologic/hydraulic model was identified as the most common type of flood prediction model used by state DOTs. Figure 1 shows more information about flood prediction platforms and models used by the states.

FLOOD WARNING SYSTEMS

To further understand how state DOTs evaluate the importance of information used within their flood warning systems, they were asked to use a scale of one to eight stars, from least to highest importance, as a ranking method. Observed stream stage, bridge scour, and observed stream inundation were identified by state DOTs as the most important ranked information used in their flood warning systems. In contrast, they typically ranked model precipitation and model inundation information as relatively less important than these other factors.

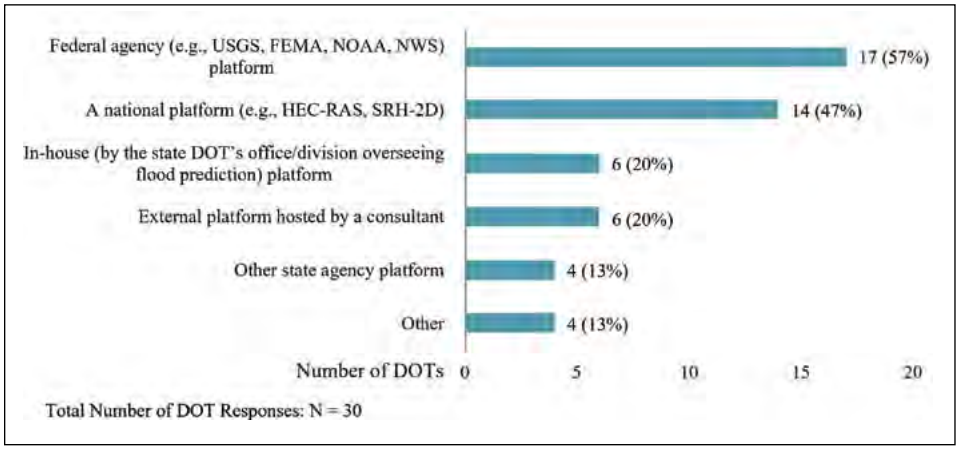

FIGURE 1 Reported flood prediction platforms and models used by states. The 30 survey respondents were allowed to select multiple answers. (Source: NCHRP Synthesis 573.)

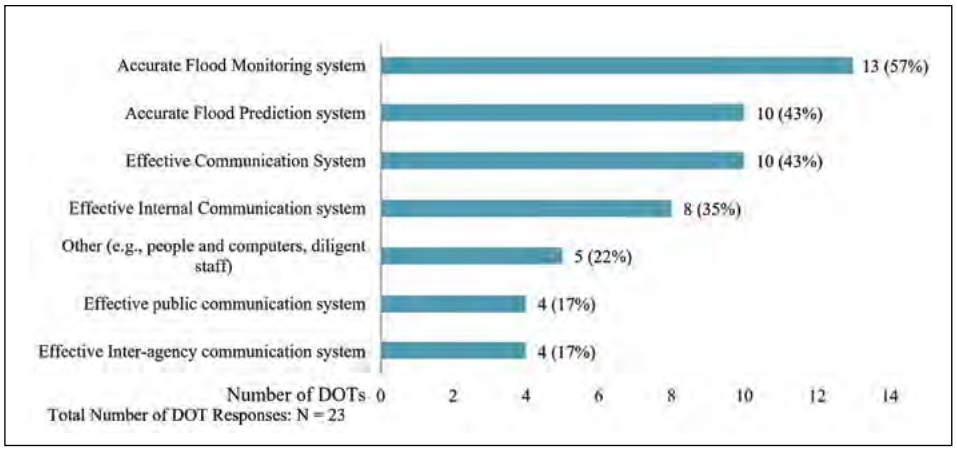

FIGURE 2 Reported key factors and attributes that have led to successful flood warning systems. The 23 survey respondents were allowed to select multiple answers. (Source: NCHRP Synthesis 573.)

Identifying the key factors and attributes that lead to a successful flood warning system was also a major task in the research project. Based on 23 responses, state DOTs reported accurate flood monitoring and prediction systems among the most essential factors and attributes for success (Figure 2).

FLOOD RESPONSE SYSTEMS

According to 34 state DOT responses, cooperation from local agencies in the state, adequate state resources for staffing and funding, and continuous public awareness campaigns regarding emergency response and warning systems were reported as key factors and attributes that have led to successful flood response systems.

Survey results also echo many challenges that state DOTs are experiencing in other areas. Many reported state resources (such as staffing, funding, and turnover), data coverage, and technical expertise as common challenges in implementing flood prediction models and flood warning systems. Survey results also show that impediments to implementing a successful flood monitoring system include these same state resources.

Interview

Based on the survey results and literature review, the team applied several criteria to select states to serve as case examples. The states' reported degrees of success with integrated systems for flood prediction and response, geographic and physiographic distribution, differing flood causes and types, different types of land cover and development, and population densities were considered when conducting in-depth interviews. Ultimately, these selection factors yielded a diverse group of states that face a range of challenges and practice innovative solutions. Figure 3 maps the selected states and provides notable features considered for selection. Through this process, seven case examples—Idaho, Iowa, New York, North Carolina, South Carolina, Texas, and Washington—were selected.

IDAHO

Key attributes for the Idaho DOT's successful flood monitoring program include the application of BridgeWatch software and efforts by the Scour Committee, a standing committee composed of a diverse group of engineering disciplines within the Idaho DOT. Notably, the interview showed that regular updating of BridgeWatch inputs and constant monitoring of its outputs contributed to success in flood management.

IOWA

The Iowa DOT has successfully implemented BridgeWatch for flood monitoring. In addition, collaboration with the Iowa Flood Center, at the University of Iowa College of Engineering, and use of the center's Iowa Flood Information System has led to a successful flood prediction program, a vital element for effective flood management.

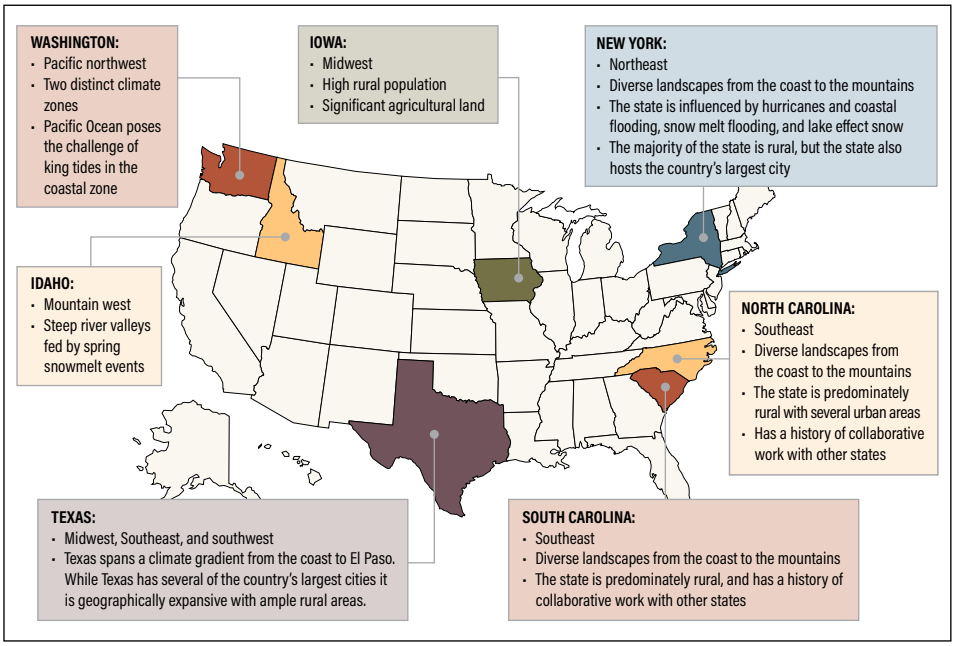

FIGURE 3 Locations and notable features of state DOTs selected as case examples. (Source: NCHRP Synthesis 573.)

Cathy Frye, Flickr, CC BY 2.0

When Reynolds Channel is as smooth as glass, it is hard to fathom the devastation that Hurricane Sandy brought to this same spot in Point Lookout, New York, on the eastern edge of one of Long Island's barrier islands 10 years ago. Long Island, the largest and longest island in the contiguous United States, is home to countless low-lying coastal areas just like this one—all of which are vulnerable to flooding.

NEW YORK

New York has applied hydraulic vulnerability assessments, flood warnings, flood watches, and post-flood inspection programs to maintain safe bridges during flooding events. Another notable feature is the state's work with the U.S. Geological Survey on developing and updating equations in geospatial application StreamStats to account for the differences in geology and groundwater present on Long Island.

NORTH CAROLINA

Developed by the North Carolina Emergency Management Division, the Flood Risk Information System aids in the collection and storage of flood data used statewide by more than 650 municipalities and state agencies. Furthermore, the Flood Inundation Mapping and Alert Network (FIMAN) System, used by North Carolina DOT, is recognized as one of the most robust surface transportation flood warning systems in the United States. The best illustration of North Carolina DOT's efforts to manage flooding, FIMAN provides critical statewide information in real time for first responders and recovery efforts. FIMAN-T—the transportation-specific version—is currently under development. This application will leverage FIMAN's success to provide a similar enhancement to North Carolina DOT's operational emergency preparedness and response capabilities.

SOUTH CAROLINA

Between 2015 and 2018, South Carolina experienced major storm events such as Hurricane Matthew in 2016 and Hurricane Florence in 2018. In response, South Carolina DOT enhanced its interagency communication, data sharing, and event management collaboration, thus gaining a deeper understanding of other agencies' activities, data, and tools for flood management. Furthermore, the use of BridgeWatch software allowed South Carolina DOT to view its bridge locations in a geospatial format with rainfall event and rainfall prediction data.

TEXAS

Texas DOT has made a well-coordinated effort to address emergency flood management. To better ensure emergency responders' safety, Texas DOT provides an application programming interface data feed for emergency response agencies, which improves coordination and acceleration of flood management efforts. Texas DOT also is engaging in research to improve streamflow measurement at its bridges, as well as to explore improved predictive modeling based on methods from the National Oceanic and Atmospheric Administration's National Water Model.

WASHINGTON

By incorporating climate predictions into their design criteria, Washington State DOT aims to anticipate flood events. It is also committed to improving its database management to clarify content and ownership for facilitating data sharing. Through a statewide Watch List, Washington State DOT oversees critical flooding locations that are monitored by region-specific maintenance crews.

Lessons Learned and Research Roadmap

The literature review, state DOT survey, and interviews provided a sound understanding regarding the practices that support effective flood prediction and

response systems, key components of flood management. BridgeWatch; National Water Information System; and close working relationships among state DOT divisions, other state agencies, and federal offices often are cited as common tools for success. Furthermore, sharing a coordinated and updated asset inventory document with key state DOT personnel is a vital approach to keeping departments informed. Many state DOTs also reported that continual advances in technology (e.g., data models, sensors, and geographic information systems) have made data collection and communication between stakeholders easier and improved the coordination of model prediction efforts.

Eric, Flickr, CC BY 2.0

King Tides occur when the orbits and alignment of the Earth, Moon, and Sun combine to produce the greatest tidal effects of the year. These highest of high tides can routinely cause coastal flooding, as shown here in Sausalito, California, on December 4, 2021.

Other observed challenges include hurdles to data collection and sharing because of siloed data and other data issues. Consequently, there is a need for research that explores novel opportunities to facilitate database sharing and integration. NCHRP Synthesis 573 also points to the need for improvement in real-time flood model predictions, especially for backwater flow conditions and hydrologically complex areas [e.g., snowmelt flooding or King Tides (the highest of high tides)]. Real-time monitoring systems at state DOTs could be enhanced with more widespread adoption of BridgeWatch or similar software.

Although this article highlights key content from the synthesis, the report findings will need future updates, in light of the evolving nature of data collection and information technology.

VOLUNTEER VOICES

“Marine transportation was not my area, but it’s fascinating! The ability to link continents and countries by ship, cargo, and people is a technological wonder humans have developed since the start of civilization. There have been no such great technology developments for other modes of transportation. Nowadays, marine transportation doesn’t normally get any news coverage—except recently, with the logistics difficulties we are currently having.

—ALFONSO CORREDOR
Senior Policy Advisor (Retired)
Toronto, Ontario, Canada

Keep It Moving! Maintaining the Global Vaccine Supply Chain

U.S. DOD Navy Petty Officer 1st Class Carlos M. Vazquez II, Flickr, CC BY 2.0

RAVI ANUPINDI, PRASHANT YADAV, AND ELIZABETH ASHBY

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One among thousands, this vial of COVID-19 vaccine was prepared to be administered at Walter Reed National Military Medical Center in Bethesda, Maryland, on December 21, 2020. Every step of the vaccine's trip from lab to arm offered unforeseen roadblocks and lessons learned that are now becoming a blueprint for the future.

The global COVID-19 pandemic has exposed serious weaknesses in the supply chain for vaccines and medical products. Global actors and U.S. government agencies have historically promoted reactive (rather than proactive) approaches to pandemic preparedness, resulting in a supply chain that was ill-prepared to meet the immense global vaccine demand. The supply chain challenges have, in turn, exposed major weaknesses in the mechanisms of global coordination.

The Advancing Pandemic and Seasonal Influenza Vaccine Preparedness and Response Initiative, launched by the National Academy of Medicine with support from the Office of Global Affairs at the U.S. Department of Health and Human Services (HHS), explores how the scientific and technological breakthroughs throughout the COVID-19 pandemic could inform and advance future pandemic and seasonal influenza vaccine preparedness and response efforts. Of the four reports produced from this initiative, *Globally Resilient Supply Chains for Seasonal and Pandemic Influenza Vaccines*[1] provides recommendations on how to enhance global vaccine development and manufacturing infrastructure and bolster vaccine distribution for

[1] The full publication is available at https://www.nap.edu/catalog/26285/. The suite of reports can be found at https://www.nationalacademies.org/our-work/advancing-pandemic-and-seasonal-influenza-vaccine-preparedness-and-response-harnessing-lessons-from-the-efforts-to-mitigate-the-covid-19-pandemic.

pandemic and seasonal influenza events, using lessons learned from COVID-19 and other infectious disease outbreaks. This article highlights select parts of the report that discuss transportation as a crucial element of preparedness.

While the world is still struggling to manage the challenges in the global COVID-19 vaccine supply chain, global institutions and vaccine industries need to prepare for a more robust vaccine supply chain to deal with future disease events. Global health experts have long warned of the risks of influenza variants with the potential to cause a pandemic. Seasonal influenza is also a significant threat, accounting for an estimated 3 to 5 million cases of severe illness and 290,000 to 650,000 deaths annually worldwide (*1*).

Vaccine manufacturing and distribution are complex tasks. They require hundreds of components, globally distributed high-quality biologic manufacturing capacity, a competent manufacturing and supply chain workforce, data and information tools, and financial resources for fast distribution and equitable deployment of vaccines.

In a global end-to-end supply chain, actions for different parts of this supply chain are taken by different agencies and actors—from private firms to national governments, regional structures, global and United Nations agencies, and nongovernmental organizations. Developing a robust and resilient supply chain relies on coordination to establish reliable means of procurement and transit within this vast and complex network. This includes ensuring the supply and movement of critical vaccine components to manufacturing facilities, as well as the equitable distribution of finished vaccines to their final destinations. Supply chain inefficiencies have resulted in reduced capacity of manufacturing facilities to produce vaccines, as well as an inability to maximize storage of finished vaccines and efficiently deliver them to points of administration.

Critical Components for Vaccine Manufacturing

Meeting the global need for influenza vaccines depends first on sustainable vaccine manufacturing. This upstream component of the vaccine supply chain requires procurement and delivery of numerous critical components to a limited number of influenza vaccine manufacturing facilities, which are largely consolidated in high-income countries. To produce vaccines, these facilities may require "9,000 different materials sourced from some 300 suppliers across approximately 30 different countries" (*2*). Manufacturers also must procure the materials needed to produce vaccines that are not components of the vaccine itself. These include glass vials, tubing, disposable bags, and stabilizing agents (*3*). Supply chains must be equipped to handle this volume of component distribution, both to "operate at one scale during 'normal' years of seasonal influenza and to dramatically scale-up during a pandemic" (*4*).

Distribution and Delivery

The downstream end of the supply chain encompasses vaccine delivery from manufacturing facilities to target countries, and then to points of administration. Both segments of the downstream supply chain pose challenges. For example, the ability to transport vaccines and needed materials to countries often relies on commercial flights for shipping cargo (*5*). The global supply chain was disrupted during the COVID-19 pandemic because of flight cancellations, trade restrictions, and closed national borders, all of which restricted the flow of goods (*6*). Low- and middle-income countries (LMICs) also experienced challenges with vaccine storage and delivery during the COVID-19 pandemic (*3*).

Administering vaccines requires carefully orchestrated global and in-country logistics. Poorly managed logistics systems can disrupt vaccination campaigns, lead to shortages of immunization-related supplies, and cause overstocking of the influenza vaccine, all of which can increase vaccination program costs. Data are critical to establishing and maintaining a well-managed influenza vaccine logistics system; however, existing tools are often limited.

Effective global vaccine distribution in a pandemic relies on the existence, coordination, and successful operation of a collection of robust and responsive systems reporting real-time information. These systems include physical infrastructure for transportation, storage, distribution, and delivery to individuals.

UNICEF, Flickr, CC BY 2.0

Although special containers traveled as refrigerated cargo and arrived at international airports capable of cold handling, the journey to points of administration proved more challenging for many low- and middle-income countries. Whether in countries large or small, rich or poor, all supply chains faced unique challenges. Globally, wherever the vaccine was needed, so were new logistics systems and handling procedures.

TRANSPORTATION CAPACITY AND COLD CHAIN LOGISTICS

Transportation capacity and cold chain considerations are primary logistical constraints in the transportation of vaccines from a manufacturer to the recipient country. Multilateral organizations, such as UNICEF (now the United Nations Children's Fund) and Gavi, the Vaccine Alliance, assist in this transport. Transportation capacity is often strained during a public health emergency and can delay the delivery to a country's point of entry. As seen in the COVID-19 pandemic, a drastic reduction in the number of commercial flights significantly reduces the available volume of cargo space, thereby limiting vaccine transport (*7*). In addition, personal protective equipment, ancillary supplies, treatment products, and other materials needed for emergency response all compete for limited space in transportation systems. Within transportation systems, safe vaccine delivery depends on reliable cold chain capacity. Different vaccines have different temperature requirements, which in turn affect transportation logistics. COVID-19 vaccines that use messenger RNA (mRNA) technology, for example, require ultra-cold storage temperatures of −20°C to −70°C (±10°C) (*8*, *9*). Although current influenza vaccines are generally stored within a range of 2°C to 8°C, cold chains are broadly recognized as a bottleneck in low-resource settings, due to equipment and energy requirements, even at these standard refrigeration temperatures.

Limited storage capacity and inefficient distribution and logistics systems have long been bottlenecks in the supply chain, particularly for LMICs (*10*). The development of mRNA vaccines for COVID-19 brought this challenge to the fore and, in response, the manufacturers of those vaccines have developed detailed logistics plans and special insulated containers to ensure that their vaccines get to the intended recipients (*9*). In addition, major delivery companies invested in new storage facilities for cold chain management that are expected to prove useful after the COVID-19 pandemic is over. Many major cargo handling airports already had extensive temperature-controlled handling facilities with direct apron (tarmac) access. Frankfurt Airport, for example, has approximately 12,000 square meters of temperature-controlled handling capacity—including 8,000 square meters (86,111 square feet) at the Lufthansa Cargo Pharma hub—that meets all international standards (*11*). Abu Dhabi has also made significant investments for cold chain transportation in its international airport, with the intent to serve as a hub for global pharmaceutical logistics (*12*). The International Air Transport Association has a program for certifying airports as pharmaceutical freight hubs capable of safely and efficiently handling temperature- and time-sensitive pharmaceuticals, including vaccines. In June 2021, the association updated its guidance for vaccine and pharmaceutical logistics and distribution (*5*).

Various international aid organizations have invested substantial funds in developing global cold chain equipment and services for distributing vaccines. UNICEF, for example, procured close to $100 million worth of cold rooms, refrigerators, cold boxes, and insulated vaccine carriers, primarily to deliver vaccines for administration to children. The United Nations Environment Programme notes, however, that even for countries with effective childhood vaccine distribution, "the sheer scale and urgency of mass . . . vaccination"

Arriving inside Ethiopian Airlines Cargo facilities on March 7, 2021, the first COVID-19 vaccine delivery totaled 2.2 million doses and was made possible via the COVID-19 Vaccines Global Access (COVAX) Facility. COVAX was created with the goal of the equitable distribution of COVID-19 vaccines globally.

UNICEF/Ethiopia, Flickr, CC BY-NC-ND 2.0

In Madagascar, workers unload COVID-19 vaccines donated by the United States in November 2021. The vaccines are held in high-performance temperature-controlled parcel shippers developed specifically for ultra-low temperature applications. Once unloaded, vaccines would have been held in an ultra-cold freezer before distribution.

USAID/Madagascar, Flickr, CC BY-NC 2.0

during a pandemic, such as COVID-19, would be very difficult for "countries with large rural populations" (*13*). Transportation considerations also are important in planning for reverse logistics, when unused vaccines are returned to be redistributed (if appropriate) or destroyed. This process requires supply management and storage at every level of the supply chain (*14*). Stringent procedures for redistributing or destroying vaccines are important for maintaining public safety.

Product and ancillary supplies could follow multiple pathways to a country. Global logistics (from manufacturer to country port of entry) require complex coordination of multiple agencies, receiving countries, manufacturers, and logistics providers. A pandemic context places strains on transport capacity that could affect flow of materials and products across the end-to-end supply chain. Better pre-pandemic planning is required to anticipate issues and address them.

The physical supply chain, from cold chain considerations to transport capacity, is already stressed in LMICs. Once vaccines reach a recipient country, it is that country's responsibility to transport vaccines to points of distribution and administration. Transportation capacity in LMICs is highly variable, which has significant effects on speed and efficiency of vaccine rollout. Current capacity is already insufficient to cover pediatric immunization platforms, which are the most globally developed and reliable vaccine supply chains. Since 2010, the number of vaccines introduced into LMICs has increased due to programs to increase global access to vaccines, such as the Expanded Program on Immunization. These introductions often require changes to immunization programs, which may alter other logistical and transport needs to achieve vaccination targets. The growing complexity of these systems has to be considered when incorporating new vaccines (*15*).

VACCINE DELIVERY AND ROLLOUT

Vaccine delivery, where vaccines will be administered, is the final step in distribution. Delivery systems vary based on the source of the vaccines and the location of delivery. In the United States, routine vaccines, and recently COVID-19 vaccines, are ordered from the federal government by states, territories, and local jurisdictions and fulfilled through a federal system. The Vaccine Tracking System is used to make orders and log data related to vaccine delivery (*16*). There is an exception even for this system, as Pfizer-BioNTech has its own system to deliver COMIRNATY vaccines.

Many LMICs receive vaccines, which are not produced domestically, from multilateral procurement and delivery institutions, such as UNICEF and Gavi, the Vaccine Alliance. Once vaccines arrive in the target country, the national government becomes responsible for delivery to the final destination. In LMICs, vaccines are often transported from the country point of entry to a national distribution center and then transported further downstream to local distribution points or to the vaccination site. This "last-mile" delivery is subject to several challenges, particularly in settings with limited resources. Lack of funding to deliver vaccines is a critical issue. Personnel, cold chain requirements, and transportation costs all can serve as added challenges to vaccine transportation funding, particularly in a pandemic scenario when a significant portion of the population is targeted for vaccination. Additional delivery costs for COVID-19 vaccines for the average LMIC are estimated to represent nearly 20 percent of the entire pre–COVID-19 health budget (*17*). Likewise, the operational cost of getting influenza vaccines to people is significant, placing a high burden on some LMIC budgets. Beyond standard transportation and distribution costs, human resource capacity for distribution and delivery is a major challenge. There are significant gaps in funding of these operational expenses. In addition to the cost, poor infrastructure often serves as a barrier to scale-up vaccine rollout efforts. There is a need to determine effective ways to resource in-country distribution and delivery.

In LMICs, primary care centers often serve as the main access point for vaccines. Vaccine uptake in these settings may be influenced by the relationship between the health care facilities and the local community. Health care workers commonly engage in community outreach activities, such as school programs, which can bolster trust in and increase knowledge of vaccines (*15*). Efforts to increase vaccine access must account for these structural and financial barriers to last-mile delivery, also accounting for local dynamics to increase vaccine uptake.

DESIGN FOR DISTRIBUTION

Vaccine characteristics have implications for downstream distribution and administration, particularly in low-resource settings. This is evident from the COVID-19 vaccine rollout. Single-dose vaccines were a lesser strain on supply chain infrastructure than two-dose vaccines. Vaccines that were stable at higher temperatures also reduced the energy and equipment requirements in the cold chain. As new influenza vaccines are developed in the future, vaccine characteristics should be accounted for early in the development process to facilitate distribution in LMICs. Longer shelf life and fewer needed doses could reduce wastage and the amount of vaccine that needs to be transported. Routes of administration (such as by injection or oral) that require fewer ancillary supplies may reduce the amount of space needed in transportation. Accounting for supply chain constraints at the beginning of the vaccine design process can increase access by facilitating use in a variety of contexts, particularly in low-resource settings.

Moving Forward

Using lessons learned from COVID-19, the report offered recommendations on how to bolster vaccine distribution and enhance global vaccine development and manufacturing infrastructure for pandemic and seasonal influenza events. Transportation and distribution issues were integrated into these recommendations, which addressed end-to-end supply chain preparedness and response. The committee recommended that the G20 countries[2] should constitute a global pandemic manufacturing and

[2] The G20 is an intergovernmental forum comprising 19 countries and the European Union.

USAID/Sudan, Flickr, CC BY-NC 2.0

In Sudan, this USAID-supported ultra-cold freezer unit kept vaccines fresh for distribution in communities. Prior to the COVID-19 pandemic, it was rare to see this type of freezer outside of a lab setting, especially in low-income countries. From this point, the last mile of the vaccine's trip also proved challenging in some countries and rural locations.

supply chain task force as a permanent structure to ensure global pandemic influenza manufacturing and supply chain preparedness and response. This would provide needed governance and increase collaboration to streamline the global vaccine supply chain.

The committee also provided guidance to U.S. government entities. The committee stated that HHS, in partnership with global stakeholders, should ensure a systems approach to the design and development of vaccines for feasible distribution and delivery in various global contexts and support relevant innovations. Encouraging development of vaccines that are practical for a variety of contexts is a step toward increasing global vaccine access and reducing supply chain burdens. HHS, the committee agreed, also should fund a comprehensive review of innovations developed and deployed during the COVID-19 pandemic. The review should cover critical areas, such as regulatory approval, manufacturing, global and in-country distribution, delivery, and lessons learned, and it should identify innovation gaps for future pandemic preparedness and response. The Office of Global Affairs, with other agencies in HHS and the World Health Organization's Expert Committee on Influenza, should periodically convene to identify the challenges in global preparedness for influenza, as well as overall preparedness for emerging pathogens, thereby benefiting from the lessons learned from recent disease outbreaks to address global supply challenges. These recommendations encourage global entities to leverage the lessons learned from COVID-19, developing systems that are more efficient and proactive in preparing for future disease events. This report emphasizes the critical role of transportation, delivery, and logistics in global health security.

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14. World Health Organization and UNICEF. COVID-19 Vaccination: Supply and Logistics Guidance. 2021. https://www.who.int/publications/i/item/who-2019-ncov-vaccine-deployment-logistics-2021-1.
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Additional Resources

Beware of Errors When Preparing Pfizer–BioNTech Covid-19 Vaccine. *Pharmacy Today*, Vol. 27, No. 5, 2021, p. 37.

Sparrow, E., J. G. Wood, C. Chadwick, A. T. Newall, S. Torvaldsen, et al. Global Production Capacity of Seasonal and Pandemic Influenza Vaccines in 2019. *Vaccine*, Vol. 39, No. 3, 2021, pp. 512–520.

National Cooperative Highway Research Program

60 Years of Collaboration in Applied Transportation Research

Vincent Desjardins, Pxhere, CC BY 2.0

ANN M. HARTELL

The author is a senior program officer at the Transportation Research Board of the National Academies of Sciences, Engineering, and Medicine in Washington, DC.

A bird's eye view of a multimodal Chicago interchange represents a compendium of applied transportation research improvements made in the past 60 years, as well as the promise of advancements yet to come.

In 1962, the leadership of the American Association of State Highway Officials (AASHO), the predecessor of today's American Association of State Highway and Transportation Officials (AASHTO), established the National Cooperative Highway Research Program (NCHRP) with the goal of a coordinated research program that could address problems of wide interest to state departments of transportation (DOTs). Each year, the state DOTs allocate a share of their federal transportation dollars to NCHRP to work on shared issues identified by state DOT staff and FHWA. Managed by TRB and housed within the National Academies of Sciences, Engineering, and Medicine in Washington, DC, NCHRP's overall mission is to provide objective, evidence-based advice to the nation.

One key feature of NCHRP is its emphasis on involving stakeholders. The practitioner community is involved from the beginning, identifying research ideas to address their day-to-day problems. These ideas are then reviewed and prioritized by the broader practitioner community, which works to build an annual research program that will directly benefit transportation practitioners.

Each NCHRP research project is developed and executed under the direction of a project panel, a small group of individuals who are appointed based on their expertise, qualifications, and ability to bring the needed perspectives to the topic (Figure 1, Page 21). The research is conducted by contractors—universities, private-sector firms, nongovernmental organizations, and others—who are selected through a competitive process.

For 60 years, NCHRP has taken on the wide variety of technical and policy issues faced by state DOTs (Figure 2, Page 21). The program stands ready to provide state DOTs with the information and advice they need for the challenges to come.

To view the NCHRP 2021 Annual Report*, visit https://onlinepubs.trb.org/onlinepubs/nchrp/nchrpannual2021.pdf.*

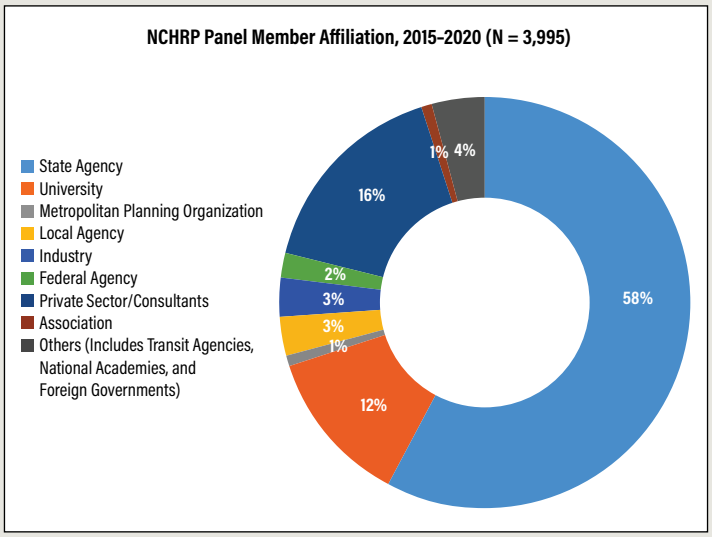


FIGURE 1 An appointed panel of subject matter experts and practitioners oversees each NCHRP project. More than half of these volunteers are staff from state DOTs, who are joined by private sector consultants, academics, staff from local and regional transportation agencies, and other organizations.

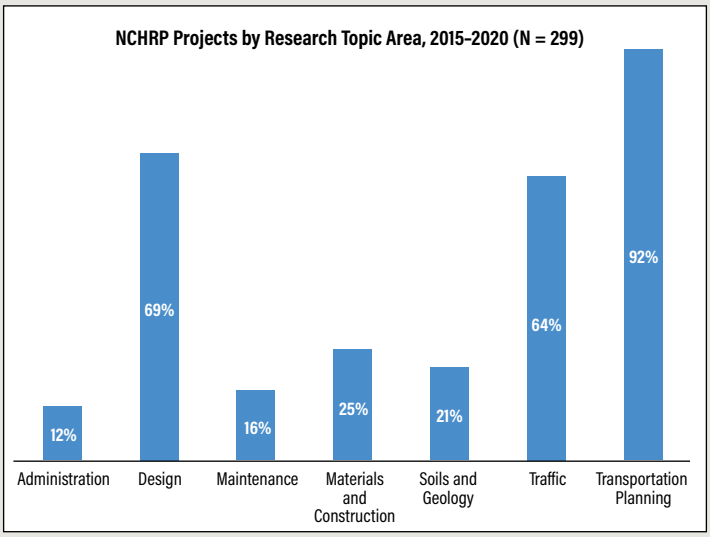


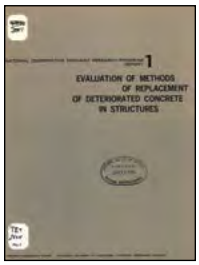
FIGURE 2 Of nearly 300 NCHRP research projects initiated from 2015 through 2020, one-third focused on planning and environmental issues, followed closely by infrastructure design and traffic topics. (Note: Does not include 437 continuations and special projects.)

NCHRP Milestones

1962

On June 19, an agreement establishing NCHRP is signed by AASHO (AASHTO predecessor), the Bureau of Public Roads (FHWA predecessor), and the National Academy of Sciences.

1964



NCHRP Report 1: Evaluation of Methods of Replacement of Deteriorated Concrete in Structures describes methods to replace concrete bridge decks and evaluates materials and methods in use.

1967

AASHO authorizes TRB to establish NCHRP Project 20-05, "Synthesis of Information Related to Highway Practices." This continuing project documents available information into concise reports on relevant topics for highway administrators and engineers.

1992

NCHRP initiates the Highway IDEA (Innovations Deserving Exploratory Analysis) Program to explore concepts and test prototypes that have the potential to significantly advance the state of the art and practice.

1987

NCHRP Project 20-24, "Administration of Highway Agencies," begins. Research topics focus on the concerns of chief executive officers and other top managers of state DOTs.

1975

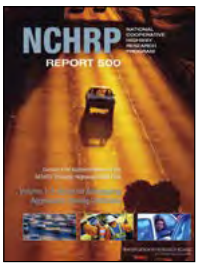
NCHRP Report 156: Transportation Decision-Making: A Guide to Social and Environmental Considerations is published. This report provides practical methods to help state DOTs implement the National Environmental Policy Act of 1969.

NCHRP Milestones (Continued)

1997

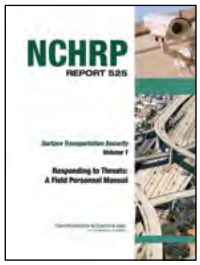
NCHRP Web-Only Document 1: Smoothness Specifications for Pavements is published. Web-only documents are fully searchable PDFs. These reports often provide the detailed technical information that underpins an NCHRP report.

2003



Volume 1 of *NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan* is published. This 23-volume series provides guidelines for transportation agencies to reduce injuries and fatalities in key AASHTO emphasis areas.

2004



In the aftermath of the 9/11 terrorist attacks, the first volume in the *NCHRP Report 525: Surface Transportation Security* series is published. This series covers security and emergency management topics.

2011

NCHRP Report 700: A Comparison of AASHTO Bridge Load Rating Methods is published. The report analyzes 1,500 bridges and includes proposed revisions to the *AASHTO Manual for Bridge Evaluation*.

2010

NCHRP research projects inform a great deal of AASHTO's first edition of the *Highway Safety Manual*, an essential reference for quantitatively evaluating traffic safety on existing or proposed roadways.

2007

NCHRP Project 20-68A, "U.S. Domestic Scan Program," begins. Scan projects combine background research with field visits by practitioners. They document innovative practices and encourage their dissemination and adoption.

2014

NCHRP Project 20-102, "Impacts of Connected Vehicles and Automated Vehicles on State and Local Transportation Agencies," starts. This project focuses on research topics related to connected and automated vehicles.

2015

NCHRP Legal Research Digest 1: Buy America Requirements for Federally Funded Rail Projects is published. This series provides concise legal history and presents regulatory and statutory requirements.

2020

NCHRP Research Report 963: A Pandemic Playbook for Transportation Agencies is published jointly with *TCRP (Transit Cooperative Research Program) Research Report 225*. This ready reference covers what needs to be done, when, and by whom during the COVID-19 pandemic and for future pandemics.

2023

The NCHRP FY 2023 program funds 58 new projects totaling $32.5 million. Topics span infrastructure improvements, extreme weather adaptation strategies, social equity, knowledge management, pedestrian and bicyclist safety, fuel taxes, highway–rail grade crossings, and more.

2022

NCHRP WebResource 1: Reducing Greenhouse Gas Emissions: A Guide for State DOTs publishes. The online format is designed to be easy to share and use collaboratively within a state DOT. Another milestone, *NCHRP Research Report 1000: Accessibility Measures in Practice—A Guide for Transportation Agencies* is published.

2021

NCHRP Project 07-29, "Development of the 8th Edition of AASHTO's *A Policy on the Geometric Design of Highways and Streets (Green Book),*" begins. Updates will tap current knowledge and evolving practices.

Measuring What Matters

ANN M. HARTELL

The author is a senior program officer for the Transportation Research Board of the National Academies of Sciences, Engineering, and Medicine in Washington, DC.

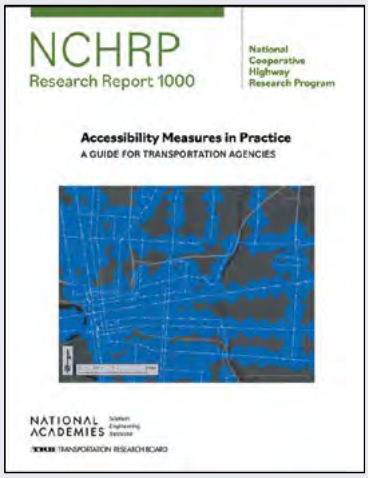
Accessibility—the ease with which people can reach valued destinations—is an essential concept for transportation planning and investment decisions. Measures of accessibility provide important information to transportation agencies and can be a key element in evaluating the performance of the transportation system in meeting human needs. Accessibility measures offer a user-centric approach to evaluating transportation investment options: cutting across or comparing modes, geographic areas, and population groups. Measures of accessibility go beyond how people move on the transportation network and link transportation with land use, making them essential for understanding and shaping many desired outcomes. For example, a measure of the number of jobs that can be reached within a 30-minute commute can reveal which investments are most likely to support economic development. A measure of access to health care services can highlight specific transportation needs for elderly populations. Accessibility measures can support an analysis of equity, bringing to light which demographic groups and neighborhoods need better connections to schools, food stores, parks, and jobs. Although many transportation agencies are interested in adopting data-driven approaches to investment decisions, some find accessibility to be challenging to implement. Accessibility measures can require large amounts of detailed data or be difficult to explain to nontechnical audiences. The wide array of available measures from the research literature and vendors can make it difficult to select a measure.

Omar Ram, Unsplash

Access is a powerful tool. It can mean getting to work on time or struggling, being close to needed medical care or putting it off. Good access—such as well-located bus stops—can make life easier.

NCHRP Research Report 1000: Accessibility Measures in Practice—A Guide for Transportation Agencies provides a review of common approaches to measuring accessibility and a step-by-step approach to selecting a measure that best fits a particular decision-making context. The report describes key considerations and differences among available measures, data sources, tools and methods for calculating measures, and keys to communicating the meaning of the results to stakeholders and partners. Underpinning the guide is extensive research into current practice, a review of published research, and pilots of the approach with several agencies. The report provides a concise, practitioner-ready, and up-to-date explanation of how and why accessibility measures can be used by transportation agencies.

The full report is available at https://doi.org/10.17226/26793.



One thousand published research reports—and counting—make a wide range of NCHRP highway research available to the world.

"One key feature of NCHRP is its emphasis on involving stakeholders."

Transit Cooperative Research Program

Three Decades of Innovation

Andre Benz, Unsplash

STEPHAN PARKER, GWEN CHISHOLM-SMITH, DIANNE SCHWAGER, AND MARIELA GARCIA-COLBERG

Parker is a senior program officer, Chisholm-Smith is the TCRP manager, and Schwager and Garcia-Colberg are senior program officers at the Transportation Research Board of the National Academies of Sciences, Engineering, and Medicine in Washington, DC.

Bound for Brooklyn, a subway train pauses at a stop to let passengers off and on. For 30 years, TCRP has helped bus and transit providers like the New York City Transit Authority keep pace with changes in technology, regulations, and other needs.

Conceived in the 1980s and created in 1992, the Transit Cooperative Research Program (TCRP) is celebrating its 30th anniversary in 2022 (see box, below). The mission of TCRP is to provide practical solutions to problems facing the public transportation industry through independent and objective research, innovation, and dissemination. Since its inception, TCRP has contributed a considerable body of knowledge and technological information that has been directly incorporated into the safety, operations, and management of the nation's transportation systems. This has resulted in improved public transit systems and increased responsiveness to the public's demands for safe and efficient public transportation. TCRP studies have helped improve transit security guidelines, new transit paradigms, transit industry best

TCRP Created on May 13, 1992

Congress authorized the Transit Cooperative Research Program (TCRP) in the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991, the law that also transformed the Urban Mass Transportation Administration (UMTA) into the Federal Transit Administration (FTA). ISTEA required an independent governing board to recommend projects and identified the National Academy of Sciences (NAS) as the preferred research manager. By cooperative agreement signed on May 13, 1992, FTA became the sponsor of TCRP, and APTA's Transit Development Corporation created the TCRP Oversight and Project Selection (TOPS) Committee (now the TOPS Commission), which acts as the required governing board. TRB manages the research program.

—Adapted from *The Transportation Research Board, 1920–2020: Everyone Interested Is Invited.*

practices, exploratory idea transit practice and testing prototypes, and new planning and management tools, as well as rail and bus certification programs, all of which help to develop and equip a quality transit workforce to meet new challenges and opportunities.

TCRP projects focus on the most pressing research needs across the public transportation enterprise, including bus and rail transit, legal issues, syntheses of current practice, access to health care, transit capacity and quality of service, and strategic issues. TCRP also has a long history of joint publications with other Cooperative Research Programs (below), and has continually produced research results with immediate and practical applications.

Over TCRP's first 30 years, TRB staff have managed more than 810 studies, including 164 synthesis of transit practice reports (see boxes, Page 26). This work depends on a diverse and inclusive cadre of volunteers and contract researchers. In addition to the described projects, TCRP runs a continuing Innovations Deserving Exploratory Analysis (IDEA) Program and funds a continuing contract with the American Public Transportation Association (APTA) for research dissemination and implementation.

A review of some of the most influential completed and continuing TCRP projects follows.

Selected Joint TCRP Publications with Other Cooperative Research Programs

ACRP/NCHRP/TCRP

Madrid, R. A., Jr. *TCRP Web-Only Document 75–NCHRP Web-Only Document 321–ACRP Web-Only Document 52: Command-Level Decision Making for Transportation Emergency Managers.* Transportation Research Board of the National Academies, Washington, DC, 2022. https://doi.org/10.17226/26587.

ACRP/TCRP

Heard, R., and E. Mannarino. *ACRP Synthesis 91–TCRP Synthesis 137: Microgrids and Their Application for Airports and Public Transit.* Transportation Research Board of the National Academies, Washington, DC, 2018. https://doi.org/10.17226/25233.

NCHRP/TCRP

Selected Studies in Transportation Law. Transportation Research Board of the National Academies, 2018. https://crp.trb.org/selected-studies-law/. Accessed Oct. 13, 2022.

Matherly, D., P. Bye, and J. Benini. *NCHRP Research Report 963–TCRP Research Report 225: A Pandemic Playbook for Transportation Agencies.* Transportation Research Board of the National Academies, Washington, DC, 2021. https://doi.org/10.17226/26145.

Parker, T. *TCRP Legal Research Digest 57–NCHRP Legal Research Digest 84: Fix It, Sign It or Close It: State of Good Repair in an Era of Budget Constraints.* Transportation Research Board of the National Academies, Washington, DC, 2021. https://doi.org/10.17226/26266.

Countermeasures Assessment and Security Experts, LLC, and Western Management and Consulting, LLC. *NCHRP Web-Only Document 221–TCRP Web-Only Document 67: Protection of Transportation Infrastructure from Cyber Attacks: A Primer.* Transportation Research Board of the National Academies, Washington, DC, 2016. https://doi.org/10.17226/23516.

Pigora, M. A. *TCRP Web-Only Document 60–NCHRP Web-Only Document 200: Command-Level Decision Making for Transit Emergency Managers.* Transportation Research Board of the National Academies, Washington, DC, 2013. https://doi.org/10.17226/22472.

Natural Hazards Center at the University of Colorado at Boulder. *NCHRP Research Results Digest 333–TCRP Research Results Digest 90: A Guide to Planning Resources on Transportation and Hazards*. Transportation Research Board of the National Academies, Washington, DC, 2009. https://doi.org/10.17226/23007.

Hubert H. Humphrey Institute of Public Affairs. *TCRP Report 120–NCHRP Report 585: Racial and Gender Diversity in State DOTs and Transit Agencies: A Benchmark Scoping.* Transportation Research Board of the National Academies, Washington, DC, 2007. https://doi.org/10.17226/22010.

Fitzpatrick, K., S. Turner, M. Brewer, P. Carlson, B. Ullman, et al. *TCRP Report 112–NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings.* Transportation Research Board of the National Academies, Washington, DC, 2006. https://doi.org/10.17226/13962.

McCormick Taylor, Inc. *TCRP Report 86–NCHRP Report 525: Transportation Security, Volume 9: Guidelines for Transportation Emergency Training Exercises.* Transportation Research Board of the National Academies, Washington, DC, 2006. https://doi.org/10.17226/13924.

Parsons Brinckerhoff Quade & Douglas, Inc., Science Applications International Corporation, and Interactive Elements Incorporated. *TCRP Report 86–NCHRP Report 525: Transportation Security, Volume 12: Making Transportation Tunnels Safe and Secure.* Transportation Research Board of the National Academies, Washington, DC, 2006. https://doi.org/10.17226/13965.

Pisarski, A. E. *NCHRP Report 550–TCRP Report 110: Commuting in America III: The Third National Report on Commuting Patterns and Trends.* Transportation Research Board of the National Academies, Washington, DC, 2006. https://www.trb.org/Publications/Blurbs/156993.aspx.

Boyd, A., J. Caton, A. Singleton, P. Bromley, and C. Yorks. *TCRP Report 86–NCHRP Report 525: Transportation Security, Volume 8: Continuity of Operations (COOP) Planning Guidelines for Transportation Agencies.* Transportation Research Board of the National Academies, Washington, DC, 2005. https://doi.org/10.17226/13553.

Campbell, S., D. Leach, K. Valentine, M. Coogan, M. Meyer, et al. *TCRP Report 106–NCHRP Report 536: From Handshake to Compact—Guidance to Foster Collaborative, Multimodal Decision Making.* Transportation Research Board of the National Academies, Washington, DC, 2005. https://doi.org/10.17226/13799.

Coogan, M., M. Meyer, and C. Casgar. *TCRP Research Results Digest 65–NCHRP Research Results Digest 288: A New Vision of Mobility: Guidance to Foster Collaborative Multimodal Decision Making.* Transportation Research Board of the National Academies, Washington, DC, 2004. https://doi.org/10.17226/22068.

Hirsch, R. *TCRP Legal Research Digest 16–NCHRP Legal Research Digest 47: Drug and Alcohol Testing—A Survey of Labor-Management Relations.* Transportation Research Board of the National Academies, Washington, DC, 2001. https://www.trb.org/Publications/Blurbs/153412.aspx.

Top Five TCRP Reports by Downloads: October 2021–November 2022

Rank	Report Title	Publication Year	Number of Downloads
First	*TCRP Report 165: Transit Capacity and Quality of Service Manual, Third Edition*	2013	3,214
Second	*TCRP Report 155: Track Design Handbook for Light Rail Transit, Second Edition*	2012	2,270
Third	*TCRP Research Report 230: Transit and Micromobility*	2021	1,890
Fourth	*TCRP Research Report 219: Guidebook for Deploying Zero-Emission Transit Buses*	2021	1,601
Fifth	*TCRP Research Report 231: Recent Decline in Public Transportation Ridership: Analysis, Causes, and Responses*	2022	1,353

Top Five TCRP Reports by Open Book Sessions: October 2021–November 2022

Rank	Report Title	Publication Year	Number of Downloads
First	*TCRP Report 155: Track Design Handbook for Light Rail Transit, Second Edition*	2012	8,306
Second	*TCRP Report 152: Guidelines for Ferry Transportation Services*	2012	6,488
Third	*TCRP Synthesis 99: Uses of Social Media in Public Transportation*	2012	3,340
Fourth	*TCRP Web-Only Document 56: Methodology for Determining the Economic Development Impacts of Transit Projects*	2012	3,279
Fifth	*TCRP Report 142: Vehicle Operator Recruitment, Retention, and Performance in ADA Complementary Paratransit Operations*	2010	2,424

DJ Choupin

The TCRP Oversight and Project Selection (TOPS) Commission meeting in Woods Hole, Massachusetts, on October 15, 2021, was the last official National Academies function held at the historic J. Erik Jonsson Conference Center. Volunteers, contract researchers, staff, and governing boards like the TOPS Commission, shown here, are the backbone of Cooperative Research Programs. Pictured left to right are Adrianne Malasky, FTA; Betsy Kachmar, consultant; Alva Carrasco, WSP; Stephan Parker, TRB; Suzie Edrington, Austin Capital Metropolitan Transit Authority; Jameson Auten, Kansas City Area Transportation Authority; Mary Leary, FTA; Nigel Wilson, Massachusetts Institute of Technology; Arthur Guzzetti, APTA; Paul Ballard, consultant; Bill McCloud, McCloud Transport and Associates; Ryan Daniel, St. Cloud Metro Bus; Doran Barnes, Foothill Transit; Nuria Fernandez, FTA; Neil Pedersen, TRB; Buddy Coleman, Clever Devices; Mallory Avis, City of Battle Creek Transit; Chris Hedges, TRB; Gwen Chisholm-Smith, TRB; Cindy Butler, TRB; Bacarra Mauldin, Memphis Area Transportation Authority; Shayne Gill, AASHTO; Vicky Shotland, Greater Hartford Transit District; Daniel Raudebaugh, Center for Transportation and the Environment; Kris Lyon, TripSpark Technologies–Medical; and Emily Griswold, TRB.

With the TCRP 30th anniversary banner to her left, Peggy Wilson, the APTA–TCRP program manager, draws attendees' interest at the TCRP booth during the 2022 APTA TRANSform Conference in Seattle, Washington.

TCRP Synthesis Series (TCRP Project J-07)

TCRP synthesis reports are among the most popular and most downloaded publications produced by TCRP. The documents are concise, easy-to-read reports on current practice. One of the highlights of synthesis reports is a chapter dedicated to case examples, which describes what other transit systems are doing, including their challenges, successes, and lessons learned.

To develop these syntheses in a comprehensive manner, TRB hires a consultant with expertise in the topic area to gather and analyze available information and write the summary report. For each synthesis, TCRP establishes a panel of experts in the subject area to guide the researcher and review the report.

Synthesis reports have been created for numerous subject areas and topics. Two of the most downloaded syntheses in the past 10 years are *TCRP Synthesis 130: Battery Electric Buses—State of the Practice*[1] and *TCRP Synthesis 126: Successful Practices and Training Initiatives to Reduce Accidents and Incidents at Transit Agencies.*[2]

[1] Read TCRP Synthesis 130 at https://doi.org/10.17226/25061.
[2] Learn more about TCRP Synthesis 126 at https://doi.org/10.17226/24686.

Selected Studies in Transportation Law

Published jointly by the National Cooperative Highway Research Program (NCHRP) and TCRP, TRB's Selected Studies in Transportation Law (SSTL) collection is designed to help public transportation agencies and state highway departments keep abreast of operating practices and legal elements of specific problems in highway and transit law. The transportation legal community reported that SSTL has been of particular interest and value to new legal staff entering the field of transportation law and serves as a refresher for senior legal staff.

The SSTL website provides access to six recent updates of selected material,[3] as well as to the original eight volumes in the series (Table 1).

TABLE 1 Original Volumes in the SSTL WebResource Series

Volume No.	Title
1	*Construction Contract Law*
2	*Eminent Domain*
3	*Environmental Law and Transportation*
4	*Tort Liabilities of Highway Agencies*
5	*Transit Law*
6	*Transit Labor 13(c) Decisions*
7	*Transit Charter Bus Service*
8	*Transportation Law and Government Relations*

Transit Bus Mechanics: Building for Success—The ASE Transit Bus Maintenance Certification Test Series (TCRP Project E-06)

The National Institute for Automotive Service Excellence (ASE), is a nonprofit organization established in 1972 to improve the quality of vehicle maintenance and repair by testing automotive technicians and certifying their abilities. Certification provides tangible proof that technicians have the skills and knowledge required to safely and efficiently carry out their jobs. ASE certifies technicians through a series of written tests. Exams are segmented by subspecialty, such as automobile, medium and heavy truck, school bus, and collision repair.

There are more than 40 individual exams; test questions are written by subject matter experts, including maintenance managers, technicians, vehicle manufacturers, and instructors. In 2004, work began to expand the ASE program to include the testing and certification of transit bus technicians.

The program was made possible through funding provided by TCRP via TCRP Project E-06. Beginning in 2006, the first of a series of ASE certification tests was developed jointly by transit agencies and organized labor as a standardized method for validating technician skills, specifically for transit bus technicians. Bringing transit technicians into the ASE fold recognized them nationally among their peers in the larger sphere of automotive professionals.

There are eight tests in the ASE Transit Bus Certification Series:

1. Diesel Engines;
2. Compressed Natural Gas (CNG) Engines;
3. Drive Train;
4. Brakes;
5. Suspension and Steering;
6. Electrical/Electronic Systems;
7. Heating, Ventilation, and Air Conditioning; and
8. Preventive Maintenance and Inspection.

An ASE Certified Master Transit Bus Technician designation has been authorized for those passing either the diesel engine or the CNG engine test and the remaining six tests. As of April 26, 2022, ASE reports there are current certifications in place for 3,655 transit bus technicians, including 1,029 master transit bus technicians.

Eric Wheeler, Metro Transit, Flickr, CC BY-NC-ND 2.0

Set to make repairs, a transit bus technician checks that the engine is in working order. In 2004, TCRP Project E-06 funded a series of ASE certification tests that standardized the evaluation of skills needed to be a certified transit bus technician.

"TCRP funding has been used to develop a self-sustaining, nationally recognized product for the public transportation industry—one that directly impacts the effectiveness, efficiency, and safety of bus operations."

—**Christopher Jenks,** former director of Cooperative Research Programs, TCRP Manager, and Manager of TCRP Project E-06

[3] Explore the SSTL website at https://crp.trb.org/selected-studies-law/.

Joint Rail Transit Research with the Association of American Railroads/Transportation Technology Center (TCRP Project D-07)

Over the years, a number of track-related research problem statements were submitted for consideration in the TCRP project selection process. In many instances, the research requested was similar to that performed for freight railroads by the Transportation Technology Center, now MxV Rail, a subsidiary of the Association of American Railroads, headquartered in Pueblo, Colorado. Because of synergies in the nature of research, TCRP, with oversight efforts from the TCRP Project D-07 panel members, identified and funded a number of track-related research topics to leverage the research performed by the Transportation Technology Center/MxV Rail for the benefit of the transit rail industry.

The long-running D-07 research program started in the late 1990s and concluded in 2022. Under this program, a total of 21 research projects were completed, covering a wide range of research topics, including wheel/rail lubrication for noise reduction, wheel/rail profile optimization and flange climb criteria, transit switch design, interpretation of American Railway Engineering and Maintenance-of-Way Association standards for transit agencies, acoustic approaches to broken rail detection, track transition design for transit, rail base corrosion, portable track geometry measurement systems, guard/restraining rails, and performance-based track geometry.

Over the years, 18 publications in the form of reports, research results digests, compendiums, and web-only documents were made available to the public through the TCRP website. Many of these publications—most notably those on transit switch designs, optimized wheel/rail lubrication, wheel/rail profile optimization and flange climb criteria, restraining/guard rails, and design of track transitions—have been widely used as references by rail professionals for the design and maintenance of track infrastructure used in transit rail systems.

TCRP Research Report 223: Guidebook and Research Plan to Help Communities Improve Transportation to Health Care Services (TCRP Project H-55)

The availability of transportation influences the ability of individuals to access health care, whether in urban, suburban, or rural areas. Those lacking transportation often miss health care appointments, resulting in delays in receiving medical intervention, which in turn can lead to poorer health outcomes and increased health care costs. *TCRP Research Report 223: Guidebook and Research Plan to Help Communities Improve Transportation to Health Care Services* provides a guide to help communities improve transportation to health care and a research plan to address the continuing need to understand how community partnerships between the health care and transportation sectors develop and can be encouraged. The guide provides useful strategies and resources for three important audiences—health care, transportation, and other stakeholders—to build effective relationships to improve customer-focused mobility services to health care providers.

Transit Capacity and Quality of Service Manual (TCRP Project A-15C)

Preparation of the fourth edition of the *Transit Capacity and Quality of Service Manual* is in progress. First released as *TCRP Research Results Digest 35* and *TCRP Web-Only Document 6*, the *Transit Capacity and Quality of Service Manual* complements TRB's *Highway Capacity Manual*[4] and has become a standard reference work. As noted in *The Transportation Research Board, 1920–2020: Everyone Interested Is Invited*, at the time of the manual's conception, "No single comprehensive and authoritative source for transit practitioners existed to help them design elements of transit service to achieve desired speed, reliability, and capacity. Nor did the transit industry have robust ways to measure the quality of transit service from the rider's perspective."

The first edition of the *Transit Capacity and Quality of Service Manual* synthesized existing research, while the second (TCRP Report 100 in 2003) and third (TCRP Report 165 in 2013) editions closed gaps in previous manuals by integrating newly developed research and best practices.

Quick-Response Research on Long-Term Strategic Issues (TCRP Project J-11)

In June 2007, TCRP initiated a new series of projects called Quick-Response Research on Long-Term Strategic Issues. These projects address hot topics for the public transportation industry, as identified by APTA. The J-11 series was designed to be nimble and responsive to current research and problem-solving needs of transit service providers and stakeholders.

The TCRP J-11 series strives to complete projects quickly. Long before most researchers convened via virtual meetings and produced exclusively free, downloadable reports, the TCRP J-11 series projects followed this approach.

Although project budgets for the TCRP J-11 series have ranged from less than $50,000 to $125,000, these projects have produced significant value. To date, 44 TCRP J-11 series projects have been authorized, and 37 have been completed. TCRP J-11 series projects completed in the past four years have produced the noteworthy reports shown in Table 2.

TCRP J-11 series projects that are underway and in development address timely topics, including fare-free transit, the impacts of automation on transit labor, people experiencing homelessness, virtual public engagement, mobility for people with disabilities during a pandemic or other emergencies, public transportation health impacts, and transit-oriented streets.

[4] Currently in its seventh edition, TRB's *Highway Capacity Manual: A Guide for Multimodal Mobility Analysis* is available at https://doi.org/10.17226/26432.

TABLE 2 TCRP Project J-11 Series Reports Published from 2018 through 2021

Task No.	Report Title	Publication Year
Task 24	*TCRP Research Report 196: Private Transit—Existing Services and Emerging Directions*	2018
Task 25	*TCRP Research Report 195: Broadening Understanding of the Interplay Among Public Transit, Shared Mobility, and Personal Automobiles*	2018
Task 26	*TCRP Research Report 204: Partnerships Between Transit Agencies and Transportation Network Companies (TNCs)*	2019
Task 27	*TCRP Research Report 220: Low-Speed Automated Vehicles (LSAVs) in Public Transportation*	2021
Task 28	*TCRP Research Report 209: Analysis of Recent Transit Ridership Trends*	2020
Task 29	*TCRP Research Report 208: Strategic Communications to Improve Support for Transit-Priority Projects—Report and Toolkit*	2019
Task 30	*TCRP Research Report 207: Fast-Tracked: A Tactical Transit Study*	2019
Task 31	*TCRP Research Report 213: Data Sharing Guidance for Public Transit Agencies—Now and in the Future*	2020
Task 32	*TCRP Research Report 205: Social and Economic Sustainability Performance Measures for Public Transportation—Final Guidance Document*	2019
Task 33	*TCRP Research Report 219: Guidebook for Deploying Zero-Emission Transit Buses*	2021
Task 34	*TCRP Research Report 232: The Impacts of Vehicle Automation on the Public Transportation Workforce*	2022
Task 35	*TCRP Research Report 228: Resource Guide for Improving Diversity and Inclusion Programs for the Public Transportation Industry*	2021
Task 36	*TCRP Research Report 226: An Update on Public Transportation's Impacts on Greenhouse Gas Emissions*	2021
Task 37	*TCRP Research Report 230: Transit and Micromobility*	2021
Task 38	*TCRP Research Report 222: Analysis of Green Bond Financing in the Public Transportation Industry*	2021

VOLUNTEER VOICES

"Knowledge is learned by experience of one's self or others. It often takes the mistakes of life to better understand the world around us, but if we can learn from the mistakes and lessons of others, we gain wisdom without as much pain. TRB allows the promotion and distribution of research, development, and lessons learned from which a shared community can adapt and grow.

—STUART BENNION
Structures Director and Assistant Vice President
WSP
Vancouver, Washington

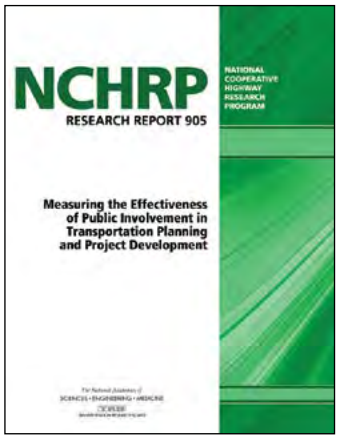
RESEARCH PAYS OFF

Practice Makes Perfect

Five State DOTs Implement a Public Involvement Effectiveness Measurement Toolkit

KATE GUNBY

The author is director of research at PRR in Seattle, Washington.



NCHRP Research Report 905: Measuring the Effectiveness of Public Involvement in Transportation Planning and Project Development provides a field-validated and practitioner-ready toolkit designed to collect feedback from the public on several indicators of effectiveness and to compare that feedback with the agency's own perceptions.

In 2019, the National Cooperative Highway Research Program (NCHRP) provided a field-validated and practitioner-ready toolkit for transportation agencies in *NCHRP Research Report 905: Measuring the Effectiveness of Public-Involvement in Transportation Planning and Project Development*.[1] This first-of-its-kind toolkit helps agency practitioners collect public feedback on six indicators of public-involvement effectiveness, compare feedback with a transportation agency's perceptions, and calculate scores for an overall effectiveness index (Figure 1).

Background

The NCHRP project that produced NCHRP Research Report 905, NCHRP Project 08-105, "Measuring the Effectiveness of Public Involvement in Transportation Planning and Project Delivery," aimed to create a method to validly measure the effectiveness of public involvement. This method was intended to be user-friendly and doable, given the constraints agencies typically face. As part of the initial research, the PRR team field-tested the survey tool with the Washington State Department of Transportation (DOT). Toolkit use was further assessed with a follow-up implementation project in which five transportation agencies with unique needs and projects provided new insights that were used to further refine the toolkit and ensure its successful implementation.

[1] Learn more about the toolkit at https://doi.org/10.17226/25447.

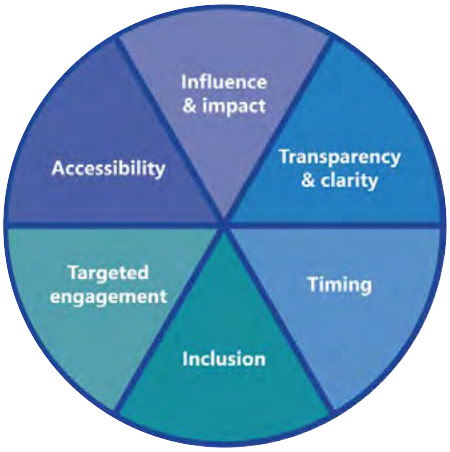


FIGURE 1 Six indicators of public involvement effectiveness.

Fine-Tuning the Toolkit

Between February 2021 and January 2022, Arizona, Georgia, North Carolina, Texas, and Utah state DOTs planned to implement the NCHRP Research Report 905 toolkit with support from research and public engagement teams. The purpose of testing the toolkit on projects in multiple states was to identify needed improvements to the toolkit for evaluating the effectiveness of public involvement and to encourage public participation in transportation decision making.

The team provided training and support through a multistep process that included staff questionnaires and virtual interviews to collect information from each participating state DOT to better understand agency culture, capabilities, needs, audiences, and project-specific challenges. Participating state DOTs

were provided with customizable and easy-to-understand resource materials for staff and the public, in addition to presentation slide decks focused on toolkit implementation.

The team conducted group trainings, as well as individual state DOT training, with all five state DOTs. The project enabled state DOT staff to share ideas, learn about how other agencies are tackling similar public involvement effectiveness measurement challenges, and spend time engaging with toolkit components through hands-on activities. Quarterly peer discussions proved to be useful forums for state DOTs sharing implementation experiences and tips.

Greens MPs, Flickr, CC BY-NC-ND 2.0

Community meetings like this one can be hard to gauge. Hosting agencies must determine whether attendees were satisfied with the amount of information and if the presentation conveyed how project decisions were made. The NCHRP Research Report 905 toolkit helps agency practitioners quantify the effectiveness of public meetings across six indicators.

Lessons Learned from Utah DOT

As one example of the use of the toolkit in this implementation project, Utah DOT deployed the survey and toolkit as part of the National Environmental Policy Act evaluation of a project. The survey was administered twice, once during the scoping phase and again during the alternatives development phase of the project.

During the scoping phase, the state was restricting in-person public meetings due to the COVID-19 pandemic, so the project team administered the survey using an online platform and made copies of the survey questionnaire available in areas with foot traffic, such as city offices and the public library. The project team used several methods—including social media posts, an e-mail to partner agencies and organizations, and local media—to encourage area stakeholders to respond to the survey.

Survey responses revealed some deficiencies. For example, Utah DOT staff discovered the online survey platform they were using downloaded the data in text format. This meant that they had to convert the data to numerical format before they could be entered into the scoring tool. The survey question data also did not download in the same order as the survey questions, which required additional processing by Utah DOT staff. Also, many people did not complete the survey past the demographic questions. Utah DOT staff noted that some survey questions were not relevant during the project scoping phase.

During the alternatives development phase, adjustments were made to move the demographic questions to the end and remove questions that were not applicable to the specific phase of the project. These adjustments significantly increased the number of survey respondents from 30 to 296 and provided Utah DOT with additional insight regarding how to engage more with stakeholders. They have since incorporated the survey into additional environmental projects.

Benefits

The toolkit enables agency professionals to track performance throughout a project's life cycle, identify strengths and weaknesses of public involvement activities, and inform decisions about the best way to allocate public engagement resources. The use of the surveys can improve relationships with affected communities because they now have a means for providing feedback, not only on projects, but also on public involvement processes. Overall, Utah DOT staff reported that they see value in using the toolkit to evaluate the effectiveness of public involvement activities and to improve their outreach activities. For example, effectiveness scores improved on the following items when comparing the August and December 2021 results:

- I understood how project decisions were made,
- I had access to enough information about the project, and
- Any barriers to participation were addressed in a timely manner.

Conclusions

The toolkit implementation program resulted in several key lessons learned for improving the use of the toolkit. Among them is ensuring that the right agency staff—such as public engagement and research specialists—are included in the planning process for transportation projects that will use the toolkit. To tailor the survey, agencies can assess language needs and demographics as soon as a project is identified and focus on questions relevant to specific phases of the project. Hands-on practice is key to training for toolkit implementation, especially for the scoring tool. Implementing staff should have adequate time and resources for toolkit training, especially regarding data processing, analysis, and reporting using the scoring tool.

Finally, a Quick Reference Guide for using the toolkit was developed that provides a model process flowchart with links to supplemental information.

PROFILE

Kris Gade

Assistant Environmental Administrator, Arizona Department of Transportation

Kris Gade is a strong believer in using collaborative approaches to improve outcomes for human and natural systems. After earning a Bachelor of Arts in environmental science from the University of California, Berkeley, she got her start in the 1990s as an environmental scientist and ecological risk assessor for a consulting company in San Francisco, where she "did a lot of work cleaning up U.S. Navy bases." She collected sediment and water samples in California and assessed the effects of hazardous chemicals and heavy metals by using food web models to determine how contaminants were moving through the ecosystems. She also conducted field surveys and conservation planning for a rapidly developing economic zone on an Indonesian island chain near Singapore. Through these projects, she realized how inextricably nature and human infrastructure are linked.

Gade returned to graduate school at Arizona State University as a National Science Foundation fellow in the Urban Ecology Integrative Graduate Education and Research Traineeship Program, which recognizes that "real-world solutions to complex national and global challenges often cannot be provided by the expertise of a single discipline." Her doctoral research project focused on the movement of plants along transportation corridors from ecological, design, and maintenance perspectives.

With her doctorate complete, Gade took a new position as senior biologist and environmental planner in Phoenix, where her focus shifted to compliance with environmental laws and regulations. She wrote and reviewed National Environmental Policy Act documents for FHWA, FTA, the National Science Foundation, and the Bureau of Indian Affairs, and coordinated with federal, state, local, and tribal government entities. She worked on Clean Water Act permitting and developed biological documents for compliance with natural resource regulations. She quickly recognized the need to apply an interdisciplinary approach to her work. "For example, when considering vegetation management, topics like enhancing habitat for pollinators, selecting vegetation treatments that work with different types of

"Having multiple perspectives represented improves research outcomes."

safety hardware, or promoting landscape connectivity for animals and reducing wildlife–vehicle collisions, are examined," she explains. "It's important to have the perspectives of landscape architects, environmental staff, and maintenance staff included—as well as engineers."

Gade credits much of her success to her ability to communicate on some typically thorny topics. "I have learned how important it is to develop a shared understanding of a problem or issue," she notes, adding that "the best way to do that is to ask questions and listen closely." This requires understanding which questions to ask and how to interpret the answers from others with divergent perspectives. "Disagreements, or seemingly insurmountable problems, often turn out to be based on different understandings of what was assumed to be shared knowledge, but is not," she points out.

After more than a decade in private consulting, the Arizona Department of Transportation hired Gade in 2012 to lead the biology team. She then took a position focused on developing guidance supporting vegetation management and served as the biologist and environmental planner for construction of the South Mountain Freeway. Recently, she became Assistant Environmental Administrator for Biology, Cultural Resources, and Water.

Underlying all of this is Gade's respect for the environment and research. She is the TRB Standing Committee on Environmental Analysis and Ecology vice chair and the co-chair of the Natural Resources Subcommittee of the AASHTO Committee on Environment and Sustainability. "I am passionate about bringing knowledge developed through research to the everyday practices of transportation agencies and helping to develop research projects that will result in improved outcomes for transportation infrastructure, as well as for the natural and social systems that this infrastructure is a part of," she shares. "TRB and AASHTO are central to accomplishing these goals." She also is a member of the steering committee for the International Conference on Ecology and Transportation and is helping plan a joint meeting of these three groups in 2023.

As an experienced chair, member, and AASHTO monitor of National Cooperative Highway Research Program (NCHRP) project panels, she finds that "NCHRP is extremely valuable because it creates a mechanism for transportation practitioners to work directly with the research community to understand and address current issues." Here too, she notes the importance of shared knowledge. "Having multiple perspectives represented improves research outcomes by providing diverse input to the researchers during the course of the study."

Gade's career has allowed her to witness—and also to assist with—avoiding, reducing, and mitigating a wide array of human impacts on natural resources. From roadside vegetation management and fire risk reduction to promoting monarch butterfly conservation, artificial bat habitats, wildlife connectivity, and conserving the camouflaging chuckwalla lizard in the U.S. Southwest, she has made a difference by communicating clearly with the humans involved.

Creating a Culture of Fairness

The overall objective of members on the National Academies of Sciences, Engineering, and Medicine's Diversity, Equity, and Inclusion (DEI) Council is to represent the diverse voices of all Academies employees in an equitable and inclusive way. Council members will assist with the development and implementation of the DEI action plan and will coordinate processes and procedures to ensure that the organization meets its DEI goals. TRB Senior Program Officer Camille Crichton-Sumners was selected as the representative from TRB and will serve a two-year term. I spoke with her to learn more about her work at TRB and on the council.

Tell me a little about your background before you came to TRB.

Prior to joining TRB, I worked at the New Jersey Department of Transportation (DOT) in several units, including Environmental Analysis, Utilities, Project Management, Preliminary Engineering, and in Research, as a state-certified public manager. This work involved the administration of a multimillion-dollar multimodal transportation research program on behalf of stakeholders within New Jersey DOT, NJ Transit, the Motor Vehicle Commission, and occasionally for the state legislature and the governor's office.

In this role, I served as state coordinator for several FHWA initiatives, including the Every Day Counts Initiative, Long-Term Pavement Performance Program, and Transportation Pooled Fund Program. I also served as a panelist on national and local process reviews, working groups, laboratory assessments, and audits of federal funds. I have administered contracts with institutions of higher education, one research consultant, and a research library. I also was the TRB

Senior Program Officer Camille Crichton-Sumners (*above*), TRB's representative on the Diversity, Equity, and Inclusion (DEI) Council, shares her thoughts with Karen Febey, TRB senior report review officer.

State Representative and the New Jersey DOT voting member of the AASHTO Research Advisory Committee, the Special Committee on Research and Innovation (formerly SCOR), and the Innovation Initiative. My education began with a bachelor of science in architectural engineering and a bachelor of science in civil engineering, both from Drexel University in Philadelphia, Pennsylvania. I completed a master of science in engineering management from the New Jersey Institute of Technology, and my studies continue with doctoral work in engineering and technology management.

What kind of work do you do at TRB?

As a senior program officer at TRB, I am responsible for a broad range of transportation research projects intended to solve critical transportation problems and advance the state of transportation practice by providing new procedures, methods, and tools related to multimodal highway systems.

What made you decide to become a member of the Academies' DEI Council?

Prior to joining TRB in 2017, I was a volunteer on the TRB Diversity Working Group. My interest did not wane after transitioning into my role at TRB. After years of voluntary effort by Academies staff, leadership demonstrated commitment to diversity, equity, and inclusion by funding the Office of Diversity and Inclusion and DEI initiatives.[1] I was inspired and interested in DEI Council membership as it provided a means to continue contributing, formally sharing ideas, and identifying successful practices that may help the Academies gain consistency and begin to make changes needed to transform the culture, increase diversity, and ensure an environment that is inclusive and equitable.

What unique contributions can TRB make to the DEI Council?

TRB can champion the principles of the Academies' six diversity, equity, and inclusion pillars (see box, page 34) and share successful practices related to developing young professionals in graduate school—particularly members from underrepresented populations—and encouraging their participation in TRB activities, as well as introducing them to the transportation industry, the conduct of transportation research, and related science, technology, engineering, and math—or STEM—fields.

[1] Review the *Office of Diversity and Inclusion Annual Report 2021–2022* by logging in at https://nap.nationalacademies.org/download/26711.

What part of the DEI work is of highest importance to you?

Fostering a culture of inclusion and equity requires culture change. I have a personal responsibility to help increase awareness and bridge the gap in understanding the importance of DEI and to help create a culture of fairness.

What do you like to do when not working at TRB or doing DEI Council work?

I might be with family and friends, traveling, doing genealogical research, spending time at the ocean, or enjoying music.

The National Academies Diversity, Equity, and Inclusion Pillars

1. Build an infrastructure and develop capacity;
2. Foster a culture of inclusion and belonging;
3. Examine and refine hiring and advancement policies and practices;
4. Apply a DEI lens to programs and initiatives;
5. Enhance policies, processes, and practices to diversify academy members, volunteers, contractors, and local partnerships; and
6. Increase accountability, communication, and data transparency.

"Fostering a culture of inclusion and equity requires culture change."

MEMBERS *ON THE MOVE*

Mazen Alsharif is a new senior program assistant who comes to TRB from Georgetown University in Washington, DC, where he was a graduate research assistant.

Dajaih Bias-Johnson has joined TRB as a senior program assistant. Previously, she worked at Urban Alliance in Washington, DC.

Karissa Bingham is the new meetings director in the Technical Activities Division. For the past 13 years, she has been with the Association for Uncrewed Vehicle Systems International in Arlington, Virginia, most recently as a senior meetings manager.

James Bryant resigned his position as senior program officer on November 1 to pursue other professional opportunities. He was with TRB for 15 years.

Dallas Hammit, former deputy director for the Arizona Department of Transportation, joined the Southwest Mountain District leadership team at WSP USA.

Leslie Harwood, a senior program officer, left TRB on November 3 to pursue a new career path.

Bijan Khaleghi joined TRB as a senior program officer on December 12. He was the state design engineer at Washington State Department of Transportation.

Sid Mohan has been promoted from NCHRP senior program officer to associate program manager for implementation and technology transfer.

Former TRB Executive Director **Neil J. Pedersen** has received the 2022 W.N. Carey, Jr. Award for more than 40 years of leadership service to TRB—30-plus years as a TRB volunteer and more than 10 years as a TRB staff member. The award will be presented at the Chair's Plenary Session on Wednesday, January 11, at the 102nd TRB Annual Meeting.

New TRB Executive Director **Victoria Sheehan,** formerly the commissioner of the New Hampshire Department of Transportation, joined TRB on December 5.

Shawn Wilson has been named chair of the 2023 TRB Executive Committee. His term begins during the 102nd TRB Annual Meeting in January.

INFLUENCER

Stephanie Atallah

Stephanie Atallah is a senior aviation consultant at WSP, USA, in St. Louis, Missouri. She earned her PhD in civil engineering, air transportation systems at Virginia Polytechnic Institute in Blacksburg. She is the aviation vice chair on the Young Members Coordinating Council, a member of the Standing Committee on Aviation Economics and Forecasting, and a member of the Standing Committee on Aviation Administration and Policy.

What is your role as aviation vice chair on the Young Members Coordinating Council?
As vice chair, I support Ryan Dittoe, our chair, in planning for quarterly meetings and preparing for the TRB Annual Meeting. I also serve as the recruitment and diversity lead, for which I direct our initiatives for promoting inclusion and diversity within the group. This involves activities such as putting together an annual diversity, equity, and inclusion survey, or hosting coffee hours and talks featuring a diverse pool of speakers.

How have you interacted with other groups within the Young Members Coordinating Council and with committees?
As a member of the Standing Committee on Aviation Economics and Forecasting, as well as the Standing Committee on Aviation Administration and Policy, I try to maintain an active role by participating in meetings, providing input for session topics, and planning sessions for the Annual Meeting. The Young Members Coordinating Council—Aviation and aviation committees have collaborated many times on joint sessions for the Annual Meeting.

What do you think is helping you to be successful in this role?
The support I get from our leadership group within Young Members Coordinating Council—Aviation along with TRB staff—specifically within the Aviation Group—helps me succeed. But, I cannot forget the many aviation professionals who have always volunteered to join us for Young Members Coordinating Council—Aviation coffee hours and to talk to our group.

How has TRB influenced your career so far?
TRB has been a great resource since my graduate years at Virginia Tech. As I was pursuing my doctorate, I took part in the Airport Cooperative Research Program (ACRP) Graduate Research Award Program. The Standing Committee on Aviation System Planning hosted me for my first TRB presentation as a 2017–2018 ACRP Graduate Research Awards Program awardee. My research paper was an "Assessment of Contributing Factors to Air Service Loss in Small Communities." TRB also has allowed me to make valuable connections within our industry and has been a great knowledge resource through the insightful information and research updates shared by the committees.

Transportation Influencer highlights the journey of young professionals active in TRB. Have someone to nominate? Send an e-mail to TRNews@nas.edu.

Let's Hear from You!

In each issue, we pose a sometimes light and fun transportation-related question that allows you to share your thoughts with other readers. To answer, **click here** or e-mail us at **TRNews@nas.edu** and follow these simple steps:

1. In the subject line, include **"Volunteer Voices: [the question you're answering]"**;
2. Answer the question thoughtfully, but keep it brief—up to about 150 words;
3. Add whether you are a TRB member or volunteer, and list the committees you are involved with; and
4. Add TRNews@nas.edu to your contacts so we avoid your spam folder when we tell you you're going to be published.

That's it! Like all *TR News* content, your response may be edited for grammar, length, and TRB style. When the issue with your quote is published, you'll get a PDF of the page featuring your response and photo.

Now that you have the details, here's the question:
What rarely mentioned transportation inequity would you eliminate, and how would you go about it?

Engineering a Legacy

TRB Executive Director Neil Pedersen Retires

Neil Pedersen, executive director of TRB since 2015, announced his intention to retire last March and, after a successful national search, welcomed a new executive director, Victoria Sheehan, to succeed him in December.

Prior to joining TRB, Neil was an active TRB volunteer for more than 30 years. During half of these years, he served in TRB volunteer leadership roles and was vice chair of the AASHTO Standing Committee on Highways from 2007 to 2011. In 2011, he chaired the TRB Executive Committee and in 2012, he joined the TRB staff as deputy director of the second Strategic Highway Research Program (SHRP 2). Before that, Neil spent 29 years at the Maryland Department of Transportation, serving the last eight years as State Highway Administrator and Governor's Highway Safety Representative. He received bachelor's degrees in civil engineering and urban studies at Bucknell University in Lewisburg, Pennsylvania, and a master's degree in civil engineering from Northerwestern University in Evanston, Illinois, quickly followed.

In 2015, while new to his role as executive director, in which he would guide TRB's programs and activities—including 200 technical committees, conferences, and publications; peer-reviewed policy consensus studies; the multimodal Cooperative Research Programs; and an annual meeting of more than 13,000 transportation professionals—Neil provided a look at the future under his leadership.[1] Acknowledging the need to bridge the gap between research and implementation, he explained how his past experience at a state DOT would help him in this goal. Thereafter, he worked to ensure that implementable research

Former TRB Executive Director Neil Pedersen will stay on to assist with the transition and "after that," he notes, "I hope to remain involved in TRB as a volunteer."

would be delivered quickly and looked to technology to make this possible for a broader audience. Shortly after his arrival, the *Transportation Research Board 2016 Annual Report* announced that the "popular webinar series has continued to grow… enabling those who cannot attend in person to participate remotely." In 2022, TRB held approximately 110 webinars, each reaching an average of approximately 350 attendees.

Neil also tapped his experience as TRB staff to consistently acknowledge the quality and quantity of all things accomplished at TRB, reminding staff, "You are the key to TRB being able to deliver the value to our sponsors and customers that we do and to leveraging the expertise and passion of our 8,500 volunteers."

During his leadership, he took a hard look at tough but important societal and racial issues. "Neil has long been a tireless advocate for the important role transportation plays in American society," commented Jim Tymon, AASHTO executive director and TRB Executive Committee ex officio member in a recent *AASHTO Journal* article, noting Neil's awareness of "the vital responsibilities of state DOTs as stewards of multimodal mobility and accessibility."[2]

With Neil's guidance, TRB has not only published research to aid in

Risdon Photography

Neil Pedersen (*center*), at the 2019 TRB Annual Meeting, had the honor of leading TRB during the following year's centennial commemoration and—starting a few months later—through the unimaginable challenges of the COVID-19 pandemic.

[1] Listen to the January 13, 2015, interview, "Neil Pedersen, TRB's New Executive Director," with Bernie Wagenblast of Transportation Radio at https://www.buzzsprout.com/18472/236709-neil-pedersen-trb-s-new-executive-director.

[2] Read the *AASHTO Journal*'s April 8, 2022, announcement: "TRB Executive Director Neil Pedersen Stepping Down," at https://aashtojournal.org/2022/04/08/trb-executive-director-neil-pedersen-stepping-down/.

The White House

Neil Pedersen (*center*), at The White House Accelerating Infrastructure Summit held on October 13, 2022, in Washington, DC, has been the voice of TRB since 2015.

acknowledging and reversing societal injustices involving transportation, but also led by example. In 2018, the Executive Committee approved the TRB Diversity and Inclusion Strategic Plan. In 2020, the plan was revised to include the concept of "equity" and released as the Diversity, Equity, and Inclusion (DE&I) Strategic Plan. During Neil's tenure, TRB's institutional culture has drawn strength from diversity of thought, as well as gender, ethnicity, and background. TRB increasingly encourages young members, supports minority students, and has no place for barriers to inclusion. Neil was recently honored with an award from the Conference of Minority Transportation Officials (COMTO), a nonprofit organization dedicated to advancing minorities in the transportation industry, for his contributions to COMTO and the industry.

For "outstanding contributions to diversity, equity and inclusion, accessibility, innovation, and community engagement at a time of disruption to the transportation industry," TRB Executive Director Neil Pedersen received the President & CEO's Award for Excellence from the Conference of Minority Transportation Officials.

With an engineer's eye for making things work, Neil's leadership at TRB has been focused on "high-impact research and policy studies, a growing portfolio of convening activities, and partnerships with transportation organizations in the United States and internationally," noted Gregory Symmes, chief program officer at the National Academies of Sciences, Engineering, and Medicine.

At the same time, Neil recognized, "I am grateful to have had the opportunity to serve in the role of executive director of an organization that plays such a critical role both nationally and internationally in solving complex transportation-related challenges and advancing the state of transportation professional practice throughout the world."

VOLUNTEER VOICES

"I attended the TRB Annual Meeting in 2010 as an undergraduate student. The profound impact of transportation on community and economy drew me to the transportation community and keeps me here. I enjoy working on solving problems in transportation safety, bridge engineering, and construction engineering and management. People in the transportation community offer a wealth of knowledge to help young faculty grow and develop.

—HONGTAO DANG
Assistant Professor (Tenure-Track)
Washington State University
Pullman

TCRP SYNTHESIS 158

Cybersecurity in Transit Systems

DAVID FLETCHER AND PATRICIA BYE

Fletcher is a principal at Geographic Paradigm Computing, Inc., in Albuquerque, New Mexico, and was the principal investigator for TCRP Synthesis 158. Bye is an independent consultant in Holicong, Pennsylvania, and was co-principal investigator for the synthesis report.

Cathy Frye, Flickr, CC BY 2.0

The COVID-19 pandemic necessitated faster automation of many systems and may have presented unprecedented opportunities for cybersecurity intrusions. Vulnerabilities, types of cybercrimes, preventive steps, and real-world examples are examined in *TCRP Synthesis Report 158: Cybersecurity in Transit Systems*.

The COVID-19 pandemic shattered the status quo way of doing business in almost every industry and infrastructure sector around the world. Goaded by the twin prods of public health imperatives and the need to keep providing essential services to the economy and the country, sector after sector are rapidly replacing older, riskier ways of doing business with digital alternatives that minimize interpersonal contact.

The transit sector has not been spared from this upheaval. Transit agencies across the country accelerated their adoption of innovative business concepts and technology investments in response to new developments such as remote working. In many areas, contactless customer services replaced traditional fare box and ticketing transactions. Transit-on-demand functionality augmented or replaced fixed-route service. Remote workers immersed themselves in this new digital environment, replete with rapidly maturing social media and group conferencing tools. Each of these innovations, in turn, was accompanied by a bewildering array of ad hoc data, communication and control platforms, applications, and devices.

Unsurprisingly, this digital acceleration also uncovered some major latent security vulnerabilities while giving rise to new ones. As the scope and scale of these vulnerabilities increased, so did the number and sophistication of attacks from a variety of bad actors. There also is the unanticipated elevated security risk from even trusted employees trying to navigate unfamiliar workflows, work spaces, and work behaviors. This increasing risk is happening while many transit organizations are adjusting to severe reductions in budgets and in personnel for cybersecurity infrastructure and operations. In other words, not only are cybersecurity staff being asked to do more with less, but they also are being asked to do things they have never done before.

Threats are continuing to evolve quickly, and the cybersecurity professional is always playing catch-up in this environment. For example, one recent industry survey estimated that only four in 10 public sector respondents are very confident in their ability to keep up with today's evolving threats (*1*). The end result of these interrelated changes is that critical infrastructures—including transit—are not as reliable, resilient, or secure as elected officials, regulators, operators, or customers assume they are. As transit services and backroom operations become even more digital, this lack of resilience and security will become increasingly more apparent and may ultimately threaten the health and safety of passengers and workers, physical transit assets, and system availability.

An assessment of this dynamic situation suggests that the transit sector could benefit from better understanding and communicating emerging cyberthreats and lessons learned from new cybersecurity practices. Such understanding can come not only from its own members, but also from practitioners in other industries. TRB's *Transit Cooperative Research Program (TCRP) Synthesis 158: Cybersecurity in Transit Systems* draws

This synthesis report identifies and documents emerging cybersecurity trends related to teleworking and remote worker offices, contactless customer services, real-time information services, transit-on-demand services, and cyber-resilience affecting transit agencies.

on a variety of open-source material that includes news reports, TRB research reports, government reports and publications, industry standards and other guidance, industry surveys (i.e., cyber, transportation, and transit), and materials supplied by various agencies and organizations (*2*). This synthesis report is intended to brief elected and appointed officials, transit organization executives, and other senior transit technology managers on the latest trends in cybersecurity and cyber-resilience.

FINDINGS

The overriding finding in TCRP Synthesis 158 is that the acceleration of the digital transformation in the transit sector reveals that many organizations are facing difficulty with absorbing, responding, and adapting to the simultaneous introduction of new technologies, evolving workplace norms, and heightened customer expectations. The inevitable consequence of this situation is that pre-pandemic cybersecurity approaches and skillsets are proving no longer adequate to effectively minimize vulnerability, defend against evermore effective attacks, and rapidly recover and restore agency services and internal operations.

The convergence of these technological, organizational, and behavioral disruptors introduces new and potentially critical cybervulnerabilities that are now being exploited by a wide variety of threat actors. These actors include geopolitical adversaries, criminals, hacktivists, and insiders. Very few agencies planned or were prepared for the scale, scope, or timing of this accelerated transformation, along with the subsequent increased risk exposure. In response to this increased risk, many agencies are increasingly reliant on third-party providers of cyber goods and services, creating even greater vulnerability from digital supply chain risks. In summary, accelerated digitalization created additional vulnerability that exceeded internal cybercapacity. This shortfall was mitigated by an increasing dependence on third-party products and services, which introduced additional uncertainty and risk.

Moreover, the ad hoc nature of the digital transformation exposed or created a number of previously unknown cybervulnerabilities that, in many cases, have not yet been mitigated. Adversaries and criminals have adapted quickly to this new computing ecosystem and dramatically increased the frequency and severity of attacks resulting in high-consequence incidents, such as the Colonial Pipeline shutdown in May 2021. In many transit agencies, pre-transformation cybersecurity architectures, policies, training, tools, skillsets, and other resources provide inadequate protection against these attacks.

NEXT-GENERATION RESPONSES TO EMERGENT VULNERABILITIES

Next-generation cybersecurity practices addressing this emerging vulnerability are being introduced in other industries and infrastructure sectors. TCRP Synthesis 158 identifies emerging cybersecurity approaches that have not yet been widely disseminated in the transit community but are of growing importance now and over the near term. These approaches, including those promoted by federal regulators, industry trade groups, and the cyberinsurance industry include the following:

- Cyber-resilience strategies, including cyberinsurance;
- Third-party cyber-risk management, including cyber supply chain risk management;
- Cybersecurity of location-agnostic access (such as remote work, teleworking, and work from home);
- Zero-trust computing architectures supporting contactless customer applications, including real-time and on-demand information and services; and
- Cybersecurity governance and workforce development.

Many public-sector agencies report that a lack of funding, the complexity of their existing environments, and a lack of internal expertise are substantial impediments to the implementation of these approaches. Agencies that do not have employees with the requisite skills are increasingly unable to recruit, on-board, and retain them for a variety of reasons, leaving agencies at greater risk for longer periods.

While TRCP Synthesis 158 provides a discussion of current cybersecurity practice in transit organizations and introduces several next generation cybersecurity approaches used in other industries, the critical need for practical, actionable guidance targeted at transit agencies remains. Such future research needs include but are not limited to

- How to vet a potential third- or fourth-party contractor, consultant, or vendor;
- How to vet software or hardware components and systems;
- How to develop cybersecurity procurement specifications across a variety of technical components or personnel;
- How and when to purchase cyberinsurance;
- Recommended policies and practices for the remote worker, including draft policies on bring-your-own-device situations;
- How to incorporate a cyber-resilience perspective into existing emergency management plans, procedures, and personnel training; and
- Transit-specific cyberincident management workshops, tabletop exercises, drills, functional exercises, and full-scale exercises.

To learn more about TCRP Synthesis Report 158: Cybersecurity in Transit Systems, *visit https://doi.org/10.17226/26475.*

REFERENCES

1. SolarWinds. *Sixth Annual Public Sector Cybersecurity Survey Report*. SolarWinds Government, February 2020. Austin, Texas. https://www.solarwinds.com/resources/survey/solarwinds-public-sector-cybersecurity-survey-report-2020.
2. National Academies of Sciences, Engineering, and Medicine. 2022. *TCRP Synthesis 158: Cybersecurity in Transit Systems*. Washington, DC: The National Academies Press. https://doi.org/10.17226/26475.

TCRP LEGAL RESEARCH DIGEST 58

Knowing the Laws on Policing and Public Transportation

LARRY W. THOMAS

The author is the founder and owner of the Thomas Law Firm in Washington, DC.

Manuel Lardizabal, Unsplash

Transit operations and equipment, such as this New York City subway car, may present opportunities for individuals to violate laws and regulations that apply to public transportation authorities. It is important for public transportation agencies to be informed of the laws and regulations that apply to policing by public transportation agencies, as well as of judicial decisions that interpret and apply the laws and regulations.

Public transportation agencies police their stations and other facilities to enforce applicable laws and rules for the safety of passengers and others, as well as to prevent trespassing and vandalism. *Transit Cooperative Research Program (TCRP) Legal Research Digest 58: Policing and Public Transportation* analyzes constitutional and other issues in cases brought against public transportation authorities under the Civil Rights Act of 1871, 42 U.S.C. Section 1983, for alleged civil rights violations in the policing of public transportation authorities' premises and vehicles. The report, which is divided into nine parts, is a resource for lawmakers, public transportation agencies, police forces, and attorneys, as well as members of the public.

Part I explains that a civil rights claim may arise when a public transportation authority either has a policy or custom that violates Section 1983 or is shown to have been deliberately indifferent to an individual's constitutional rights. Part I discusses when a police officer may have qualified immunity to a Section 1983 claim, as well as whether a police officer's mistake of fact or law affects potential liability under Section 1983.

TCRP Legal Research Digest 58: Policing and Public Transportation examines legal issues and problems unique to transit agencies.

Part II addresses Section 1983 claims against public transportation authorities and police officers for alleged false arrest or false imprisonment, unlawful searches and seizures, use of excessive force, malicious prosecution or abuse of process, and invasion of privacy, as well as liability for a police officer's failure to intervene to prevent another officer from violating a person's civil liberties.

Part III covers Section 1983 claims brought against public transportation authorities or police officers for allegedly denying a defendant's right to due process, such as a defendant's right to a fair trial, or for denying a defendant's right to the equal protection of the law under the Fourteenth Amendment to the U.S. Constitution. In addition, Part III analyzes the question of whether public transportation authorities may be held liable for disparate treatment or disparate impact under Title VI of the Civil Rights Act of 1964.

Part IV analyzes Section 1983 actions against public transportation authorities under the Eighth Amendment, the Equal Protection Clause of the Fourteenth Amendment, or both because of laws or practices that limit or prohibit homeless persons' use or occupancy of public property or space, such as stations and other property belonging to public transportation authorities.

Part V considers the impact of the Second Amendment to the U.S. Constitution on public transportation authorities' ability to regulate or prohibit the carrying of firearms by members of the public in stations or on a means of public transportation. Note that after the completion of TCRP Legal Research Digest 58, the U.S. Supreme Court issued its decision in *New York State Rifle & Pistol Association, Inc. v. Bruen* (*1*). In *Bruen*, the Court held that a New York statute, which required an applicant for a concealed-carry permit to show proper cause for the issuance of a permit, violated the Second Amendment. Moreover, the Court held that New York's proper-cause requirement violated the Fourteenth Amendment by "prevent[ing] law-abiding citizens with ordinary self-defense needs from exercising their right to keep and bear arms."

Part VI discusses whether a public transportation authority as a common carrier is subject to a higher standard of care when the authority is sued, for example, for negligently failing to protect passengers from assaults by other passengers.

Part VII reviews public transportation authorities' actions in response to the

COVID-19 pandemic, such as compliance by the authorities and passengers with federal and state public health and safety mandates or directives.

Part VIII analyzes how public transportation authorities are making effective use of public relations to support their policing, the agencies' organizational and contractual structures for law enforcement, and the authorities' administration of law enforcement and training. TCRP Legal Research Digest 58 includes examples and discussion of public transportation authorities' organizational structures and contractual agreements that apply to their policing, including interagency and interforce agreements.

Part IX discusses best practices that public transportation authorities have adopted for the policing of their stations, vehicles, and other property. Also included are best practices that some public transportation authorities have adopted regarding fare collection and for detecting and responding to fare evasion.

A full-text copy of the report is available at https://nap.nationalacademies.org/catalog/26652/.

REFERENCE

1. *New York State Rifle & Pistol Association, Inc. v. Bruen*, 142 S. Ct. 2111 (2022).

COOPERATIVE RESEARCH PROGRAMS NEWS

RISK MANAGEMENT AT STATE DOTS

Jacobs Engineering Group received a $350,000, 24-month contract [National Cooperative Highway Research Program (NCHRP) Project 08-151] to develop content on how to implement and sustain the use of formal risk management at state departments of transportation (DOTs). The content will be suitable for the AASHTO Transportation Management Hub. It will include—but not be limited to—establishing and communicating the value of risk management for decision making across state DOTs, initiating organizational changes that enable and strengthen the use of formal risk management, and developing and sustaining a risk-management mindset and agency culture across programs and into key decision-making processes.

For further information, contact Ann Hartell, TRB, at 202-334-2369 or AHartell@nas.edu.

SAFE SYSTEM APPROACH TO U.S. TRANSPORTATION PLANNING, DESIGN, AND OPERATIONS

The University of North Carolina, Chapel Hill, received a $450,000, 24-month contract [NCHRP Project 17-101] to perform Safe System research. The Safe System approach acknowledges that road users make mistakes and prioritizes saving lives above all other considerations. With this proactive mindset, in the event of a crash, the impact energies remain below the threshold likely to produce either death or serious injury. Although some Safe System strategies currently are included in zero-fatality efforts in the United States, this research will aid transportation agencies by providing practical resources for transportation planners, designers, and operations managers to consult during problem identification, project development, and countermeasure selection.

For further information, contact David Jared, TRB, at 202-334-2358 or DJared@nas.edu.

EFFECTS OF REAL-TIME WARNINGS AND VARIABLE SPEED LIMITS ON SAFETY AND TRAVEL DURING WEATHER EVENTS

The University of Connecticut received a $400,000, 36-month contract [NCHRP Project 03-142] to perform research to create a report that identifies strategies and information needed to formulate effective messaging to elicit appropriate driver behavior and aid highway safety and mobility.

Oregon DOT, Flickr, CC BY 2.0

Real-time weather and road condition data make it possible to warn drivers, often via variable speed limits and real-time motorist warnings like this one reminding drivers to chain up near Detroit, Oregon.

The report will describe how to convey messaging, with consideration of message locations, content, platform, and timing. It also will identify the means to determine the effectiveness of the deployment of real-time messaging on safety and travel reliability.

For further information, contact Camille Crichton-Sumners, TRB, at 202-334-1695 or CCrichton-Sumners@nas.edu.

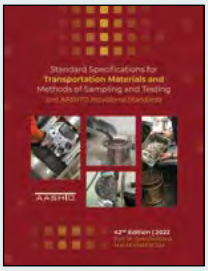
THE FUTURE OF AIRPORTS AND THE AIRPORT SYSTEM

The RAND Corporation received a $650,000, 18-month contract [Airport Cooperative Research Program (ACRP) Project 01-52] to perform research resulting in a report that identifies the role of airports in supporting the future of aviation. The report will consider the structure of the U.S. airport system, as well as individual airports and their relationships with and effects upon citizens, the environment, and local communities. The first phase will research and analyze the history and rationale of legislation, regulations, or programs affecting airports and the airport system. The second phase will consist of a strategic futuring exercise—a systematic process of conceptualizing the future and planning based on possible future outcomes—to develop a vision of the role of airports to support the aviation ecosystem of the future. Issues, challenges, and opportunities needing further consideration will be included.

For further information, contact Marci Greenberger, TRB, at 202-334-1371 or MGreenberger@nas.edu.

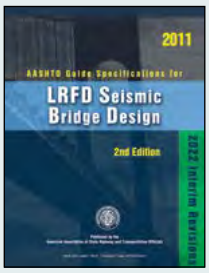
Maintenance Guidelines for Steel Bridges: Addressing Fatigue Cracking and Details at Risk of Constraint-Induced Fracture

This AASHTO publication provides guidelines for maintenance actions to address fatigue cracking, as well as details at risk of constraint-induced fracture in steel bridges. It is a synthesis of best practices from published literature, project reports, and past and ongoing research projects, as well as input from industry professionals.



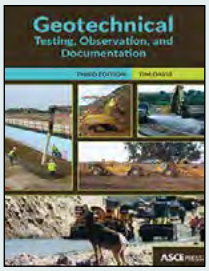
Standard Specifications for Transportation Materials and Methods of Sampling and Testing and AASHTO Provisional Standards, 42nd Edition

These standards contain specifications, recommended practices, test methods, and provisional standards used in highway facilities construction. In addition to revisions to harmonize industry standards, update technology, and improve the standards, this edition includes changes related to temperature measurement—many that resulted from a recent NCHRP report that defined appropriate choices for replacing mercury thermometers.



2022 Interim Revisions to the AASHTO Guide Specifications for LRFD Seismic Bridge Design, 2nd Edition

The 2022 interim revisions update the 2nd edition. Changes were made to Sections 3: General Requirements; 4: Analysis and Design Requirements; 5: Analytical Models and Procedures; and 6: Foundation and Abutment Design. An up-to-date 2nd edition will have these, as well as the 2012, 2014, and 2015 interim revisions.



Geotechnical Testing, Observation, and Documentation, 3rd Edition

Designed for soil technicians, inspectors, and geotechnical engineers needing guidance during the investigation, grading, and construction phases of geotechnical projects, this in-depth ASCE field manual is ideal for training new technicians or as a refresher for professionals. Each chapter includes test questions, and the appendices define more than 500 geotechnical terms.

The titles in this section are not TRB publications.
To order or check pricing and format options, contact the publishers listed.

TRB PUBLICATIONS

Transportation Research Record 2676
Issue 6

Transportation challenges for disadvantaged job seekers, pedestrian stress in urban streetscapes, detecting anomalies in national bridge inventory databases, and more topics are examined in this issue.

Transportation Research Record 2676
Issue 7

This issue includes research on the impact of dynamic loading on confined asphalt concrete surfaces, using wrong-way driving detection data, examining electric vehicle miles traveled, and low-cost connected work zone devices.

Transportation Research Record 2676
Issue 8

This issue provides research on prioritizing bus routes for electrification, distracted driving crashes, the effects of urban expressways on housing prices, and network inefficiency, among other topics.

SAGE is 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 TRR, visit https://us.sagepub.com/en-us/nam/transportation-research-record/journal203503#subscribe.

Rural Transportation Issues: Research Roadmap
NCHRP Research Report 988

This report is designed to assist state departments of transportation (DOTs) and other public agencies and to help inform policy-driven investment decisions.

2022; 414 pp.; TRB affiliates, $88.50; TRB nonaffiliates, $118. Subscriber categories: research, public transportation, administration and management.

Reliability-Based Geotechnical Resistance Factors for Axially Loaded Micropiles
NCHRP Research Report 989

This report details the development of reliability-based geotechnical resistance factors for axially loaded micropiles and related design specifications.

2022; 118 pp.; TRB affiliates, $60.75; TRB nonaffiliates, $81. Subscriber categories: bridges and other structures, geotechnology.

Subsurface Drainage Practices in Pavement Design, Construction, and Maintenance
NCHRP Synthesis 579

This synthesis documents the current state of practice by state DOTs for subsurface drainage, which is a critical component of pavement design, construction, and maintenance.

2022; 138 pp.; TRB affiliates, $64.50; TRB nonaffiliates, $86. Subscriber categories: construction, design, maintenance and preservation.

Practices for Ensuring the Smoothness of Concrete Bridge Decks
NCHRP Synthesis 580

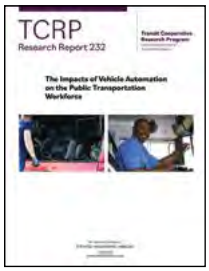
This synthesis documents practices used by state DOTs to evaluate the smoothness of concrete bridge decks when constructed, procedures used to keep track of the roughness of concrete bridge decks over time, and practices used to maintain the smoothness of concrete bridge decks throughout the life cycle of the structure.

2022; 84 pp.; TRB affiliates, $53.25; TRB nonaffiliates, $71. Subscriber categories: bridges and other structures, construction, maintenance and preservation.

Bridge Element Data Collection and Use
NCHRP Synthesis 585

This synthesis documents current state DOT practices and experiences regarding collecting element-level data and ensuring data accuracy. Also examined is how state DOTs are using the data from inspection reports.

2022; 114 pp.; TRB affiliates, $60.75; TRB nonaffiliates, $81. Subscriber categories: bridges and other structures, design, highways.



The Impacts of Vehicle Automation on the Public Transportation Workforce
TCRP Research Report 232

This report provides an analysis of the possible impacts of automation on the public transportation workforce.

2022; 140 pp.; TRB affiliates, $64.60; TRB nonaffiliates, $86. Subscriber categories: public transportation, passenger transportation, vehicles and equipment.

Considering the Unbanked in Cashless Fare Payment at Point of Service for Bus/Demand-Response Services
TCRP Synthesis 163

This synthesis is designed to help inform transit systems of the impacts of going cashless and considers facets of cashless fare payment systems, including operational aspects, advantages and drawbacks, policy and regulations, and populations of riders such as the unbanked—those who do not use mainstream financial services and may not have a way to use a cashless system.

2022; 90 pp.; TRB affiliates, $57.75; TRB nonaffiliates, $77. Subscriber categories: public transportation, administration and management, policy.

Evaluation of the Asphalt Binder Quality Tester
CRP Special Release 1

This report presents an evaluation of an effort that supported the development of the Asphalt Binder Quality Tester. This is a rapid testing device for binder quality.

2022; 66 pp.; TRB affiliates, $52.50; TRB nonaffiliates, $70.00. Subscriber categories: materials, pavements, research (about research).

Evaluation of the Exploratory Advanced Research Program
CRP Special Release 2

This report presents an evaluation of the Exploratory Advanced Research Program, which works on a range of topics, including human–automation interaction, safety improvements through advanced data analysis, innovative materials for highway pavements and structures, methods to improve transportation system resilience, and technologies for the development of alternative fuels.

2022; 72 pp.; TRB affiliates, $52.50; TRB nonaffiliates, $70. Subscriber categories: materials, pavements, research (about research).

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

MEETINGS, WEBINARS, AND WORKSHOPS

December

12 **TRB Webinar: Expanding Microtransit Services and Improving the Rider Experience**

12–14 **Advances in Materials and Pavement Performance Prediction***
Hong Kong
For more information, contact Nelson Gibson, TRB, 202-334-2953, NGibson@nas.edu.

13 **TRB Webinar: Trends in Transit Ridership—Analysis, Causes, and Responses**

15 **TRB Webinar: Measuring and Managing Fare Evasion**

January

8–12 **TRB 102nd Annual Meeting**
Washington, DC
For more information, contact TRBMeetings@nas.edu.

17 **Road Safety Research Meeting**
Online
For more information, e-mail Michael Covington, TRB, at mcovington@nas.edu.

February

5–8 **Geosynthetics Conference***
Kansas City, Missouri
For more information, contact Nancy Whiting, TRB, 202-334-2956, NWhiting@nas.edu.

April

11–12 **Workshop on Building More Resilient Supply Chains**
Washington, DC
For more information, contact Thomas Palmerlee, TRB, 202-334-2907, TPalmerlee@nas.edu.

May

15–18 **11th National Aviation System Planning Symposium**
Washington, DC
For more information, contact Christine Gerencher, TRB, 202-334-2970, CGerencher@nas.edu.

17–19 **11th Young Researchers Seminar***
Lisbon, Portugal
For more information, contact Bill Anderson, TRB, 202-334-2514, WBAnderson@nas.edu.

*TRB is co-sponsor of the meeting.

Please contact TRB for up-to-date information on meeting cancellations or postponements. For Technical Activities meetings, visit www.TRB.org/calendar/calendar or e-mail TRBMeetings@nas.edu. For more information on a TRB webinar, contact TRBwebinar@nas.edu. For information on all other events or deadlines, inquire with the listed contact.

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."

Did You Know?

In 1902, a streetcar ride on a snowy day in New York City inspired a Birmingham, Alabama, woman to invent the first operational windshield wiper.

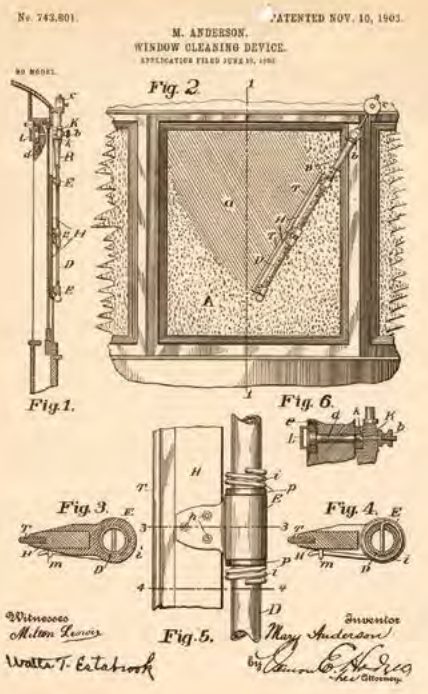
While riding, Mary Anderson noticed that the streetcar driver was forced to hop off and on to clear snow from the windshield. That observation led her to ponder the possibility of a device that could be operated from inside, wipe the windshield, and be hidden from view when not in use. She returned home, got to work on her design, and applied for a patent that would be accepted on November 10, 1903.

Courtesy of the Birmingham Public Library

Unfortunately, Anderson was unable to interest manufacturers in fabricating her Window Cleaning Device. One rejection letter read, "We regret to state we do not consider it to be of such commercial value as would warrant our undertaking its sale."

Today—120 years later when windshield wipers have become ubiquitous—it's clear they were wrong. In 2011, Mary Anderson finally received credit when she was inducted into the National Inventors Hall of Fame.

—Cassandra Franklin-Barbajosa
Senior Editor, *TR News*



Courtesy of the U.S. National Archives

INFORMATION FOR CONTRIBUTORS TO TR NEWS

TR News welcomes the submission of articles for possible publication in the categories listed below. All articles 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 articles accepted for publication are subject to editing for conciseness and appropriate language and style. Authors review and approve the edited version of the article before publication. All authors are asked to review our policy to prevent discrimination, harassment, and bullying behavior, available at https://www.nationalacademies.org/about/institutional-policies-and-procedures/policy-of-harrassment.

ARTICLES

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, technology, etc.). Manuscripts should be no longer than 3,000 words. Authors also should provide tables and graphics with corresponding captions (see Submission Requirements). Prospective authors are encouraged to submit a summary or outline of a proposed article for preliminary review.

MINIFEATURES are concise feature articles, typically 1,500 words in length. These can accompany feature articles as a supporting or related topic or can address a standalone topic.

SIDEBARS generally are embedded in a feature or minifeature article, going into additional detail on a topic addressed in the main article or highlighting important additional information related to that article. Sidebars are usually up to 750 words in length.

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 graphics, and are subject to review and editing.

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. Research Pays Off 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 the logo of the agency or organization submitting the article, as well as one or two photos or graphics. Research Pays Off topics must be approved by the RPO Task Force; to submit a topic for consideration, contact Nancy Whiting at 202-334-2956 or nwhiting@nas.edu.

OTHER CONTENT

TRB HIGHLIGHTS are short (500- to 750-word) articles about TRB-specific news, initiatives, deliverables, or projects. Cooperative Research Programs project announcements and write-ups are welcomed, as are news from other divisions of the National Academies of Sciences, Engineering, and Medicine.

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, Web link, and DOI or ISBN. Publishers are invited to submit copies of new publications for announcement (see contact information below).

SUBMISSION REQUIREMENTS:

- **Articles** submitted for possible publication in *TR News* and any correspondence on editorial matters should be sent to the *TR News* Editor, Cassandra Franklin-Barbajosa, cfranklin-barbajosa@nas.edu, 202-334-2278.
- Submit **graphic** elements—photos, illustrations, tables, and figures—to complement the text. Photos must be submitted as JPEG or TIFF files and must be at least 3 in. by 5 in. and 2 megabytes with a resolution of 300 dpi. Large photos (8 in. by 11 in. with a minimum of 4 megabytes at 300 dpi) are welcome for possible use as magazine cover images. A detailed caption must be supplied for each graphic element.

Note: Authors are responsible for the authenticity of their articles and for obtaining written permissions from publishers or persons who own the copyright to any previously published or copyrighted material used in the articles, **as well as any copyrighted images** submitted as graphics.

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