TR NEWS

January–February 2022 NUMBER 337

Preservation, Maintenance, and Renewal

A Strategic Approach to Prepare for the Future

PLUS

Safe Navigation for Pedestrians and Bicyclists at Intersections

How We Move Matters

Serving Passengers with Hearing Loss

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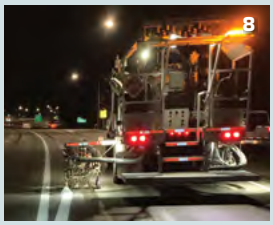

COVER The road—and work day—stretch ahead for an Arizona Department of Transportation (DOT) crew conducting pavement preservation operations on SR-88. The results of efficient, effective preservation include reduced life-cycle costs, shorter down time, and better system performance. (Photo: Arizona DOT)

ALSO IN THIS ISSUE

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 March–April 2022 issue of *TR News* features photo highlights from the 101st TRB Annual Meeting. Authors also explore how transit agencies interact to improve bus stops and pedestrian access; roadway lighting research; and the role transportation plays in trafficking missing and murdered Indigenous women and girls and what the industry can do to address the problem.

Photo: Jeff Ferguson

Arm raised in protest, Colville tribal member Virginia Redstar of Nespelem, Washington, rallies against the plight of missing and murdered Indigenous women, symbolized by the red hand painted over her mouth. As much as transportation plays a role in the trafficking of these victims, the industry is increasing its efforts to stop the exploitation of these vulnerable women and girls.

TR NEWS

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

***TR News* is produced by the Transportation Research Board**

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NCHRP RESEARCH REPORT 948

GETTING TO THE OTHER SIDE

Safe Navigation for Pedestrians and Bicyclists at Alternative and Other Intersections and Interchanges

Photo: Roman K, Flickr

BASTIAN SCHROEDER, SHANNON WARCHOL, AND MIKE ALSTON

Schroeder is a senior principal engineer, Warchol is a senior engineer, and Alston is an engineering associate and planner at Kittelson and Associates.

Above: Contending with two-way traffic and turning lanes, a pair of pedestrians wait their turn to cross a busy street in Chicago, Illinois. Traditionally, roadway engineers and planners have placed priority on traffic flow and driver safety. Now there is a move toward designing intersections that consider the needs—and safety—of pedestrians and bicyclists alike.

A driver makes a right turn, travels about 500 to 800 feet, then enters a left-turn lane to make a U-turn, rather than crossing or turning left on a high-speed road. This configuration, called a restricted crossing U-turn (RCUT) intersection,[1] is one of many alternative intersection and interchange (A.I.I.) designs that has emerged in the past decade.

Since driving an extra 500 feet can take only seconds, the RCUT intersection design significantly reduces the chance of a severe or fatal car crash from left turns on high-speed roads. For motor vehicle drivers, the RCUT and many of its A.I.I. cousins provide operations and safety benefits over a traditional intersection with direct left turns.

For a bicyclist at most RCUTs, however, crossing or turning left means contending with drivers in that 500 feet of roadway, as well as a left-turn lane. For a pedestrian, it means crossing an unfamiliar intersection and encountering out-of-direction travel. Neither of these experiences are convenient or comfortable, and some movements—like a bicyclist forced to weave across lanes of fast-moving traffic to a U-turn bay—can be dangerous (Figure 1). But are these experiences worse than at whatever the conventional design of this intersection would be? What if there are ways to mitigate the safety and comfort concerns at conventional—as well as RCUT—intersections? How can engineers and planners compare these design alternatives for aspects of multimodal safety and comfort?

The experience for people walking and biking at an RCUT intersection reflects a common issue among many alternative intersections built to date: Pedestrians and bicyclists have not been prioritized in the design. *National Cooperative Highway Research Program (NCHRP) Research Report 948: Guide for Pedestrian and Bicyclist Safety at Alternative and Other Intersections*

[1] This FHWA brief provides details about RCUT intersections at https://www.fhwa.dot.gov/publications/research/safety/09059/.

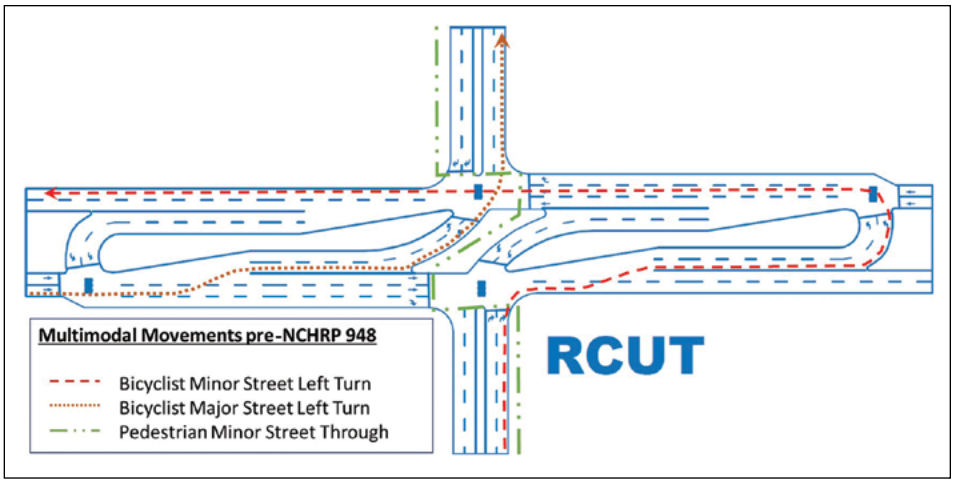


FIGURE 1 **Pedestrian and bicyclist movements at RCUT before *NCHRP Research Report 948*. (Source: Kittelson.)**

and Interchanges addresses how this can be measured and how improvements can be evaluated.

Designing to Integrate All Users

An RCUT is just one example of an A.I.I., a category that encompasses complex intersections designed to improve efficiency and safety for drivers. Common A.I.I.s include the diverging diamond interchange, median U-turn, displaced left turn, quadrant roadway, jug handle, and continuous green-T.

To achieve these benefits for drivers, A.I.I.s adjust geometric features (e.g., a reversal of traffic lanes from their traditional directions), which can be unintuitive or uncomfortable for people walking and biking and could increase their risk or exposure at the intersection. In addition, pedestrian paths and bicycle facilities may cross through islands or take different routes than expected. The concern is acute for pedestrians with disabilities.

NCHRP Research Report 948 is a response to these realities. The report is a guide for transportation practitioners to improve pedestrian and bicycle safety and quality of service at intersections—including A.I.I.s—through planning, design, and operational treatments.

Guiding Principles

The NCHRP report is rooted in a performance-based design approach that is familiar to many transportation professionals through *NCHRP Report 672: Roundabouts: An Informational Guide, Second Edition* and *NCHRP Report 785: Performance-Based Analysis of Geometric Design of Highways and Streets. NCHRP Research Report 948* adapts many of the guiding principles of these earlier NCHRP reports to the specific challenge of pedestrian and bicyclist safety at intersections, including the alternative designs.

Through a two-year research effort that included field-based data collection of people walking and bicycling through A.I.I.s, national focus groups in locations where a high rate of existing A.I.I. design is constructed, and engagement with national experts that generated more than 8,000 comments, *NCHRP Research Report 948* provides a performance-based assessment method that can be applied in the concept or final design stages, as well as in safety audits of existing locations.

A Test of "20 Questions"

At the heart of *NCHRP Research Report 948* is a quantitative analysis method built around 20 design flags: 20 performance-based design checks a designer may evaluate when assessing the level of

#	Flag Description	Pedestrian	Bicycle
1	Motor Vehicle Right Turns		
2	Uncomfortable/Tight Walking Environment		
3	Nonintuitive Motor Vehicle Movements		
4	Crossing Yield- or Uncontrolled Vehicle Paths		
5	Indirect Paths		
6	Executing Unusual Movements		
7	Multilane Crossings		
8	Long Red Times		
9	Undefined Crossing at Intersections		
10	Motor Vehicle Left Turns		
11	Intersecting Driveways and Side Streets		
12	Sight Distance for Gap Acceptance Movements		
13	Grade Change		
14	Riding in Mixed Traffic		
15	Bicycle Clearance Times		
16	Bicyclist Crossing Motor Vehicle Travel Lane(s)		
17	Channelized Lanes		
18	Turning Motorists Crossing Bicycle Path		
19	Riding Between Travel Lanes, Lane Additions, or Lane Merges		
20	Off-Tracking Trucks in Multilane Curves		

FIGURE 2 **Applicability of flags to pedestrian and bicyclist movements. (Source: Kittelson.)**

comfort and safety for multimodal users at an intersection or interchange.

The 20 design flags highlight design characteristics that impact safety and quality of service for people walking and biking, regardless of the intersection type. Examples include tight walking environments, nonintuitive motor vehicle movements, grade changes, and motorists crossing bicycle paths. The list is meant to be a tool for evaluation and comparison that is worked through during the design phase, one flag at a time (Figure 2). Some of the flags are associated with pedestrian movements, some with bicyclist movements, and some apply to both user groups.

Each of the 20 flags includes thresholds for a yellow flag and for a red flag at a given intersection. A yellow flag is generally associated with user comfort and a red flag with safety. Working through the list gives a percentage of red flags and a percentage of yellow flags for the intersection design being studied. To help convey the nuances of these design flags, the guide encompasses nearly 200 original graphics that illustrate the design flags, countermeasures, and alternative intersection and interchange design concepts (Figure 3).

The flags also can be used to indicate where safety countermeasures would be appropriate. To assist practitioners with these design and countermeasure decisions, the guide includes a chapter dedicated specifically to countermeasures and treatments that can help address the design flags. In addition, four chapters of the guide are dedicated to providing solutions to specific intersections: the RCUT, median U-turn, displaced left turn, and diverging diamond interchange.

A Methodology That Serves All Intersections

The project started out with a focus on the alternative intersection and interchange designs, but it was quickly determined that the true value in an assessment method was in the comparison of an A.I.I. to a conventional design. This realization was so profound that it ultimately led to a title change midway through the project. What was originally

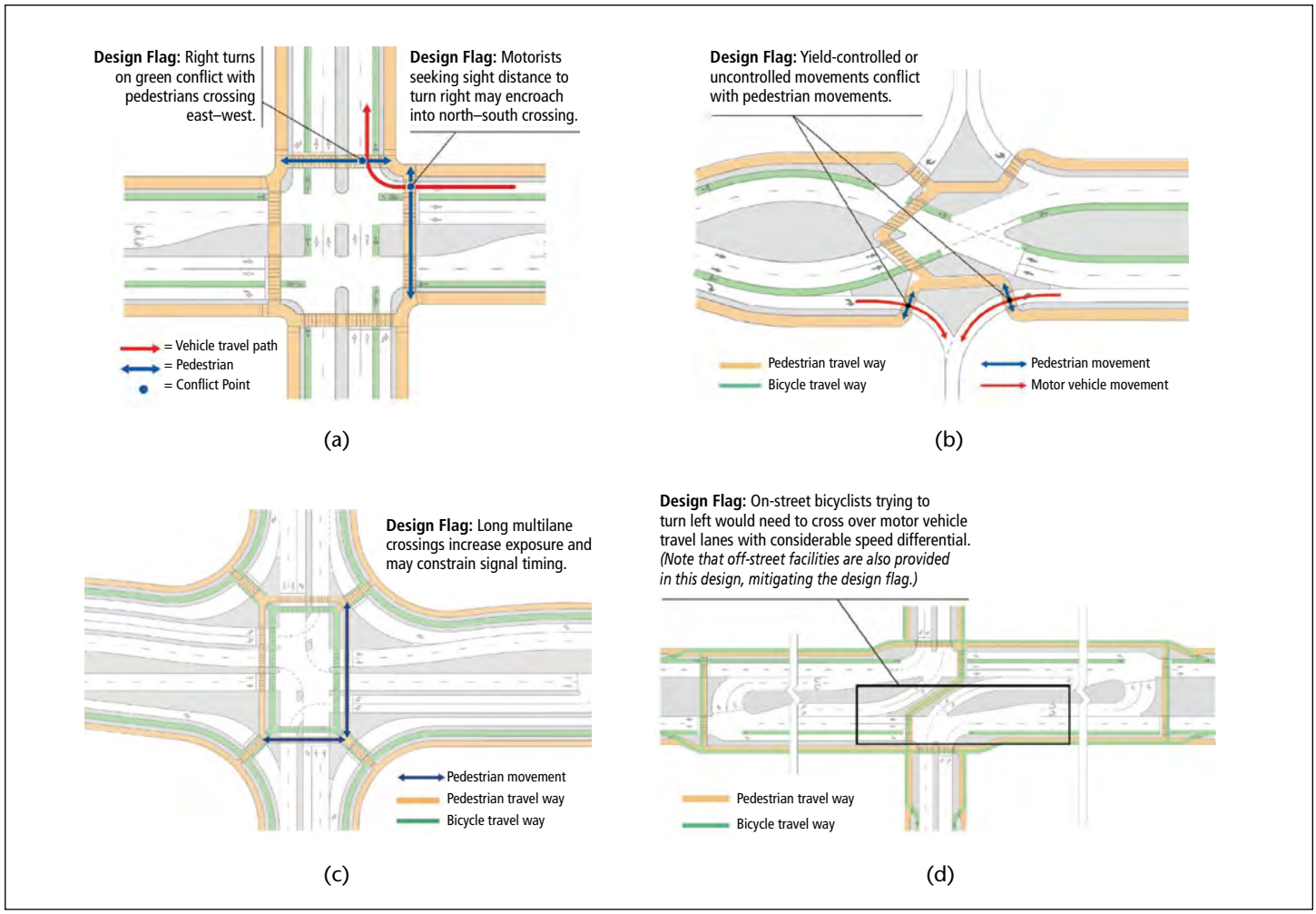


FIGURE 3 Examples of design flags include (*a*) Design Flag 1—motor vehicle right turn, (*b*) Design Flag 4—crossing yield-controlled or uncontrolled vehicle paths, (*c*) Design Flag 7—multilane crossings, and (*d*) Design Flag 14—riding in mixed traffic. (Source: *NCHRP Research Report 948*.)

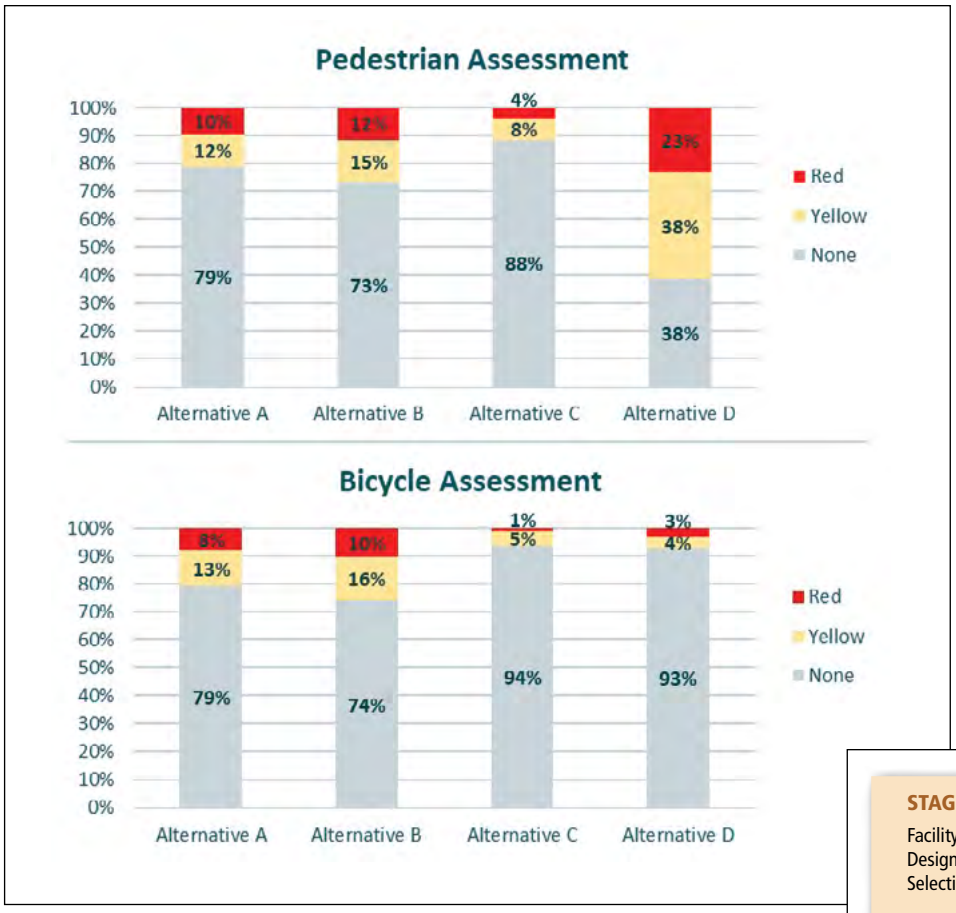


FIGURE 4 Potential outcome of the 20 Design Flag method. (Source: *NCHRP Research Report 948*.)

named *Guide for Pedestrian and Bicycle Safety at Alternative Intersections and Interchanges (A.I.I.)* became *Guide for Pedestrian and Bicycle Safety at Alternative and Other Intersections and Interchanges*.

The performance-based design process and the 20 Design Flag method are geared to evaluating design elements of an intersection rather than the intersection form as a whole. As such, the method benefits agencies despite whether they are currently evaluating alternative designs. In fact, the guide provides specific examples of design flags for conventional designs.

The 20 Design Flag method is applied to all pedestrian and bicyclist movements through an intersection, which are then tallied to the total of yellow and red flags identified. The percentages of flags allow for comparison of proposed designs and can be used in screening designs to move forward. In Figure 4, four intersection alternatives are evaluated and compared relative to their safety for multimodal users. This quantitative look at intersections is the first time designers can explicitly consider the effects of design choices on the safety of pedestrians and bicyclists.

These results can now be used in combination with other desired design outcomes, including heavy vehicle accommodations, fastest path checks, and sight distance. Through an iterative design process to address the multimodal safety and other intended outcomes, an optimal design solution is developed that ultimately serves all users.

Relationship to Project Development and Intersection Control Evaluation

The *NCHRP Research Report 948* methodology is intended to be integrated into an agency's project development, including a formalized intersection control evaluation (ICE) process. The performance-based assessment process is ideally suited for what many agencies refer to as Stage 2 of an ICE process: a stage at which the feasible list of intersection concepts has been reduced to three or four alternatives (Figure 5). The 20 Design Flag method is intended to

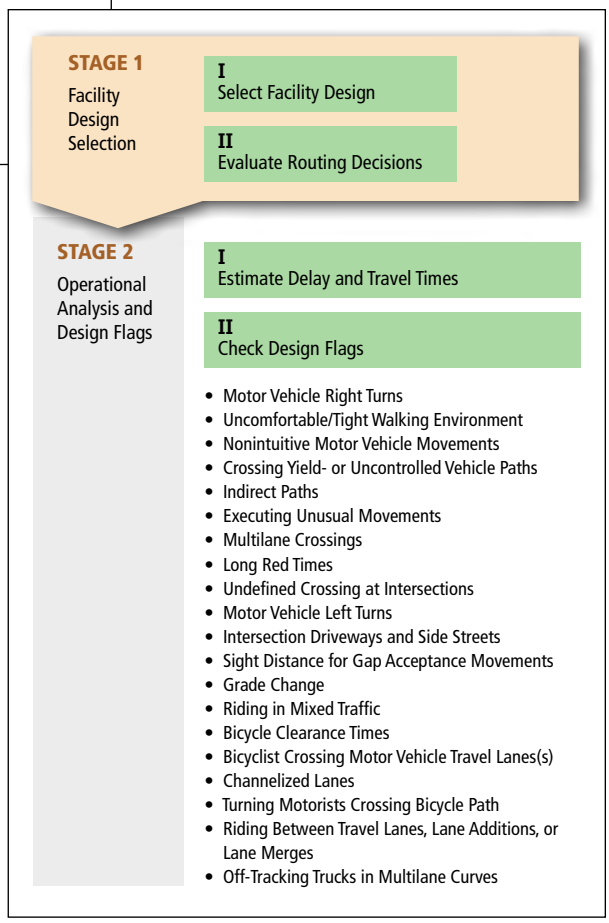


FIGURE 5 Two-stage ICE assessment for nonmotorized users.

fill a specific gap at this stage of ICE. In addition, the guide provides direction for Stage 1 of ICE, at which agencies may be confronted with a much larger potential pool of design alternatives.

Reenvisioning Standard Designs

NCHRP Research Report 948 provides detailed strategies for the four most common A.I.I. designs—RCUT, median U-turn, displaced left turn, and diverging diamond interchange—and reenvisions what engineers and planners think of as standard designs. A striking review of 141 existing RCUTs across the United States showed that 113 sites (80 percent) did not have pedestrian or bicyclist facilities, and only 11 sites (7.8 percent) had a way for pedestrians to cross the mainline arterial. In an effort to change this, the guide presents new ways of looking at RCUTs, as well as the other designs, with new concepts that integrate multimodal users from the start (Figure 6). Over time, the hope is that agencies will begin to rethink their approaches to these intersections and integrate all users in their designs from the start.

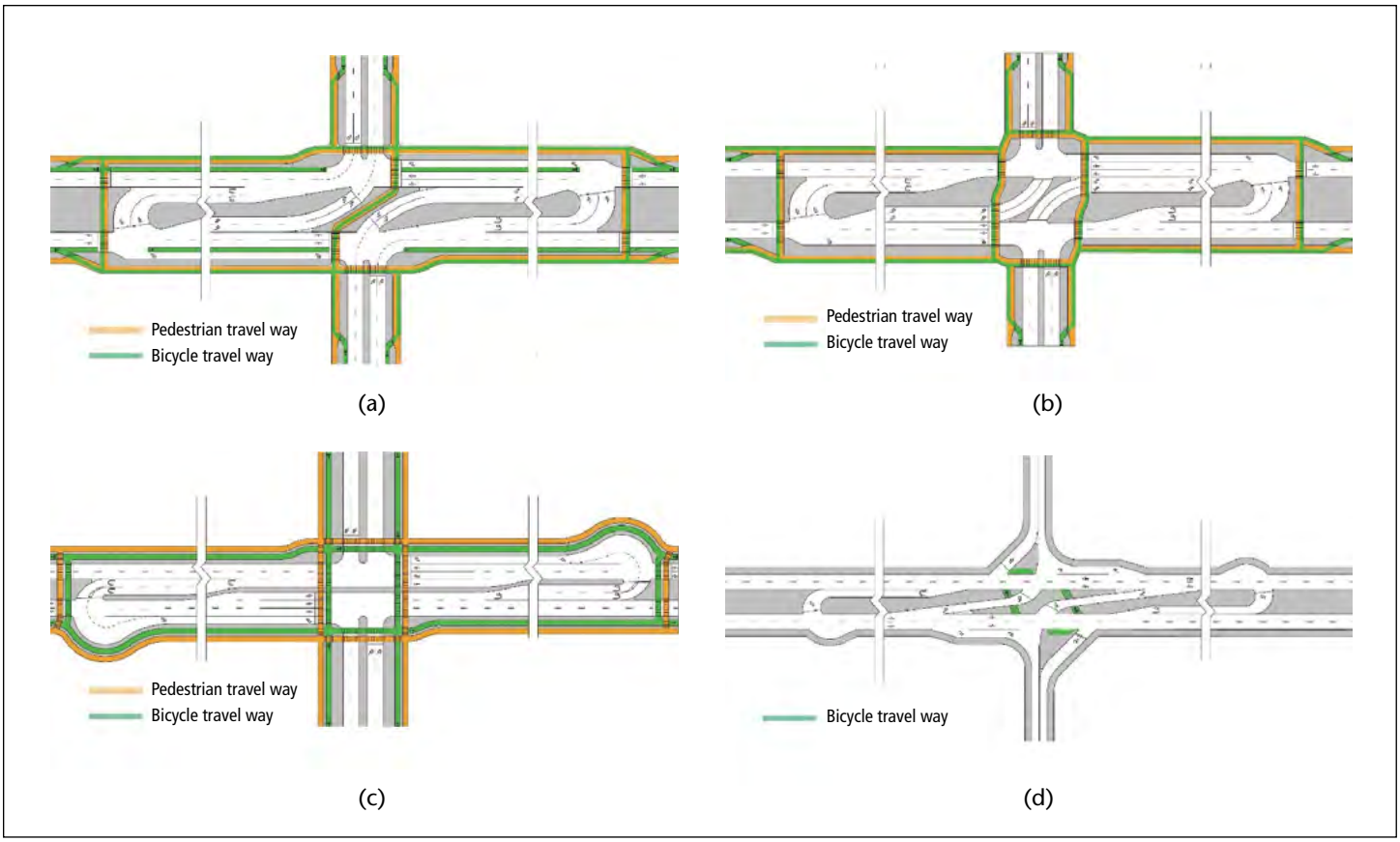


FIGURE 6 New RCUT design concepts to integrate all users include (*a*) RCUT with on-street bike lanes and shared-use path and diagonal crossing, (*b*) RCUT with shared-use path and direct crossings, (*c*) RCUT without any left turns with protected bike lanes, and (*d*) RCUT for rural application without pedestrian facilities with bicycle cut-throughs. (Source: *NCHRP Research Report 948*.)

NCHRP REPORT 750, VOL. 7

Preservation, Maintenance, and Renewal

A Strategic Approach to Prepare for the Future

Photo: Washington State DOT

JAGANNATH MALLELA, HAL KASSOFF, AND AMIR N. HANNA

Mallela is a senior vice president and Kassoff is a senior vice president (retired) for WSP USA. Hanna is a senior program officer for the Transportation Research Board at the National Academies of Sciences, Engineering, and Medicine in Washington, D.C.

Above: Construction crews restripe southbound I-5 to open a new auxiliary lane near Joint Base Lewis–McChord in Washington State. Transportation agencies like Washington State DOT must stay abreast of innovations to add to highway preservation, maintenance, and renewal activities, ensuring a robust, resilient, and adaptive roadway network.

As the world rapidly changes, state departments of transportation (DOTs) and their institutional responsibilities also change. A robust and increasingly resilient and adaptive network of streets and highways need a continuing focus on highway preservation, maintenance, and renewal (PMR). Even while vehicle and infrastructure technologies advance, the network will continue to include pavements, bridges, tunnels, drainage systems, and other fundamental components of highway infrastructure.

However, methods of preserving, maintaining, and renewing highway infrastructure will undoubtedly involve significant changes over the coming decades. These changes will occur in response to inevitable changes in the level and patterns of usage of the system, the introduction of innovative practices (materials, methods, tools, and technologies), the availability of financial and human resources, and customer expectations.

Caring for the assets that are essential to a highway agency's mission is fundamental to the agency's success, and many PMR activities are, of necessity, the outcome of short-term, tactical decisions made in response to routine and "fix-it-first" needs.

PMR activities are never-ending and consume a large share of highway agency budgets. They present the challenge of balancing short-term, immediate needs with longer-term strategic actions to optimize PMR expenditures, practices, and performance outcomes and better align them with strategic applications of asset management. Embracing emerging and innovative PMR practices also facilitates the use of available resources to enhance customer service and agency credibility.

Emerging and Innovative Practices

The high-priority status, large budget share, and never-ending needs of PMR indicate a necessity for emerging and innovative practices and ways to address future risks, threats, and customer requirements efficiently and cost-effectively. Additionally,

Photo: Arizona DOT

Crews conduct pavement preservation operations on SR-88 in Arizona. Efficient, effective preservation activities can lead to reduced life-cycle costs, shorter down time, and better system performance.

the positive effects of improved efficiency and effectiveness—reduced life-cycle costs; faster response times; shorter down time; improved durability, reliability, and safety; enhanced system performance; elevated staff capabilities; improved customer satisfaction; and enhanced credibility and support—are attractive and compelling.

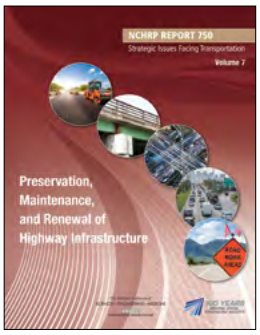
As emphasis on performance, accountability, and transparency grows, public agencies may not want to seem indifferent or slow to adopt emerging and innovative practices. At the same time, it is important for these agencies to avoid the "bleeding edge" for potential practices, or the point at which the costs and probabilities of successful outcomes are not worth the risk.

Few, if any, agencies become leaders in adopting innovative practices across all their functions. Rather, those that strive to be at the forefront of innovative practices tend to focus on specific areas that are important to them and in which they have made significant investments to establish and sustain a critical mass of expertise and capability. PMR, or individual functional categories of PMR, may well be such an area.

Project Background

Major trends affecting the future of the United States and the world will reshape transportation priorities and needs dramatically. AASHTO established the National Cooperative Highway Research Program (NCHRP) Project 20-83 research series to examine global and domestic long-range strategic issues and their implications for state DOTs to help prepare agencies for the challenges and benefits created by these trends.

One of these projects, NCHRP Project 20-83(03)A, "Long-Range Strategic Issues Affecting Preservation, Maintenance, and Renewal of Highway Infrastructure," developed guidance for transportation stakeholders on the application of emerging and innovative materials, tools, approaches, and technologies to deal with long-range (i.e., 30 to 50 years) highway infrastructure PMR needs, thereby fostering enhanced system condition and performance. The seventh report in the series, *NCHRP Report 750: Strategic Issues Facing Transportation, Volume 7—Preservation, Maintenance, and Renewal of Highway Infrastructure* presents the findings of this research.



For more information on *NCHRP Report 750: Strategic Issues Facing Transportation, Volume 7—Preservation, Maintenance, and Renewal of Highway Infrastructure*, visit https://dx.doi.org/10.17226/25757.

Guidance for Leaders and Practitioners

For emerging or innovative practices to flourish in an organization, leadership must be on board, whether via visible and encouraging actions or less visible—but no less important—support for champions who will challenge the status quo in a quest for continuous improvement. At the same time, seasoned practitioners know that to advance the state of the practice requires not only a threshold of technical expertise but also an enterprising, proactive approach that results in upward pressure on leadership to invest in emerging and innovative practices. This is particularly true for PMR-related activities, in which many of the opportunities for improvement are highly specialized and may not appear on the radar of even the most progressive and enlightened leaders.

The NCHRP project research team prepared two guides—*Practitioner's Guide to Emerging Highway Preservation, Maintenance, and Renewal Practices* and *Leadership's Guide to Emerging Highway Preservation, Maintenance, and Renewal Practices*—to help navigate the identification, understanding, application, and

implementation of emerging and innovative highway PMR practices. The future is uncertain and largely unknowable, so these guides focus on preparation rather than prediction.

PRACTITIONER'S GUIDE

The *Practitioner's Guide* examines the capability to advance specific emerging and innovative practices that respond to future PMR business needs and assist with "go/no-go" decisions for their adoption and then aids in developing a plan for implementation and advancement (Figure 1).

Practitioners and their agencies need to be prepared for a range of future scenarios in which highway PMR evolves and adapts and for opportunities to capitalize on those practices that can improve agency efficiency and effectiveness, as well as user experience. The *Practitioner's Guide* addresses all forms of emerging and innovative PMR practices: those recognizable today (i.e., those being tested and implemented or those that are still mostly theoretical) and those yet to be developed. The guidance and tools provide for assessment and advancement of those practices that are relevant to agency professionals not only today but also in years to come, as these practices evolve and become clearer.

LEADERSHIP'S GUIDE

The *Leadership's Guide* focuses on an agency's inclination and capability to foster an organizational and cultural environment that encourages considering the advancement of emerging and innovative practices and recommends strategic actions for implementation. A key component of leadership is anticipating and helping to shape the future while guiding the organization through strategic deliberations and decision making.

Predicting the future over the next 30 to 50 years is a daunting and uncertain task. With that in mind, the *Leadership's Guide* does not offer a long-term blueprint to guide future PMR practices in the coming decades, but rather it addresses the benefits of embracing emerging PMR practices to maximize value for money over the long run. The *Leadership's Guide* offers examples of highly promising emerging and innovative practices, and suggests specific ways for an agency to self-assess its ability to foster emerging and innovative practices related to PMR and other applications.

Photo: Hannah Schafer, Portland Bureau of Transportation

In 2016, the Portland Bureau of Transportation in Oregon completed—and surpassed—a street maintenance goal of preserving 100 miles of city streets, using a variety of treatments. Agency leaders can encourage a systems approach to identifying emerging and innovative PMR practices by incorporating performance metrics and learning from setbacks and successes.

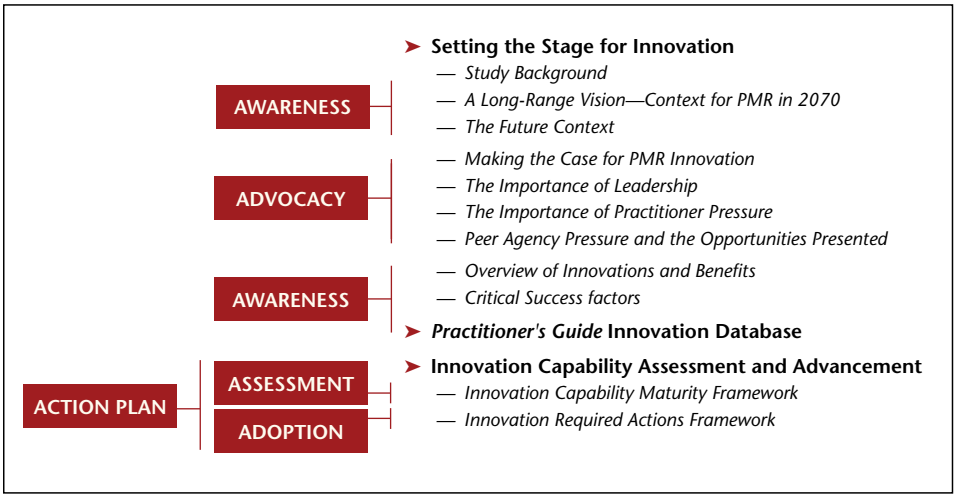


FIGURE 1 Navigating the *Practitioner's Guide*.

Role of Leadership

Leaders understand the big picture at the enterprise level and can recognize opportunities for emerging and innovative practices that cut across and extend beyond organizational boundaries. Leaders can also facilitate a multidisciplinary, interoffice systems approach to identifying the value and impacts of PMR practices that intersect multiple agency disciplines and functions.

Such actions may include anticipating differences and facilitating a collaborative approach both within and, where appropriate, beyond the agency's boundaries; cultivating talent; providing support (e.g., programs and dollars); relying on performance metrics; recognizing and accepting

a degree of risk in relation to potential rewards; and learning from setbacks and celebrating successes.

Role of Practitioners

If an agency has been recruiting and advancing top-tier technical talent and fostering a learning culture that seeks out new ways of doing business, via leadership actions or other means, there inevitably will be a bottom-up pressure to encourage innovative practices.

Just as leaders must build trust with external stakeholders by communicating the benefits and progress (or failures) of emerging and innovative practices, practitioners must educate leadership on the key details of PMR, including costs, benefits, probabilities of success, and implications beyond the agency. Presentations and discussions with leadership need to be clear, concise, and tailored to their agency's particular interests and concerns, as well as the broad policies and priorities of the agency, which must be researched and anticipated.

Critical Success Factors

Moving beyond the awareness and advocacy provided by leadership and the role of seasoned practitioners in advancing emerging practices, agency capabilities and required actions can be assessed for individual PMR practices deemed worthy of investigation. Seven critical success factors were identified to help agencies cultivate and evaluate their capabilities to advance emerging and innovative practices and to identify the actions required to assess and, ultimately, implement those that prove worthy. They are

- Awareness of emerging or innovative PMR practice;
- Awareness of performance and application;
- Systems, programs, and budgets that support emerging and innovative PMR practices;
- Culture and organization that are receptive to innovative practices;
- Supportive staff for emerging and innovative practices;
- Legal, regulatory, and policy issue management; and
- Internal and external collaboration.

Photo: Washington State DOT

A project designed to reduce crossover collisions along U.S. 101 in Port Angeles, Washington, incorporated highway paving and striping, as well as a raised median. Practitioners can help encourage PMR buy-in by sharing costs, benefits, effects, and chances of success with transportation agency leaders.

From Assessment to Action

Two capability assessment tools using these critical success factors were developed to facilitate the assessment and advancement of emerging and innovative PMR practices: 1) a practice capability maturity framework (CMF) that helps evaluate a particular emerging or innovative PMR practice and 2) an organization CMF that helps evaluate the agency's ability and tendency to foster emerging and innovative practices.

The assessments will determine if the agency possesses sufficient capability across the seven critical success factors to evaluate and potentially adopt these PMR practices, and what key actions/steps would be necessary. In addition to the CMF for practitioners, a follow-on required actions framework (RAF) provides a template for laying out a high-level action plan to determine whether and how to advance a given emerging or innovative PMR practice. The combination of the RAF and CMFs provides the essential information for deciding whether to advance the practice (i.e., moving from adoption to action to implementation).

The practice CMF assists the practitioner in determining the extent to which the agency, unit, or discipline is positioned to seriously evaluate and potentially adopt an emerging or innovative PMR practice by assessing key capabilities and identifying potential gaps. The CMF assessment can be conducted individually by an interested staff person—ideally, one who will champion emerging and innovative practices (e.g., the manager or a staff member of a key agency unit responsible for highway PMR)—or collaboratively by a group of motivated managers and staff. Objectivity is essential.

The CMF assessment process systematically evaluates the specific capabilities of a practice in terms of each critical success factor. The agency's ability to advance a specific emerging PMR practice is characterized by one of three levels.

- Level 1: The agency has significant gaps in capability and is therefore in a relatively weak position to advance the PMR practice.
- Level 2: The agency can address some gaps in capability that could pose risks to a successful implementation and is thus in a tenable position to advance the practice.

Photo: Doo Ho Kim, Wikimedia Commons

The Illinois Structural Health Monitoring Project installed a wireless sensor network setup on the Jindo Bridge in South Korea (as part of an international collaborative research effort of the United States, South Korea, and Japan) to collect an array of real-time data for examining bridge health. Structural health monitoring is one of 16 emerging PMR practices identified by researchers as of greatest interest to agencies.

- Level 3: The agency is well positioned to advance the PMR practice.

A follow-on organization improvement framework (OIF) suggests strategic actions to cultivate, advance, and apply innovative practices within the agency, unit, or discipline. The combination of the organization CMF and OIF facilitates an examination of general capabilities at any level of the organization, ranging from the enterprise as a whole to individual units within the agency. Wherever it is applied, the basic goal is to foster interest in and be open to emerging PMR practices. In doing so, agencies draw upon the same seven critical success factors used in assessing capabilities.

These same tools also are the focus of the *Leadership's Guide*, which may serve any level of leadership, including technical managers who are interested in understanding how emerging or innovative practices may be cultivated within their discipline areas, as well as a process for facilitating positive change to improve areas of identified weaknesses.

Finally, the RAF lays out a high-level action plan for advancing emerging and innovative practices that have been evaluated and are proposed for implementation. It provides the justification for moving forward with an agency commitment for advancing such practices. The RAF contains four parts: 1) addressing CMF gaps, 2) delineating agency-specific required actions, 3) conducting a preliminary long-term benefit–cost assessment, and 4) making a "go/no-go" decision. Use of the RAF presumes that the value of implementing such practices is apparent to a certain degree, even though they may not be completely understood. For these reasons, these practices must be advanced through an iterative process that involves testing, evaluation, refinement, retesting, and reevaluation.

"Sweet 16" Identifies Representative Emerging Practices

As part of the research, eight broad-based driver categories were identified, focused on long-term change and likely scenarios that may emerge over the next 30 to 50 years. These eight drivers of long-term change then were dissected into dozens of descriptive scenarios, which in turn were characterized according to their implications for PMR highway infrastructure activities.

This approach provided a framework for identifying, researching, evaluating, promoting, and implementing promising materials, tools, technologies, and approaches. After a comprehensive review, a list of more than 60 candidate materials, tools, technologies, and approaches was developed.

A series of screening criteria with rating scores within each criterion was used to identify the most promising practices. These criteria included the tie-in to likely scenarios, whether an innovation was a departure from current practice, the scale of impact, and plausibility. In applying

Materials

- Hyper-Performance Materials

Tools

- Structural Health Monitoring
- Machine Learning – Artificial Intelligence for Asset Management
- Integrated Building Information Modeling (iBIM) for Highways
- Enterprise Information Systems – PMR Applications
- Connected Vehicle Applications to Study Real-Time Conditions Information
- Artificial Intelligence – PMR Traffic Management Applications

Approaches

- Predictive–Proactive Maintenance Regime for Roadway Assets
- The Internet of Things (IoT) – PMR Applications
- Self Diagnosing/Reporting and Work Ordering
- Perpetual/Long-Life Highway Infrastructure
- Advanced TSMO Device and Communications Systems Maintenance
- Connected Vehicle to Infrastructure (V2I) Technology Providing Communications Between Passing Vehicles and Roadside Units
- Automated Enforcement for Work Zones

Technologies

- Construction Robotics
- Remote Sensing Systems – PMR Applications

FIGURE 2 The "sweet 16" of emerging preservation, maintenance, and renewal practices.

Follow-Up Implementation

Although most state DOT leaders will agree that PMR is unsurpassed in priority, these activities often escape their close and sustained attention, except during emergencies or times of crisis. And yet, advancements in technology such as remote sensing, collection and mining of big data, artificial intelligence, robotics, and materials science—all of which have growing applications in the management of transportation assets—present major opportunities, as well as significant challenges to agency leaders and practitioners who are open to careful and systematic consideration of emerging and innovative practices. Agencies that move toward the leading edge of such advancements, while prudently avoiding the bleeding edge, will have a noticeable advantage over those who lack the inclination and the capacity to seriously consider such possibilities. This research has been intended to spark interest in—and facilitate movement of—state DOTs toward the potential that emerging and innovative practices may offer to them. It provides tools to assess their interest and their capacity, as well as processes to facilitate advancements toward such practices should they so choose.

Recognizing the immediate practical value of the work performed under NCHRP Project 20-83(03)A, the NCHRP Implementation Program approved Project 20-44(36), tentatively titled "Workshops on Long-Range Strategic Issues Affecting Preservation, Maintenance, and Renewal of Highway Infrastructure."

This project will develop and hold a series of workshops for state DOT leaders, managers, and subject-matter experts to 1) share information on emerging preservation, maintenance, and renewal (PMR) practices and technologies and their potential impact on agency PMR efforts and 2) with assistance from the guidance documents discussed earlier, assess the specific benefits that these practices and technologies can bring, the investment of time and funding required, the risks that are involved, and the agency's capabilities and actions required to advance toward implementation.

For more information on the project, visit https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=5047.

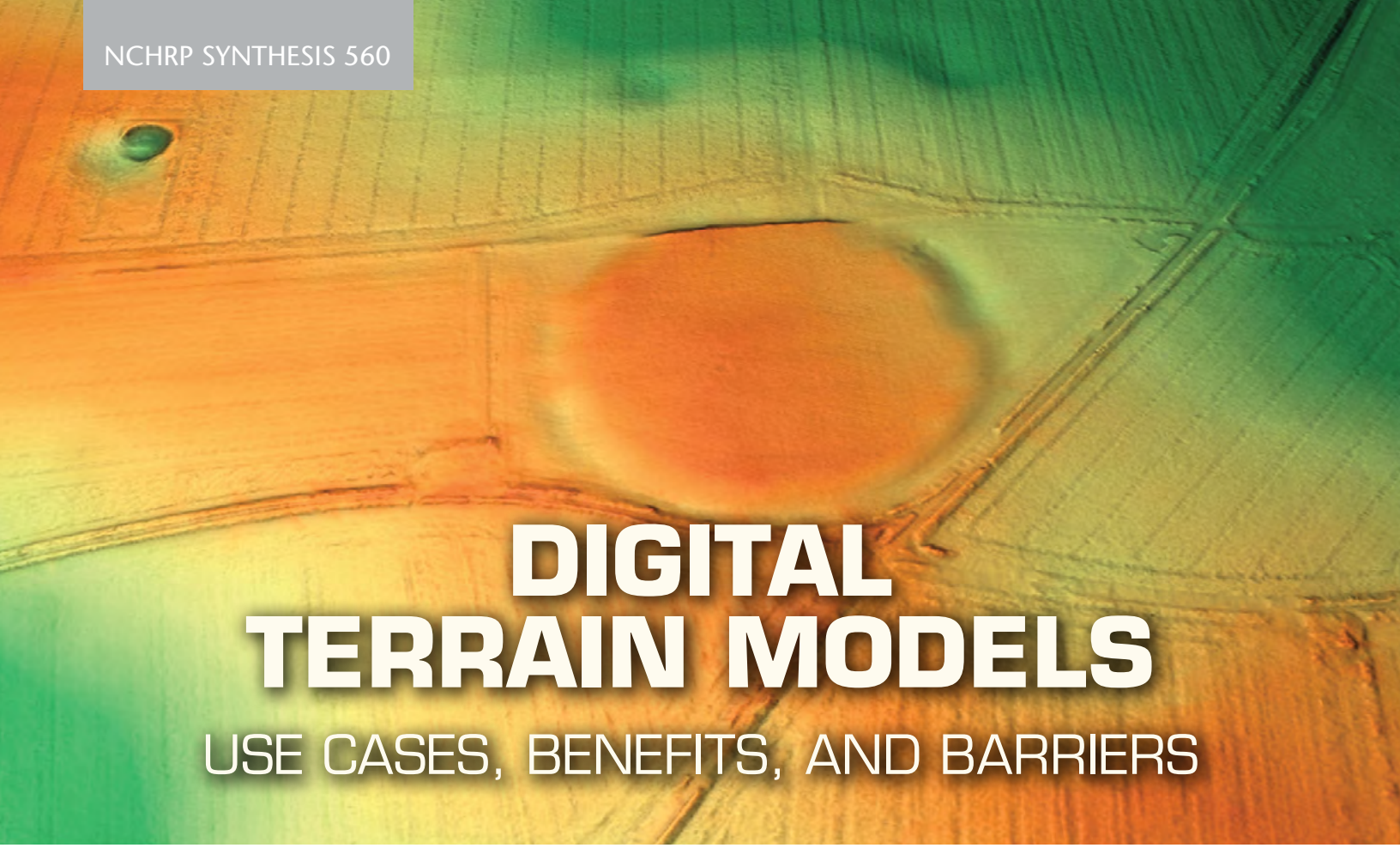
these criteria, the set of more than 60 candidates was reduced to 24 potential PMR practices. Outreach with transportation stakeholders identified the most promising practices and provided input on how to organize the guidance to help agencies deal with these practices.

The 24 emerging PMR practices underwent a final evaluation using the criteria of scale of impact, plausibility, and benefits and then were placed into three categories reflecting their priority for inclusion in the guidance (must include, should include, and not urgent to include).

As a result, 16 PMR practices involving emerging and innovative materials, tools, technologies, and approaches were identified as the most responsive to drivers, most reflective of likely scenarios, and of most interest to agencies (Figure 2). These practices span different disciplines and various functions within those disciplines and are applicable to a variety of contexts, including urban and rural highways. Most of these practices cover broad areas encompassing a multitude of materials, methods, and technologies and a plethora of application ideas. They are illustrative of the many possibilities that will emerge over time.

Narratives for each of the 16 selected PMR practices were prepared and a database was developed that includes pertinent information customized according to seven key disciplines associated with highways: pavements, structures, drainage and roadsides, equipment, transportation system maintenance and operations, connected and automated vehicles, and information technology. These customized narratives allow PMR-related professionals to build awareness; initiate evaluations of the emerging materials, tools, technologies, and approaches; and, eventually, advance them using the guidance described earlier.

This article is based on work performed under NCHRP Project 20-83(03)A by WSP USA. Jagannath Mallela was the principal investigator, and Hal Kassoff was the co-author of *NCHRP Report 750, Vol. 7*. Amir N. Hanna was the NCHRP project manager.



DIGITAL TERRAIN MODELS

USE CASES, BENEFITS, AND BARRIERS

Image: Rouven Meidlinger, Wikimedia Commons

MAKRAM BOU HATOUM, HALA NASSEREDDINE, AND GABRIEL DADI

Bou Hatoum is a graduate research assistant and PhD candidate, and Nassereddine is an assistant professor in Construction Engineering and Project Management. Dadi is the W. L. Raymond and R. E. Shaver Chair Associate Professor at the University of Kentucky in Lexington.

Above: The visualization capabilities of digital terrain models (DTMs) are apparent in this image of Bloodgate Hill, an Iron Age fort in the United Kingdom, and its surrounding roadways. Using lidar, 3-D laser scanning, and advanced survey technology, DTMs capture landform characteristics and terrain features, facilitating a thorough analysis of an area.

Because many engineering problems require accurate representations of the Earth's surface, solutions have been developed to efficiently transform terrain data into 3-D models that can be analyzed by computers, also called digital terrain models (DTMs) (*1*). For highway designers, modeling in 3-D with DTMs for visualization and design purposes is not a new capability. More recently, however, with the advancement of surveying technology and automated machine guidance (AMG), construction and inspection staff also can leverage DTMs for improved production and efficiency.

Despite this technological advancement, the handover of DTMs from design to construction has significant inefficiencies for a variety of reasons, and it remains an inconsistent practice nationally. This article builds on the findings of the National Cooperative Highway Research Program (NCHRP) Synthesis Project 20-05, Topic 51-01, "Practices for Construction-Ready Digital Terrain Models," and further investigates, via cluster analysis, significant use cases of DTMs during the construction phase of a highway project, project-specific and long-term benefits of using DTMs, and barriers to implementing the models.

Digital Terrain Models

DTMs use a collection of many selected points of the ground surface to produce a 3-D model that can be analyzed using computer algorithms. Generally, these models capture landform characteristics (e.g., elevation and slope) and terrain features (e.g., hydrographic and transportation networks). DTMs are constructed using data acquired via remote sensing technologies such as lidar, 3-D laser scanning, and geo-referenced point clouds with high-resolution imagery.

Background

Several recent initiatives have sought to push the use of 3-D models specifically into the construction phase of projects. One of these initiatives is FHWA's Every Day Counts (EDC) program, which began in 2009 as a joint venture between FHWA and AASHTO.

Photo: Oregon DOT

Oregon DOT used lidar technology to plan changes to passing lanes and speed zones when speed limit changes were enacted in 2016. The state's use of survey data served as a case study for the EDC program.

The EDC program focuses on pushing new innovations to accelerate highway project delivery by capturing and sharing case studies and workshops (*1, 2*). The program works in a two-year cycle, starting by securing buy-in from stakeholders and soliciting recommendations on innovations. A baseline evaluation of the innovation is reported while state and local agencies are tracked for the deployment and use of those innovations. Beyond improving project delivery, another goal of EDC is to encourage intelligent risk taking at transportation agencies, which can be hesitant to embrace emerging technologies.

EDC Rounds 2 and 3 (EDC-2 and EDC-3), which took place from 2013 to 2014 and 2015 to 2016 respectively, involved 3-D models in construction. EDC-2 explored "3-D Engineered Models for Construction," while EDC-3 drilled down on "3-D Engineered Models: Schedule, Cost, and Post-Construction."

EDC-2

EDC-2 found the primary benefits to be improved project delivery, improved communication, enhanced identification of errors, and improved visualization (*3, 4*). Specific benefits were identified across various stakeholders, as well. For project owners like state departments of transportation (DOTs), 3-D models provide such benefits as facilitating random grade checks instead of checks at specified cross-sections, material cost savings, and easier identification of quality assurance test locations.

For contractors, 3-D models achieved labor cost savings and resulted in fewer conflicts. Labor cost savings were achieved by reducing the need to set string lines for paving and staking for grading, as well as increased productivity. Reduced conflicts were achieved by a significant decrease in changes during the construction phase. Contractors claim savings of 4–6 percent of total project costs by using 3-D models, and others claim productivity increases of up to 50 percent.

Consultants also benefited from early identification of constructability concerns, improved design accuracy, and improved visual verification for quality control. Overall, FHWA identified a 66 percent savings in grade checking, an 85 percent reduction in stakes, improved material yields of 3–6 percent, and a 30–50 percent reduction in earthwork interruptions (*4*). Ultimately, researchers found a total project cost savings of 4–6 percent (*4*).

EDC-3

In 2015 and 2016, EDC-3 focused on integrating cost, schedule, and post-construction data (survey, as-built, and other asset

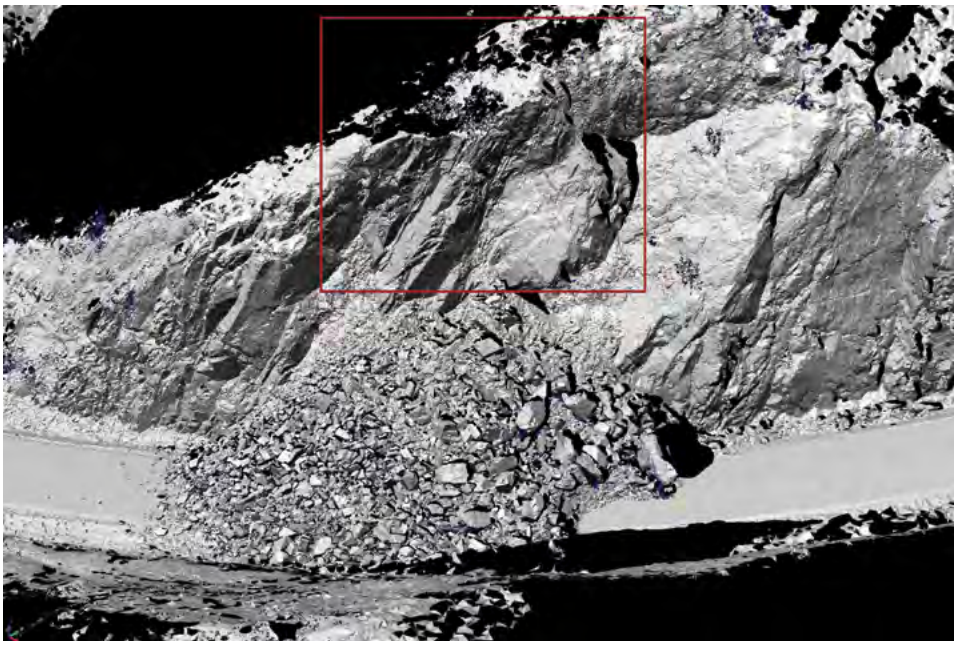


Image: Washington State DOT

A 2016 landslide dumped approximately 7,000 cubic yards of material onto U.S.-2 in Pine Canyon, Washington. A lidar image developed to assess slope safety showed nearly 6,000 cubic feet of material that still was unstable a few days later. Case studies in EDC-3 found many benefits of digital modeling.

management data) into the 3-D models. The benefits included improved project management, more accurate cost estimates, and a living record throughout the project life cycle (*4*, *5*). FHWA captured case studies from the California, Washington State, and Massachusetts DOTs to identify these benefits.

Ultimately, the final report from EDC-3 published data on the degree of implementation for 3-D models used in planning, design, and construction (*6*). The data showed significant improvements in adoption from the baseline in January 2015 to the end of the EDC round in December 2016. However, it is not clear whether this was strictly the DTM of existing terrain or if it included the 3-D design file.

Asking the Industry

As part of NCHRP Synthesis Project 20-05, Topic 51-01, an electronic survey was created and distributed to members of the AASHTO Committee on Construction. A total of 40 completed responses were received across 40 different DOTs (*7*, *8*).

DTM Use Cases

To determine how DOTs utilize DTMs, the survey provided respondents with a list of 11 DTM use cases. They were asked to specify how frequently their DOT practices each use case: "rarely," "sometimes," "often," or "always." The cluster analysis groups the 11 DTM use cases into three clusters according to their average frequency of usage based on a five-point Likert scale (Figure 1). The five DTM use cases included in the first cluster (highlighted in gray) were grade work, survey verification, automated machine guidance, quantity measurements, and field staking. These were the use cases utilized most frequently among state DOTs.

Project-Specific and Long-Term Benefits

The survey offered respondents a list of six project-specific benefits of using DTM. Respondents were asked to rate the degree that each benefit had been realized using a five-point Likert scale: very low (1), low (2), moderate (3), high (4), and very high (5). The cluster analysis grouped the six project-specific benefits into three clusters based on their average rating (Figure 2), with each cluster including two benefits. The two project-specific benefits of the first cluster (highlighted in gray)—having, on average, a high impact on highway construction projects—are as follows: easier to calculate construction quantities (with a score of 3.97) and earlier identification of plan discrepancies and conflicts (with a score of 3.79).

Respondents also were asked to indicate how agreeable they were with a list of long-term benefits of DTMs, using a five-point Likert scale: strongly disagree (1), disagree (2), unsure (3), agree (4),

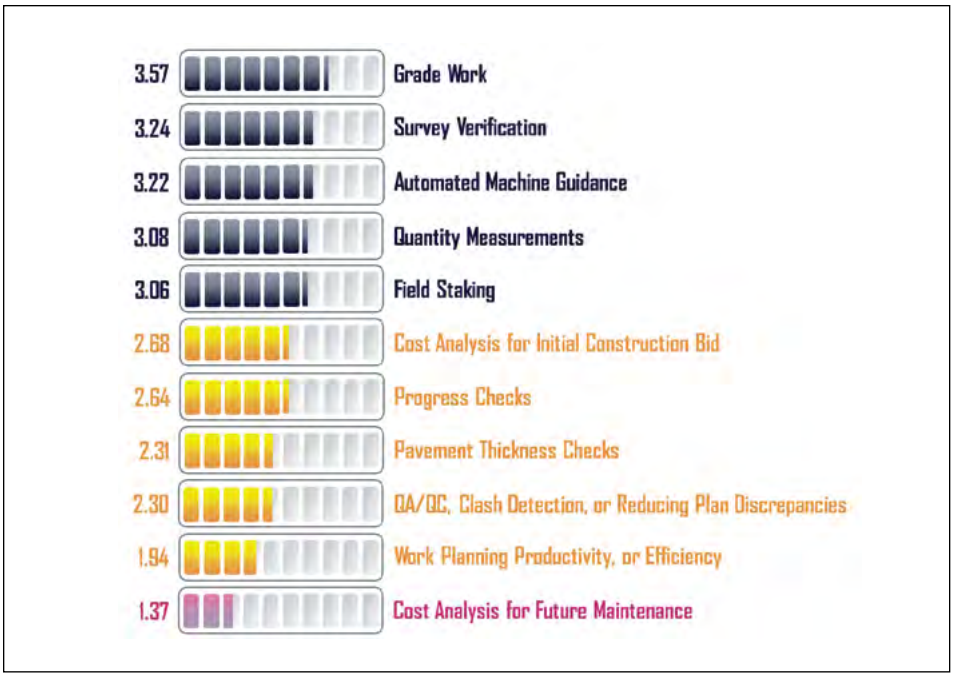


FIGURE 1 Cluster analysis of DTM use cases. (QA/QC = Quality Assurance/Quality Control.)

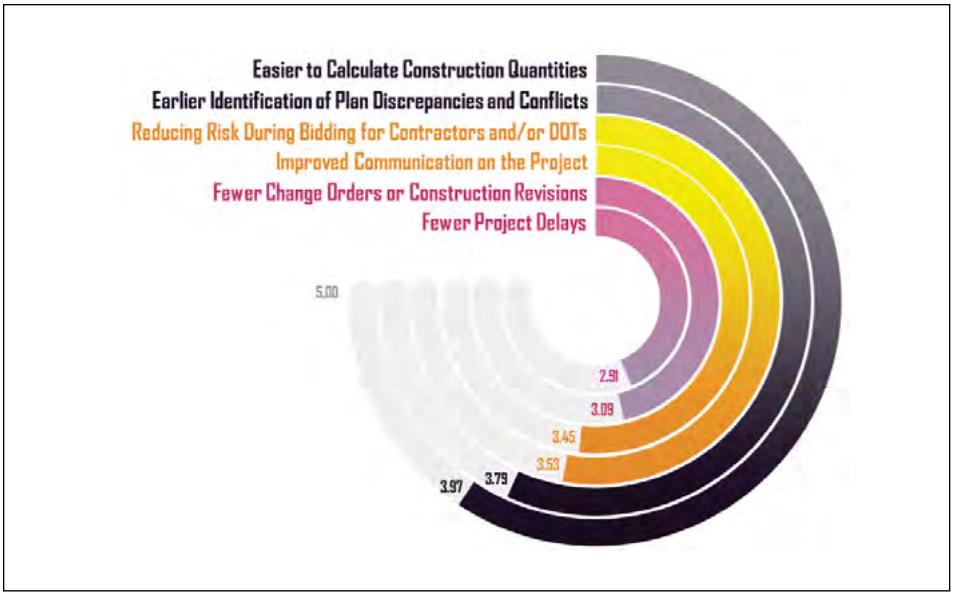


FIGURE 2 Project-specific benefits of DTM, based on a five-point Likert scale.

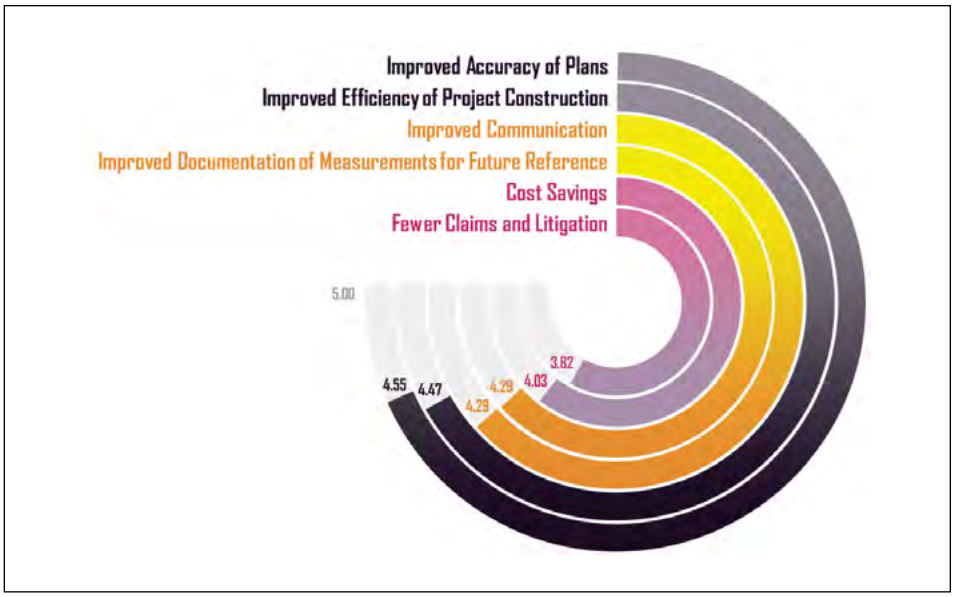


FIGURE 3 Long-term benefits of DTM, based on a five-point Likert scale.

and strongly agree (5). The cluster analysis grouped the six long-term benefits into three clusters based on their average score (Figure 3), with each cluster including two benefits. The two long-term benefits of the first cluster (highlighted in gray) have, on average, a very high level of agreement from state DOTs on their impact on highway construction projects: improved accuracy of plans (with a score of 4.55) and improved efficiency of project construction (with a score of 4.47).

DTM Barriers

Survey respondents selected from a list of 13 barriers to wider adoption of DTM on highway construction projects. The cluster analysis grouped the 13 barriers into three clusters based on their perceived potential to challenge the implementation of DTM (Figure 4). According to the results, the main deterrent to wider adoption of DTM was insufficient knowledge or training for inspectors (70 percent), office staff (65 percent), and field survey staff (62 percent).

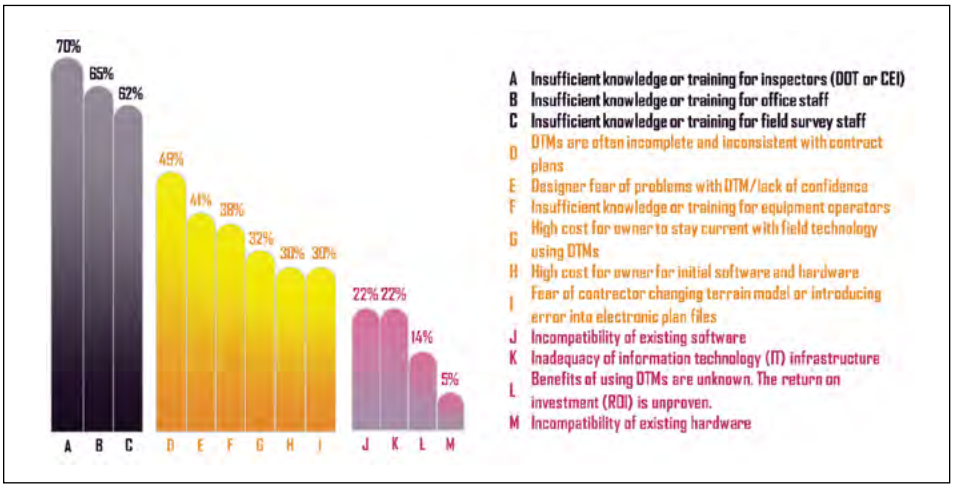


FIGURE 4 Barriers to DTM use. (CEI = construction engineering and inspection.)

Summary

DTMs are a subset of 3-D models that can provide significant value to the delivery of highway projects throughout its life cycle. The primary use cases of DTMs are in supporting grade work and surveying, and most DOTs realize benefits for calculating quantities and verifying accuracy of plans.

The most significant barriers to the use of DTMs relate to training and knowledge for staff and other direct stakeholders. There are some concerns with accuracy and completeness of the DTMs and overall trust of the technology. But as technological capabilities advance and DOTs seek to improve personnel efficiencies, the use of DTMs to support digital project management and delivery likely will continue to increase.

This article is based on work performed under NCHRP Synthesis Project 20-05, Topic 51-01 by the University of Kentucky. Gabriel Dadi was the principal investigator. Makram Bou Hatoum and Hala Nassereddine co-authored *NCHRP Synthesis 560*.

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How We Move Matters

Connections Between New Transportation and Mobility Options and Environmental Health

Photo: AEMoreira042281, Wikimedia Commons

ANNE JOHNSON AND KATHERINE KORTUM

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Above: Just before dawn in New York City, an all-electric New Flyer Xcelsior XE60 articulated bus waits on West 14th Street at 6th Avenue before heading to Manhattan's East Side. Such vehicles achieve two environmental health goals: They reduce harmful emissions and put a damper on noise pollution.

Recent years have brought dramatic changes to the ways people and goods move around communities. Many of these changes have important ramifications—for better or worse—for human health, equity, pollution, and climate. How We Move Matters: Exploring the Connections Between New Transportation and Mobility Options and Environmental Health, a virtual workshop held over three sessions from July 13–21, 2021, provided a forum to discuss these developments, consider their risks and benefits, and identify opportunities to chart a healthier and more equitable mobility future.

The workshop was organized by the Workshop Planning Committee on How We Move Matters as part of the Environmental Health Matters Initiative (EHMI), a program that spans the major units of the National Academies of Sciences, Engineering, and Medicine to facilitate a multisector, multidisciplinary exchange around complex environmental health challenges.[1] Given the initiative's focus on opportunities for action, the workshop's structure was designed to highlight priorities to address challenges surrounding transportation and mobility and to elicit suggestions for concrete actions to advance these priorities.

Workshop Planning Committee Chair Daniel Greenbaum summarized the workshop's goals to include the following:

- Facilitating a detailed discussion of how environmental health perspectives can be applied to consider transportation services and new mobility options over the coming decade;
- Identifying research, policy, and communication needs in this sphere; and
- Stimulating collaborations to address opportunities in environmental health and transportation.

[1] Learn more about EHMI at https://www.nationalacademies.org/our-work/environmental-health-matters-initiative.

In presentations and moderated discussions attended by more than 1,000 virtual participants, speakers from academia, community groups, government, and industry shared their perspectives on current trends, future directions, and implications of evolving transportation and mobility options for people and the environment.

The Mobility Revolution

The workshop began with an overview of why transportation matters and the thorny issues it raises: The tradeoffs of connections made possible by transportation include monetary costs to individuals and societies, the impacts on climate from the emissions generated, and the effects of pollutants on human health. To explore how the evolving transportation environment could affect these tradeoffs, speakers discussed new transportation technologies, factors driving adoption of such technologies, and the economic and environmental implications.

A variety of new transportation trends are emerging in communities across the United States. For movement of individuals, the mobility ecosystem is expanding from a traditional focus on personal vehicles and mass transit systems to include ride-hailing and car-sharing services; personal and shared scooters and bikes; and infrastructure to support walking and biking. At the same time, the adoption of virtual meeting technologies during the COVID-19 pandemic has substantially reduced commuting and business travel, possibly permanently.

For movement of goods, an emphasis on rapid home delivery has driven major shifts in warehousing and logistics while bringing more delivery trucks and vans into urban areas. For goods and personal mobility, trends toward electrification, self-driving vehicles, and other automated technologies are opening new opportunities and resulting in tradeoffs. Planners are considering how these trends could support different frameworks for urban mobility, such as the goal of the 15-minute city, a design that allows people to reach everything they need within 15 minutes of home.

Photo: Getty Images

Technology-enabled transportation services, such as ride-hailing, have revolutionized the way we move, as well as how those choices impact our environment.

Health and How We Move

Transportation affects health in numerous ways. Speakers explored how air pollution, noise, safety, and other factors play into the risks (or benefits) posed by mobility models and technologies, transportation infrastructure, transportation mode choice, and transportation technologies and disruptors. They, in turn, influence rates of illness and disease, modified by factors such as coexposures, socioeconomic status, and nutrition. Issues of equity underlie these pathways and the entire transportation and health ecosystem.

Driving Change

Participants explored the many complex factors that drive change in the transportation ecosystem, from investments by governments and companies to the role of individual behavior. The COVID-19 pandemic and several seasons of worsening climate impacts have increased awareness of the need for systemic changes to the way we live and work—and the need to do it in a way that benefits everyone, not just a particular industry or sector of society.

The workshop addressed that federal, state, and local governments, as well as the private sector, play critical roles in shaping future mobility. Speakers discussed the unique contributions of each sector, along with areas of synergy and potential friction among them. Individual choices play a role in which modes of transportation people use and how goods are transported within communities. However, individuals make choices within the context of systems. Habits are ingrained, and driving change—encouraging people to make choices that are healthier or more sustainable, for example—requires that it be easy for individuals to make those choices. People also need the tools to understand the consequences of their actions in order to make informed choices.

A Path Forward

Throughout the workshop's sessions, participants offered suggestions for informing transitions toward a more healthy and equitable mobility and transportation ecosystem. Key elements include establishing shared visions and values, centering innovation in communities, advancing research to inform decisions, and finding the right incentives to guide positive change.

ESTABLISHING SHARED VISIONS AND VALUES

Participants explored their visions of what the future of mobility could hold. Many focused on the importance of reducing emissions in order to curb pollution and reduce its health and climate impacts. Several speakers urged a deemphasis on personal vehicles, but participants had a variety of

Photo: New York City DOT, Flickr

Transportation officials, local authorities, and area residents come together to support the New York City Department of Transportation Better Buses Action Plan. Engagement is key in developing initiatives that directly affect community members.

visions for what this would entail. Achieving any of these envisioned futures relies not only on technology and investment but on shared values. Values also are central to weighing the sorts of tradeoffs that are inherent in any transportation decision.

COMMUNITY-CENTERED INNOVATION

For a change to stick, it is essential that it meets the needs of the community. The goal of transportation research and experimentation is creating meaningful change, not completing a project or publishing a paper. Knowledge gained through research must be accessible to those who need to use it and to consider communication and engagement strategies early in the process rather than only at the end. Instead of pursuing community engagement as something that comes from academia, government, or businesses, speakers urged a more bottom-up, community-led approach.

RESEARCH STRATEGIES AND NEEDS

Participants discussed how research can help address questions around mobility and health and inform decisions. Speakers highlighted current studies and research approaches, as well as key needs and future directions for the field. They underscored the importance of interactivity within the transportation ecosystem and suggested a more holistic approach to mobility research, both from an infrastructure standpoint and from a health standpoint. Finally, speakers stressed the importance of pilot testing as a means of evaluating options in real-world settings.

INCENTIVIZING CHANGE THROUGH POLICY

When considering how to incentivize positive developments that bring benefits across society, many speakers pointed to the critical role of government—not only at the federal level, but state and local governments, as well—in driving systemic change through policy. Given that many of the developments in mobility propose to disrupt the system, local regulation is key to directing that innovation to the benefit of the community. Conversely, the ability to realize the full potential of the technology is dependent on incentives and policies, and regulation can help set incentives and prices in a way that reflects the true cost of particular choices.

INCENTIVIZING CHANGE THROUGH INFRASTRUCTURE

Governments also have the power to drive change through their investments in infrastructure. Policies and investments around land use, road allocation, parking, and other factors have made driving a personal vehicle the easy and convenient choice. Technology developers and start-ups respond to the infrastructure that exists and to the infrastructure investments that are being made; as such, infrastructure

will play an important role in incentivizing movement toward goals like environmental health or sustainability.

Final Reflections

Wrapping up the workshop, moderators from each session reviewed the key priorities and suggested actions raised throughout the workshop. No mobility solutions are inherently good or bad. Their value lies in how they are used and balanced with policies to make sure they are going to really solve problems rather than create more. Major areas of focus and suggestions from individual participants are summarized in Table 1.

These suggestions are only a start, but moderators expressed their hope that communities, researchers, businesses, governments, and leaders will continue to pursue important conversations about the future of mobility. "Let's hope that one result of this is that we all move forward to engage communities, to seek better understanding of everybody's needs in the transportation system, and to come up with constructive solutions for how we move, because we know that how we move matters," Greenbaum expressed.[2]

[2] Review the Proceedings of a Workshop—in Brief at https://www.nap.edu/read/26382/chapter/1.

TABLE 1 Suggested Actions to Guide Future Approaches to Mobility and Transportation

FOCUS AREA	POTENTIAL ACTION	POSSIBLE ACTORS
Addressing equity issues	Acknowledge and study how the burdens and benefits of transportation systems are spread unequally across communities.	Researchers, research funders, government
	Share power and create meaningful pathways for priorities and solutions to arise from communities themselves.	Government, technology developers, researchers
Adapting governance	Adapt management and policy approaches to more creatively and nimbly identify drivers and make choices.	Government, standards-setting bodies
	Revisit past policies that create barriers and may no longer be relevant in the current context.	Government, standards-setting bodies
Integrating knowledge	Facilitate interdisciplinary and cross-sector integration in evaluating and planning transportation and mobility options.	Government, industry, researchers, research funders
	Develop and share best practices and tools for assessing transportation systems and options.	Researchers, government, industry, standards-setting bodies
	Gather and share high-quality baseline data on current transportation and mobility environments.	Researchers, government, industry
	Pilot-test solutions before widespread deployment.	Researchers, government, industry
Assessing needs	Identify the hierarchy of needs of the targeted communities, focusing on functional needs rather than technological solutions.	Researchers, government
	Incentivize and fund community-engaged research drawing upon communities' lived experiences.	Researchers, research funders, communities
Evaluating tradeoffs	Evaluate the full slate of tradeoffs—including key environmental health tradeoffs—for all options.	Communities, researchers, government
	Facilitate bidirectional exchange to elicit perspectives from communities, customers, and decision makers on the potential environmental health burdens and benefits of new mobility and transportation options.	Foundations/NGOs, researchers, government
Incentivizing holistic change	Establish partnerships and create meaningful incentives to holistically minimize risk and maximize benefits.	Government, standards-setting bodies, communities, industry

NOTE: NGOs = nongovernmental organizations.

VOLUNTEER VOICES

"I wanted a job where I could be a structural engineer designing aircraft, spacecraft, or bridges. I was fortunate to land a job in aerospace for five years, then to be able to transition to bridges. I've stayed [in transportation] because I've been abundantly blessed by many wonderful mentors and great opportunities."

—DOMENIC COLETTI
Principal Professional Associate,
HDR, Raleigh, North Carolina

TCRP RESEARCH REPORT 222

Green Bonds and the Transit Industry

Photo: Pi.1415926535, Wikimedia Commons

DAMON FORDHAM

The author is a director at High Street Consulting Group in Denver, Colorado, and former principal at The Cadmus Group.

Above: Bound for Daly City, California, an all-electric Bay Area Rapid Transit (BART) train waits at the Berryessa/North San José Station on June 13, 2020, its first day of service. Part of the first phase of the Valley Transportation Authority's 16-mile BART Silicon Valley Extension, the station's architecture and landscaping reflect environmental features such as water flow and natural habitat from the region's agricultural past. And its trains help reduce greenhouse gas emissions by offering an alternative to driving on two of the region's most congested corridors, all components of an ideal green bond transit project.

Green bonds have emerged in recent years as a compelling means of leveraging finance to advance global sustainability goals. Generally, a green bond is any bond in which the proceeds are earmarked for green projects—that is, those with climate or environmental benefits. Based on this broad definition, many transit projects have been obvious candidates for green bond funding due to their role in reducing the need for single-occupant vehicle use and, therefore, helping to reduce greenhouse gas emissions. For issuers such as transit agencies, these funding instruments are designed to realize the value of initiatives that have positive environmental impacts. For fund managers, green bonds provide a means of identifying initiatives with the environmental impacts that their investors are increasingly demanding while offering a more attractive risk profile due to the active management of environmental, social, and governance issues.

At the most basic level, green bonds are identical to traditional bonds—but with additional nonfinancial disclosures attached to satisfy the core components of the International Capital Markets Association's Green Bond Principles, namely:

1. **Use of Proceeds**—the green projects that will be funded by the proceeds of the bond.
2. **Process for Project Evaluation and Selection**—how and why the selected projects are considered green.
3. **Management of Proceeds**—how the issuer will ensure that the proceeds from the bond go only to the identified green projects.
4. **Reporting**—how the issuer will communicate progress of projects funded by the bond.

Although a green bond—as an instrument—is explicitly defined, there is less clarity surrounding what types of projects should qualify for the issuance of green

bonds. Generally, transit agencies are in a uniquely advantageous position for green bond issuance because most transit projects have an inherently positive impact on the environment. However, not all transit projects are equal. Transit projects that do not burn fossil fuels (such as the purchase of electric buses or the construction of tramways) will almost certainly qualify for green bond issuance. Conversely, green bond issuances to fund station upgrades and other aesthetic or user-experience projects may not be received well by the markets. Gray areas also exist, such as replacing older transit vehicles with newer, more fuel-efficient internal combustion engine assets that still burn fossil fuels but produce a considerable net savings in emissions. Notwithstanding these distinctions, the general alignment of transit projects with sustainability goals, combined with widespread familiarity of public transportation as an asset class and the large size of typical transit bond issuances, make for a rather attractive investment opportunity.

Costs for issuing a green bond are variable but tend to be relatively low, given the typical size of a transit bond issuance. An agency's first green bond issuance requires some additional one-time expenditures to lay forth an organization's sustainability goals and strategy and either develop or identify an existing green bond framework to organize its offering. After the initial cost of developing the organizational capacity to issue a green bond, preparing the required disclosures to issue the green bond may cost about $10,000 in staff time. Should an issuer elect to hire a third-party verifier (an external party who confirms the green benefits of a project), there will be costs associated with the verification process.

While published research surrounding the existence of a green premium—an incremental price that buyers are willing to pay for a green bond over a traditional bond—is inconclusive, there are nevertheless several advantages to issuing a green bond and very little downside, since the green bond is identical to a traditional bond (but for the nonfinancial disclosures to satisfy the Green Bond Principles' core components). Theoretically, a green bond attracts three types of investors:

1. Investors who are committed to supporting environmentally sound securities and, therefore, seek out green bonds;
2. Investors who believe that issuance of a green bond is indicative of strong management and good corporate governance, which, in turn, mitigate risk; and
3. Investors who place no incremental value in the green element of the bond but are interested in the asset class.

Traditional bonds would only attract the third of these groups, so green bonds should attract a broader pool of investors. Attracting additional investors does not automatically provide a financial advantage. However, broadening the pool of investors does increase the likelihood that a subset of those investors is willing to pay a higher price for the issue.

Aside from the previously mentioned benefits, green bonds also provide an opportunity for transit agencies to make a statement regarding their commitment to sustainability and to establish a platform for driving toward their sustainability objectives. This demonstrated commitment could be an advantage as global financial markets realign to direct funding to projects with positive environmental impacts. And, initiating a directive to either issue a green bond or develop a green bond financing framework advances the organization's sustainability culture by signaling to employees that the agency is prioritizing meeting sustainability targets and following through on a sustainability plan.

The only downside unique to green bond issuance is the risk of greenwashing—that is, marketing a project as green that does not actually contribute a positive environmental impact. Greenwashing can occur because an issuer has the option to self-label any project as "green." However, if an organization issues a green bond that the market receives poorly (because it is not believed to provide a significant positive environmental impact), the credibility of the issuer can be damaged and the issuer's ability to effectively issue green bonds

Photo: gradyreese, iStock

A broader investor pool may be drawn to green bonds over traditional transit bonds. Although evidence is inconclusive that a premium exists that buyers are willing to pay for a green bond over a traditional bond, a broader pool increases the chance that some of those investors may be willing to pay a higher price.

in the future can be negatively impacted. For transit agencies, an obvious example is a green bond issuance that provides funding for assets that burn fossil fuels, even if they are replacing older, less-efficient internal combustion engines. Issuers should carefully consider this risk when considering which projects to include in the green bond issuance.

Green bonds are a single instrument in a wider universe of financial tools that are being developed to help mobilize finance to confront larger environmental and societal issues. They are one important part of a wider push to make finance more sustainable by considering costs that have traditionally been ignored. While green bonds are a compelling option for transit agencies in many cases, certain instances exist in which green bond issuance would not be advisable.

- When the decision to issue a green bond is made after the issuance process has already begun, as this can require considerable additional work, including duplication of effort;
- When the project has unclear environmental impacts; these projects can be poorly received by the market, which can damage the issuer's reputation and make future green bond issuances more difficult; and
- If a bond issuance is small enough that the costs associated with reporting or verification significantly increase the net cost of funding.

For more information on *TCRP Research Report 222: Analysis of Green Bond Financing in the Public Transportation Industry*, visit https://dx.doi.org/10.17226/26066.

Transit Cooperative Research Program (TCRP) Research Report 222: Analysis of Green Bond Financing in the Public Transportation Industry provides transit agencies and other stakeholders with more detailed information about green bonds and resources to develop green bond programs. The report covers key concepts, such as the main components of green bonds, elements that differentiate green bonds from traditional bonds, and costs and benefits of issuing green bonds instead of traditional bonds. The report also provides case studies that demonstrate how transit agencies have implemented green bond programs and an appendix of resources for potential green bond issuers.

To prepare the report, the research team—led by the author as principal investigator for work performed by The Cadmus Group (under TCRP Project J-11/Task 38, "An Analysis of Green Bond Financing in the Public Transportation Industry")—reviewed available literature and conducted 13 interviews with representatives from transit agencies, financial advisors, rating agencies, and standards boards. The interviews explored the participants' experiences with—and perspectives on—key concepts, such as the definitions of green bonds, determining the value and costs of green bonds, and assessing how public transportation projects fit within green bond frameworks.

Practical Tips for the Use of Green Bonds in Transit

1. Decide early to issue a green bond.
2. Ensure funded projects and assets are green.
3. Develop a green bond program.
4. Adhere to your green bond framework.
5. Identify internal and external expertise.
6. Draw on lessons learned from other agencies and leverage available resources.

VOLUNTEER VOICES

"I was initially drawn to the transportation community by my love of maps and geography. I remain in this community in part because of the diverse and interesting set of people I have met at the TRB annual conferences."

—JORDAN LEWIS
Associate Project Manager,
FAM Construction, Fairfax, Virginia

Serving Passengers with Hearing Loss

Photo: iStock

STEPHEN O. FRAZIER

The author is a hearing loss support specialist and freelance writer based in Albuquerque, New Mexico.

Above: A commuter with hearing loss waits for his train to arrive. But, for people with his disability, navigating noisy transportation venues can be daunting. Assistive listening systems (or hearing loops)—technology that has been around since 1937—make maneuvering easier. Today, airports, rail systems, and taxicabs are picking up the pace to incorporate such hearing loops into their operations.

Years ago, Howard (Rocky) Stone, the founder of the Hearing Loss Association of America (HLAA), popularized the notion that hearing loss is an invisible disability experienced today by more than 48 million Americans. People with hearing loss do not use wheelchairs or crutches, and many don't have the training to communicate using sign language.

The National Institute on Deafness and Other Communication Disorders (NIDCD) reports that nearly two-thirds of people with hearing loss—about 28.8 million people—could benefit from using hearing aids (*1*; Figure 1). Further, roughly 2 percent of adults ages 45 to 54 have disabling hearing loss, reports the NIDCD; this figure grows to 8.5 percent for those ages 55 to 64 and up to 25 percent for ages 65 to 74 (*1*). Reporting statistics on the Hearing Industries Association's most recent MarkeTrak survey, *The Hearing Review* stated that, over the past 30 years, the percentage of people with self-reported hearing loss who own hearing aids has increased from just under 23 percent to more than 34 percent (*2*).

For those with hearing loss, passage through a transportation terminal is fraught with difficulty: Hearing aids often are unable to suppress background noise adequately, and the typical cacophony of a terminal can make speech comprehension anywhere from challenging to impossible.

Announcements about a gate change, departure delay, or other critical information made over a bus terminal's or airport's public address (PA) system, can be lost under the drone of the ventilation system, people's voices, rolling luggage, and other sounds that are nearly always present in such spaces. Therefore, people with hearing loss must often rely on note-passing or strangers to communicate with an agent at the ticket counter; if these methods are not available, not only misunderstandings but also missed departures can occur.

By themselves, simple hearing aids are not a solution to this problem, because

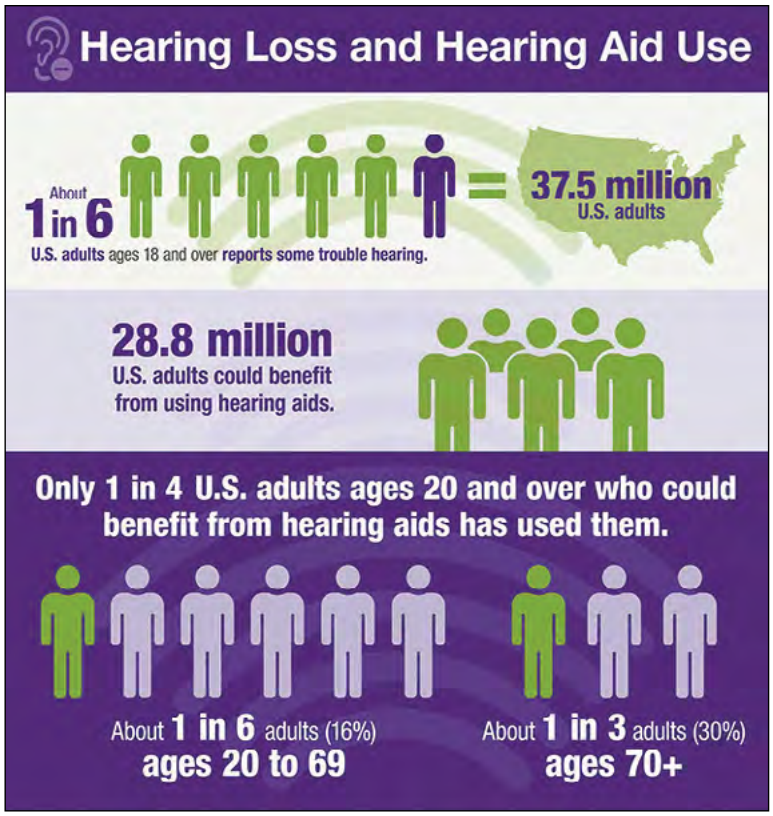

FIGURE 1 Hearing loss and hearing aid use. (Source: National Institute on Deafness and Other Communication Disorders, National Institutes of Health.)

often they are not able to adequately block the speech-covering sounds of the typical terminal concourse that make it difficult or impossible to identify consonants and to tell the difference between words such as "gate" and "late."

Researchers at the Institute of Hearing Research note that "the ability to hear and understand speech in the presence of background noise is highly dependent on the speech-to-noise ratio (SNR), that is, the level of the speech relative to the level of the background noise" (*3*). Hearing care providers are taught that for those who have normal hearing, a 10-decibel difference is considered an acceptable SNR (*4*). For those who have hearing loss, however, the SNR often must be 20 decibels—or even as much as 25 decibels—for adequate comprehension of what the speaker is saying. That means background noise should not exceed 55 decibels for those with normal hearing to carry on a conversation without raising their voices—but that the background noise might have to be as low as 40 decibels for a person with even moderate hearing loss to hear and understand a speaker whose voice measures 65 decibels.

In *Airport Cooperative Research Program (ACRP) Research Report 175: Improving Intelligibility of Airport Terminal Public Address Systems*, researchers state that a typical daytime sound level reading in a hub airport concourse ranges from 67 to 72 decibels (*5*). At a gate, this level can be as high as 79 decibels. A speaker's voice would have to be well above the normal level even for a person with normal hearing to hear and understand at such a gate. Hearing aids raise not just a speaker's voice but also the background noise—therefore, even with hearing aids, a person with hearing loss could not hear with noise levels at that magnitude.

If the person is in an airport and a speaker is wearing a face mask, even a modest 50-decibel background noise level often makes hearing more difficult. *The Hearing Review* reports that the typical mask reduces the volume of a user's speech by up to 3 decibels and up to 10

Photo: Paulo O, Flickr

The vaulted ceilings at the Ronald Reagan Washington National Airport in the District of Columbia cause echoes and a noisy environment. A typical daytime sound-level reading in a hub airport concourse ranges from 67 to 72 decibels—about the same level as a running washing machine.

Photo: Melinda Young Stuart, Flickr

A sign reminds customers to speak up when checking out at a store. A face mask can reduce the volume of a user's speech by up to 50 percent; in an area with a lot of background noise, this poses difficulties for people who are hard of hearing.

decibels if the speaker is wearing an N95 mask; this represents a 50 percent reduction in volume (*6*).

Hearing Loops

More and more transportation centers and other places of public assembly are turning to an old, yet effective, technology to address these communication problems: audio frequency induction loop systems, also called "hearing loops." In settings applicable to transportation, a hearing loop is an assistive listening system (ALS) connected to a venue's PA system that relays that system's signal to a copper wire laid out in a loop or grid pattern on the floor or in the ceiling. The copper loop then broadcasts the PA system's sound as a silent, electromagnetic signal. Tiny coils—found in 70 percent of current hearing aid models and in most cochlear implant processors—receive that signal, and the hearing aids or cochlear implant processors turn it back into sound.

Called telecoils, these receivers are activated by a T-switch on the device or its remote control, and the sound level can be adjusted by using the volume control in the same way. It usually is possible to turn the telecoils on and the microphone off on hearing aids or in a cochlear implant, so the only sound relayed is the feed from the PA system. Doing this eliminates much ambient noise, improving the SNR and making speech more comprehensible. Another form of hearing loops is counter loops, which may be built into a counter, and invisible, or self-contained, free-standing units.[1]

HISTORY

Hearing loops were invented and developed in Great Britain. Electromagnetic induction was discovered by British scientist Michael Faraday in 1831, but it was not developed for assistive listening until 1937, when Russian-born British telephone and sound engineer Joseph Poliakoff invented the first electromagnetic induction loop system. One year later, the first wearable hearing aid with a telecoil—worn in a chest pocket—was made by the Multitone Electric Company in England. Today, the United Kingdom is one of the world's largest producers of hearing loop equipment. The technology can be found throughout the country: in transportation terminals, places of worship, theaters, meeting halls, the London Underground, and even in London's signature black taxicabs.

[1] This statement was taken from a report by hearing loop maker Williams AV and cites data from the International Hearing Loop Manufacturers Association stating that hearing loops "can boost comprehension from roughly 10 percent to as much as 90 percent." To read the article, visit https://williamsav.com/airports-must-consider-how-hearing-loss-affects-travelers-business-and-flight-schedules.

Loops and telecoils are different from Bluetooth, a wireless technology found in many hearing aids that allows users to connect their hearing aids remotely to a telephone, computer, or microphone but that cannot serve groups of people. The hearing loop signal, on the other hand, can be accessed by an unlimited number of people, as long as they have a telecoil-equipped receiver via hearing aids, cochlear implants, or portable loop receivers and earphones.

AMERICANS WITH DISABILITIES ACT

The Americans with Disabilities Act of 1990 (ADA) addressed accommodations for the communication needs of people with hearing loss. Revisions in 2010 added more hearing-disabled accommodations by requiring hearing aid–compatible ALSs for theaters, legislative chambers, and other "places of assembly" if they are served by a PA system. Loops offer the only technology that currently meets all the ADA requirements. FM, infrared, or WiFi systems meet these requirements only if they offer users a choice of earphones or neckloops coupled with a venue-loaned receiver—but such devices would not be a

Photo: Wikimedia Commons

Wireless hands-free devices for hearing aid users that operate via FM, infrared, or Bluetooth systems meet ADA requirements if they offer users earphones or neckloops; this is workable in some venues, but not in transportation hubs.

workable ALS in transportation terminals. The ADA does not require hearing loops in facilities like travel terminals, but hearing loops are being installed voluntarily to make the travel experience less stressful for those with hearing loss.

Airports

In the United States, hearing loops increasingly are used in airports at ticket and at rental counters, information centers, departure gates, and baggage claims. More than a decade ago, the Gerald R. Ford International Airport in Grand Rapids, Michigan, became the country's first looped airport (*7*). Today, 18 other airports are looped as well, such as Wittman Regional Airport in Oshkosh, Wisconsin, and Phoenix Sky Harbor International Airport in Arizona. Hearing loops also are planned in the new concourse at Memphis International Airport in Tennessee and the car rental center currently under construction at Los Angeles International Airport.

Last March, the Port Authority of New York and New Jersey announced new accessibility requirements that mandate the installation of hearing loops at departure gates and information counters in all new or significantly upgraded airports. The mandate also applies to information counters at all train, bus, and ferry terminals under the Port Authority's management.

More and more transportation centers and other places of public assembly are turning to an old, yet effective, technology to address communication problems.

Even before the Port Authority's mandate, all departure gates at the recently completed Delta Air Lines terminal at LaGuardia Airport were fitted with hearing loops, as some of Delta's gates in Michigan's Detroit Metro Airport and the Minneapolis–Saint Paul International Airport in Minnesota have been.

In addition, the information counters at Georgia's Hartsfield–Jackson Atlanta International Airport utilize the technology. Global examples include Muscat International Airport in Oman, where 300 counter loops have been installed throughout the terminal. At Charles de Gaulle Airport in Paris, the waiting and customer assistance areas in each terminal are equipped with hearing loops. Hearing loops are placed in a variety of locations at the Adolfo Suárez Madrid–Barajas Airport in Spain; Incheon International Airport in Seoul, South Korea; and all of the international airports in Australia. Also in Australia, the Digital Bus Stop Totems in Adelaide are fitted with hearing loops to relay aural announcements in addition to those via text.

Rail Travel

The rail and transit industries are utilizing hearing loop technology in a variety of contexts, as well. More than 600 of New York City's Metropolitan Transit Authority (MTA) subway information booths feature counter loops that enable users to communicate with the agent in the booth, even as express trains rumble underneath. The MTA has issued a request for proposals for more than 1,000 new hearing loop–equipped subway cars, and loops are being tested on subway boarding platforms.

After a similar test at Bay Area Rapid Transit's (BART's) Fremont Station platform, the *San Francisco Chronicle* reported one hard-of-hearing commuter at that station saying, "Oh, my goodness. 'Do not board'— I heard that!'" after she heard via

Photo: avlxyz, Flickr

Hearing loops appear in bus and train facilities throughout Australia, including in a Metlink (now Public Transport Victoria) station in Melbourne.

Photo: Melinda Young Stuart, Flickr

Bay Area Rapid Transit deployed new cars that include a hearing loop among their features, helping passengers who are hard of hearing to catch announcements during their ride.

the telecoils in her hearing aids that the train at her platform was out of service (*8*). The rider went on to say: "I never would have heard that." A symbol is visible in all new BART train cars that have hearing loops installed (see page 28).

As part of a $7.3 billion contract with Siemens Mobility, Amtrak recently announced the purchase of 83 new trainsets (approximately 500 cars total) that feature hearing loops (*9*). The deal includes an option for 130 additional trainsets, as Amtrak implements a growth plan that adds 160 new communities to the 525 that it currently serves. Some Amtrak ticket and information booths have been looped at Grand Central and Penn Stations in New York City and at Union Station ticket counters in Washington, D.C.

At the Milwaukee Intermodal Station in Wisconsin, the passenger concourse was looped to serve the hard of hearing among its nearly 2,000 local and long-distance bus and train passengers each day. Among the communication access recommendations under consideration by the U.S. Access Board is the inclusion of a requirement that hearing loops be installed in all new rail cars that are also fitted with PA systems.

Buses

Many bus systems have implemented the loop technology. The local bus service in Seattle, Washington, has addressed the needs of the hard of hearing in its King County Metro Customer Service Office, where a hearing loop was installed at the service counter for customers who rely on hearing aids or cochlear implants. Indian Trails, Inc., with help from the Michigan Department of Transportation, installed hearing loops in their fleet of 17 motorcoaches that serves 34 routes in the state's Upper and Lower Peninsulas and in neighboring Wisconsin.

In addition, New York MTA is testing buses fitted with hearing loops. An HLAA volunteer who helped evaluate a couple of loop-equipped buses reported: "We were able to hear announcements from both the bus driver (live) and from outside (recorded). The sound quality varied between the two sources, but both were pretty good."

In London, such buses have been in service for some time.

Photo courtesy Stephen O. Frazier

The international hearing loop symbol, seen on the outside of this New York City taxicab, alerts passengers that the cab features hearing loop technology.

Taxicabs

For years, London taxis have been equipped with hearing loops to facilitate better communication between the driver and backseat passengers. The New York Taxi and Limousine Commission was encouraged by looping advocates to do the same, and now all new taxis in New York are delivered with a hearing loop installed. Signs inside the taxicab alert backseat passengers to the presence of the loop and how to use it. Many cabs also carry the international hearing loop symbol on the outside of the cab, like the one shown in the photo above.

Down the Road

Some of the loop installations noted in this article—the looping of Indian Trails buses and the Gerald R. Ford International Airport, both in Michigan—began more than a decade ago. Others, like the Delta terminal at LaGuardia Airport or the Amtrak train loop initiative, are very recent.

The "Get in the Hearing Loop" initiative, started by HLAA and the American Academy of Audiology in 2010, has played a significant role in this revolution in communication access. The work of New Yorker Janice Schacter Lintz and her Hearing Access and Innovations Program also has been enormously effective. The looping campaign of the nation's Sertoma clubs, "A Sound Investment," has contributed financial and other support in communities throughout the nation.

The efforts of independent hearing loop advocacy groups, like the Adult Loss of Hearing Association in Tucson, Arizona, or Loop Minnesota in Minneapolis, are evident nationwide. These groups and other looping advocates share the hope that, at some point, it won't be necessary for people to ask: "What's a hearing loop?"

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Liying Gu

Vice President, Economic Affairs and Research, Airports Council International

Liying Gu is a supporter of evidence-based public policies. "I think research should be the foundation for public policy decision making, particularly for U.S. airports, most of which are publicly owned and operated," she explains. Gu's responsibilities for the North American arm of Airports Council International (ACI–NA) include preparing ACI–NA's economic position papers, representing ACI–NA on economic issues at industry and government meetings, overseeing the Finance and Risk Management Committees, and directing the ACI–NA research programs that support legislative, regulatory, and policy initiatives. She is a Chartered Financial Analyst (CFA) Charter Holder with a master's degree in finance from Johns Hopkins University and a master's degree in business administration in aviation from Embry–Riddle Aeronautical University, where she graduated with distinction.

In her more than 20 years in the aviation industry, nearly two-thirds of which have been with ACI–NA, Gu has developed expertise in airport finance and policy that has helped her manage many critical policy issues related to capital needs, infrastructure development, innovative financing, financial reporting, performance benchmarking, airport congestion, and risk management. She has a keen eye for data analysis and has designed comprehensive market research to highlight demographics data, competitor initiatives, and industry trends. Her proficiency in Mandarin Chinese, Cantonese, and English have helped her forge and strengthen national and international partnerships.

"Recently, the COVID-19 pandemic created the need for many different data points and information," Gu notes. Her quick response addressed the many needs of stakeholders and her insights supported ACI–NA's policy advocacy, which helped secure three rounds of U.S. federal COVID-19 relief to date, totaling $20 billion for U.S. airports struggling during the pandemic.

When the financial challenges resulting from the pandemic reverberated throughout all aspects of airport operations, Gu and her team supported the industry through monthly chief financial officer (CFO) calls, polls, and survey efforts, as well as traffic and financial loss forecasts for U.S. airports. According to Gu, "these monthly CFO calls addressed timely legislative and regulatory updates, issues and questions on the relief package (especially as it relates to the concession portion), the impact of COVID-19 on airport cash policy, rates and charges, workforce challenges and potential solutions, rental car contracts, and contracts with a car-sharing program."

"The COVID-19 pandemic created the need for many different data points and information."

Gu has led many research projects to gather insightful information regarding the impact of the COVID-19 pandemic. "Polls and surveys have included testing cost, projected cost per enplanement post-COVID, return-to-office policy, how airports are using the relief funds to help their airline partners and concessionaires, the percent of food and beverage as well as retail locations still closed, airport traffic forecasts, and how long the federal relief grants will last," she relates. The uncertainty of new COVID-19 variants makes it especially difficult to forecast future traffic.

Since 2004, Gu has taken the lead in producing ACI–NA's biennial Airport Infrastructure Needs Survey, which provides the only comprehensive data on the infrastructure needs of airports in the United States. This effort helps ACI–NA ensure that airports have adequate resources to enhance and preserve capacity and to meet their communities' needs. Gu notes that working through the ACI–NA Strategic Planning and Performance Management Working Group, she and her team have "piloted the airport industry's most well-recognized financial performance benchmarking efforts."

Gu is particularly proud of her contribution to ACI–NA's annual Financial Benchmarking Survey. This tool, which pinpoints industry best practices that foster airport strategic planning and augment efficiency, is used by U.S. and Canadian airports to evaluate their operational and financial performance relative to that of their peers. In working closely with ACI–NA member airports, Gu and her team managed to increase the number of airports participating in the survey from 15 in 2007 to nearly 100 in 2021.

Gu also has overseen the ACI–NA internship program, coaching undergraduate students during one-year placement programs with ACI–NA and providing research guidance. Her advice to young professionals is simple: "Believe in yourself. Believe that you can make a difference, identify your core competencies, and continue to enhance your core competencies."

Gu is the author of 10 widely recognized research reports on U.S. airport capital development needs. She chairs the TRB Standing Committee on Aviation Economics and Forecasting, and has been an ACRP panel liaison on numerous projects dating back to 2007. She also co-chairs the National Association of Business Economics' Transportation Roundtable and is an Air Transport Research International Forum board member. "Airports in the United States benefit tremendously from federally funded research programs such as ACRP," she comments, quickly pointing out that the program "does not exist elsewhere in the world."

Mark L. Reno

Vice President–Principal, Murraysmith and Quincy Engineering

Mark L. Reno began his career designing bridges for the California Department of Transportation (Caltrans) in 1988 after receiving a bachelor's degree in civil engineering from the University of California, Davis. About a year later, he was selected to coordinate and direct emergency response efforts at the I-880 Nimitz Freeway collapse after the Loma Prieta earthquake. "This was something I never thought I would be involved in," he notes.

The experience shaped Reno's future and resulted in a certificate of meritorious conduct from the California Highway Patrol for leading search and recovery work that helped ensure safe entry of personnel to evacuate those stranded and victims who died from the tragedy. "Every time we have an earthquake, it's like a life-sized laboratory," Reno explains. "This is where we learn, apply lessons learned, update and modify designs, and implement changes."

Reno became part of a Caltrans emergency response team. When an earthquake larger than magnitude 6.0 struck, he recalls, "we were deployed to inspect, document, identify damage, and evaluate how structures performed; make critical decisions on closures or possible temporary shoring of structures; and assess the need for changes to be considered in current designs." He worked on the response for four other major earthquakes—including the 1994 Northridge earthquake—before becoming Caltrans' structure project manager and engineer of record for the seismic retrofit of the historic San Francisco–Oakland Bay Bridge west spans. He delivered this effort under estimate and on schedule. Reno won the American Society of Civil Engineers' Arthur M. Wellington Prize in 2001 for his *Journal of Bridge Engineering* paper on this work, and the project received the Seismic Retrofit of the Decade Award from the Applied Technology Council and Structural Engineering Institute.

With a reputation for success on complex projects, Reno became a structures design branch chief at Caltrans, supervising a bridge design team with more than 20 members. He was assistant chair of Caltrans' Structural Steel Committee, a member of the Caltrans Earthquake Committee, and a member of the Post-Earthquake Investigation Team.

"Every time we have an earthquake, we learn something new."

After 13 years with the Caltrans Bridge Department, Reno joined Quincy Engineering as a consultant and was project engineer and engineer of record for the 2,400-foot Foresthill Bridge over the North Fork of the American River Canyon. This seismic retrofit and widening project, in an area surrounded by active faults, incorporated the largest buckling restrained braces ever used in a bridge application at that time. It received a Caltrans Excellence Award, presented by the Governor's Seismic Advisory Board. After more than three decades—and about 160 projects involving 240 bridges since he worked on the Nimitz Freeway collapse—Reno is a highly regarded expert in bridge structure design, a nationally recognized project manager, and seismic specialist at Murraysmith and Quincy Engineering.

Early in his career, a TRB committee chair invited him to join the Standing Committee on Steel Bridges. His TRB involvement was fostered by the inventive support of Caltrans' state bridge engineer—who gave his personal frequent flyer miles to Reno for travel to TRB meetings and coached him on making the most of what Reno characterizes as "the opportunity to work with legends in the field of bridge engineering." He has risen from committee member to chair, section chair, at-large group executive board member, and is now chair of the Transportation Infrastructure Group, overseeing eight sections that include 54 separate standing committees. He is a member of the TRB Technical Activities Council. He also has been an NCHRP project panel member and chaired the project panel for NCHRP Project 12-54, "Integral Connections of Modern Steel Bridges." His papers have appeared in *Transportation Research Record*, and he has presented at the TRB Annual Meeting.

"TRB is an integral part of my career," Reno observes. He has seen TRB evolve along with bridge engineering research needs. He recalls the push in the 1980s to find ways to build longer, larger, new structures, followed by a shift to building more durable structures after the Interstate System's 50-year anniversary. Reno describes accelerated bridge construction as the most recent trend. "Project construction length is directly proportional to user-delay costs, risks to construction personnel and the traveling public, and traffic impacts," he cautions, adding that "these shifts in how the bridge community plans, designs, and constructs must be based on sound engineering backed up by research and analysis."

Reno notes that the bridge industry has completed some of its most important research in the field of seismic design following major seismic events. He is fond of reminding young engineers that "every time we have an earthquake, we learn something new."

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Data and Policy Program Manager, Environmental Research & Education Foundation (EREF), Raleigh, North Carolina

Brittney Gick, Stephen Wong, and Suzie Boxman—co-chairs of the recently formed Young Members Council (YMC) for the Transportation Sustainability and Resilience Group—have a synergy that is getting noticed and *influencing* those around them. Each co-chair represents a different section of the Transportation Sustainability and Resilience Group. "We refer to our council as the YMC–S&R," offers Gick, who represents the Transportation and Society Section.

"The YMC–S&R is a subcommittee of S&R that also works with the larger Young Members Coordinating Council (YMCC) to share ideas and assist young members across TRB," explains Wong. "As the representative for the Transportation Systems Resilience Section, I work closely with the committee chairs within the section and am the primary contact and liaison for young members interested in transportation resilience."

Since their first meeting in June 2021, the co-chairs have coordinated virtually, meeting every six to eight weeks to get ready for the TRB Annual Meeting and determine what direction they would like to see the group take. They're using online tools—setting up an e-mail account, creating shared documents for coordinating with each other, and releasing online surveys to collect information about the needs of the young members in the YMC–S&R. Notes Boxman, Transportation and Sustainability Section representative: "We all work together."

"We also try to interact with YMCs in other groups," Gick adds. "We have a very good working relationship with the YMC in the Aviation Group, which has been instrumental in helping us get off the ground at the group level as a new YMC. We met with our TRB staff representatives Christine Gerencher and Bill Anderson, YMC Chair Ria Kontou, YMC–Aviation Group Chair Jonathan Schneider, and with each other to plan out what YMC–S&R would look like and how we could best handle administrative areas."

"Rather than assuming what the young members in our group want and need, we're asking them directly, then act on their requests," Boxman states. "This is setting us up for good engagement and success."

The co-chairs' responsibilities include organizing meetings, setting vision and goals, developing guides and programs for young members, and delegating tasks to other volunteers. "This can quickly become overwhelming," cautions Wong. "My experience in research management—wearing multiple hats at the same time—has been especially important for my role as co-chair."

Gick agrees that her prior leadership experience helped her learn the importance of being a good leader and maintaining strong communication channels and professional networks. A former TRB staffer, she admits, "I know a lot of the inner workings and can use that to help young members understand how to fully engage in TRB activities. I have long been very passionate about the need for young members to have a seat at the table."

"Committee leadership is a great experience and a way to connect with other professionals," Boxman emphasizes. "You have more to offer than you think as a young professional, and the more that you volunteer and take on similar leadership roles, the more you are able to offer in the future. People want you to succeed, so they will be there to help you if you need it."

Wong's advice for young professionals is to first "find a committee that feels like a community. For young professionals in leadership positions, form a team that works well together and moves forward even without your direct supervision. Collaborating and delegating are important, as they reduce the leader's many tasks while also giving others the opportunity to volunteer, contribute, and learn."

"My advice for anyone considering taking on this role is to be confident but realistic about the time commitments," Gick suggests. "While it may be intimidating, it is an awesome experience to be able to help other young members learn about all things TRB. So, don't be afraid to get out there and get involved!"

To reach the YMC–S&R, send an e-mail to ymcsustainabilityresilience@gmail.com.

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, 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.

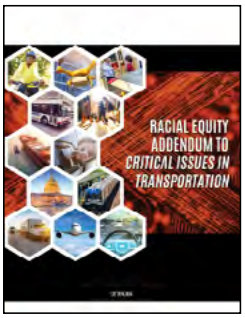
That's it! Like all *TR News* content, your response may be edited for grammar, length, and TRB style. When the issue with your quote is published, you'll get a PDF of the page featuring your response and photo.

Your Picture Here

Now that you have the details, here's the question:
What area of transportation—outside of your own—fascinates you, and why?

Addendum Focuses on Racial Equity Issues

In an addendum to *Critical Issues in Transportation 2019*, the Transportation Research Board (TRB) probes transportation's role in contributing to (and redressing) racial discrimination and identifies areas of research to inform equity-enhancing public policies. The focus of this addendum is identifying—but not trying to answer—important questions about transportation's impacts on equity.



The Black Lives Matter movement and other events in 2020 and 2021 made it clear that the United States continues to struggle with racism. Racism manifests in different ways, from the biased attitudes and discriminatory behaviors of individuals to the policies, practices, and norms of institutions and society that have created and maintained racial inequalities. Many of the troubling racial inequalities that persist today are a consequence of systemic racism—an undercurrent of discriminatory policies and practices that have contributed to racial disparities in access to goods, services, and opportunities.

The country's transportation enterprise is a major area of government responsibility that is central to the economy and everyday lives of Americans. As such, it warrants scrutiny as a potential conduit of systemic racism and as a means of reducing the inequalities that stem from systemic racism.

Access to Transportation

Research has shown that people of color living in racially segregated communities and Native Americans living on reservations often face disproportionately high transportation access constraints, including cost burdens. Across all household income levels, most people travel primarily by automobile. Even among households with annual incomes of less than $25,000, nearly 80 percent own at least one vehicle. More granular research can be valuable for understanding the importance of having access to an automobile to seek and retain employment.

Public transit service is a necessity for many workers to reach their jobs, including those who provide essential services for relatively low pay—disproportionately, these workers are people of color. Decision makers need to understand how policies can be designed to ensure more equity in the availability of all modes of transportation, including shared modes, sidewalks, bicycle paths, and other active transportation facilities.

Institutional Issues and Decision Making

Critics of transportation planning and investment priorities, particularly in urban areas, have pointed to patterns of decision making indicative of racial bias. Curbing racism in the decision-making processes and power structures across all levels of government is essential to equitable transportation planning and investment choices, and understanding racial bias in transportation institutions is a critical step.

Equity in Planning and Public Participation Processes

Transportation plans and policies had disparate effects on communities of color and low-income populations for decades, and the civil rights implications were largely neglected until the 1990s. Today, more laws, policies, standard practices, and regulations attempt to prevent and remedy such inequities, although evidence shows they have not been especially effective for ensuring environmental justice. Research can shed light on real-world strategies for effective engagement with all affected communities, particularly those consisting of people of color.

Land Use, Affordable Housing, and Displacement

Transportation networks, especially links between employment centers and residential areas, are inextricably tied to land use. The built environment, whether in areas that are sparse and rural or dense and urban, is also an important factor in equity analyses. Transportation plays an important role in the availability and affordability of housing but often results in long commutes between low- and moderate-income residential areas and job locations. The spatial mismatch between jobs and housing is pronounced for people of color.

Gentrification, resulting in part from transportation investments, can displace low-income residents to areas with poorer transportation infrastructure and service. Furthermore, decades of redlining and exclusionary zoning helped shape the spatial distribution of racial groups across regional

landscapes, tending to concentrate people of color into areas of poor accessibility.

Native American Transportation Equity Issues

Native American lands and communities often face restricted mobility, isolation, and underdeveloped infrastructure including roads, bridges, aviation, Internet connectivity, and electricity. These access and mobility shortcomings contribute to the health, education, social welfare, and economic development deficits of many tribal lands and communities. However, transportation issues, like many other issues, are different for Native Americans than for other communities of color, in part because of the sovereign status of tribes and their lands.

A starting point for research to inform policy choices will be to identify the data needed to address equity issues related to tribal lands and communities to bring about and manage high-performing modern transportation systems.

Conclusion

The transportation industry suffers from several of the same biases and discriminatory behaviors that have prompted demands for more equitable treatment across many facets of American society. The transportation industry is continually changing, providing fresh opportunities to build more equity into the system. All will require a better understanding to develop and implement effective solutions supported by cross-disciplinary research and improvements to a wide array of data, metrics, and analytical methods.

For more information on *Racial Equity Addendum to Critical Issues in Transportation*, visit https://dx.doi.org/10.17226/26264.

—Katherine Kortum, Senior Program Officer, Transportation Research Board, National Academies of Sciences, Engineering, and Medicine, Washington, D.C.

MEMBERS ON THE MOVE

Sarah Abel, member of the NCHRP Project Panel on Traffic Safety Culture Research Roadmap, left ITE in December 2021 to join Toole Design Group as the Sustainable Safety Practice lead.

Claire Aelion-Moss joined TRB's Cooperative Research Programs as an editor in January. Previously, she was an editor for the Dumbarton Oaks Research Library and Collection.

Members of the National Academies' new Diversity, Equity, and Inclusion (DEI) Council are **Anton Bandy, LaVonne Burgess, James Burke, Franklin Carrero-Martinez, Ivory Clarke, Camille Crichton-Sumners, Clifford Duke, Iliana Espinal, Jatryce Jackson, Leigh Miles Jackson, Amisha Jinandra, Vanessa Lazar, Elana Lippa, Orin Luke, Devona Overton, Heidi Schweingruber, Cyndi Trang, Melissa Walter, Jesse Willis**, and **Colleen Willis**. **Zach Thomas** is council chair, **Karen Autrey** is vice chair, and **Laura Castillo-Page** is executive sponsor.

Lida Beninson is now senior program officer for Emerging Trends in Aviation Safety in TRB's Consensus and Advisory Studies Division.

Lea Camarda, a senior editor for TRB's Cooperative Research Programs and *TR News* co-editor, has joined the National Transportation Safety Board in Washington, D.C., as a technical writer/editor.

Doug Ceva, vice president of global customer services at Prologis, is a new member of the TRB Executive Committee.

Elaine Ferrell, TRB Distance Learning Program coordinator, who has aided in the creation of webinars and served as the co-host/lead producer of TRB podcasts, has accepted a position at USAging.

Damon Fordham, formerly a principal with The Cadmus Group, is now a director with High Street Consulting.

Greg Hansen, fleet administrator at Washington State DOT, retired after 32 years of service.

Ed Harrigan, senior program officer, retired December 31, 2021, after 25 years with TRB's Cooperative Research Programs and four years with the first Strategic Highway Research Program.

Andy Lemer, an NCHRP senior program officer for 15 years, retired on January 14, 2022. He also worked for TRB's Cooperative Research Programs and Consensus and Advisory Studies Division.

Jarrel McAfee, TRB senior program assistant, has joined Tides Advocacy, a California-based nonprofit.

Noel Popwell, formerly with the New Jersey Department of Agriculture, is now a senior program officer with the TRB Consensus and Advisory Studies Division.

N. Christopher Rajaratnam, former District of Columbia Department of Disability Services operations/budget manager, is the new director of operations for the TRB Technical Activities Division.

Costa Samaras, a member of TRB's Standing Committee on Transportation Energy, joined the White House Office of Science and Technology Policy's new energy division as principal assistant director for energy.

Polly Trottenberg, U.S. Department of Transportation Deputy Secretary, has been appointed to the TRB Executive Committee.

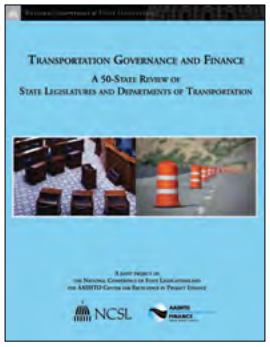
COOPERATIVE RESEARCH PROGRAMS NEWS

Virtual Public Involvement: A Manual for Effective, Equitable, and Efficient Practices for Transportation Agencies

When the COVID-19 pandemic's stay-at-home orders and physical distancing guidelines limited transportation agencies' ability to conduct public hearings and meetings for transportation plans, projects, and programs, agencies turned to virtual public involvement. Although today's communication technologies can enable outreach activities during an emergency and overcome challenges of travel and time, these technologies may not provide equitable access for all. This recent experience offers an opportunity to identify successful practices in virtual public involvement from many agencies and across a wide range of decision-making contexts.

Rutgers, the state university of New Jersey, has received a $650,000, 30-month contract [National Cooperative Highway Research Program (NCHRP) Project 08-142] to evaluate recent transportation agency experience in using virtual public involvement with a particular focus on equity and to develop a manual on virtual public involvement.

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



An NCHRP project will update *Transportation Governance and Finance*. (Photo: National Conference of State Legislatures and AASHTO)

Photo: Oran Viriyincy, Flickr

New NCHRP research will provide guidance on how to enhance risk management activities, including effectively managing vehicle insurance pools.

UPDATE TO *TRANSPORTATION GOVERNANCE AND FINANCE: A 50-STATE REVIEW OF STATE LEGISLATURES AND DEPARTMENTS OF TRANSPORTATION*

In 2011, the National Conference of State Legislatures and AASHTO produced a report on transportation funding and finance policy. In 2016, the report was updated to reflect the enactment of federal legislation and relevant changes in state legislation. Since 2016, 20 states have enacted legislation to increase and modernize transportation revenues; other states have considered how to restructure or replace gasoline taxes to ensure sustainable funding; all states are reckoning with technology changes and the COVID-19 pandemic's impact on state transportation revenue streams.

J.R. Rall Consulting has received a $200,000, 18-month contract [NCHRP Project 20-24(133)] to update *Transportation Governance,* including new survey data and to help AASHTO staff disseminate the update.

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

STATEWIDE INSURANCE POOLING FOR PUBLIC TRANSIT

It has become increasingly difficult for transit agencies to find, purchase, and maintain adequate and affordable insurance coverage for public transit vehicles. The cost of adequately insuring vehicles is increasing, as well as the ability to cover costs for each agency's individual policy premiums.

AECOM Technical Services has received a $300,000, 24-month contract (NCHRP Project 23-04) to create a guidebook on effectively implementing a statewide or regional pooled transit vehicle insurance policy model.

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

ACTIONS FOR STATE DEPARTMENTS OF TRANSPORTATION FOR THE NEXT ERA OF AMERICA'S TRANSPORTATION INFRASTRUCTURE

Cambridge Systematics was awarded a 12-month, $400,000 contract [NCHRP Project 20-24(138)] to explore and articulate what state departments of transportation (DOTs) can do, collectively and individually, to establish and realize a transformative vision of the next era of America's transportation infrastructure.

Phase I activities should produce a comprehensive analysis of available research on emerging social, technological, and economic trends and evolution of community values and priorities influencing transportation's contribution to prosperity and well-being and of state DOTs as mediators of that role; workshops or peer exchanges of thought leaders and state DOT leaders to discuss the project's objectives and anticipated products; a well-developed concept of the final products of this project if subsequent phases are undertaken; and a preliminary plan for achieving the overall project objectives.

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

Transportation Research Thesaurus Website

TRB's new Transportation Research Thesaurus (TRT) website provides updated features and functionality to facilitate access to TRT, including enhanced browse and search options, customized exports, and curated lists of hot topic terms. The website was developed as part of NCHRP Project 20-109, "Enhancement of the Transportation Research Thesaurus," to increase the TRT's value to its growing community of stakeholders.

To view the website, go to trt.trb.org.

FHWA–TRB Emerging Trends Symposium on Future Travel Demand

KATHERINE KORTUM

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

In November 2020, FHWA and TRB convened an expert panel of professionals virtually. This discussion on the topic of future travel demand for the latest iteration of the Emerging Trends Symposium focused on how the events of 2020 are transforming travel behavior in all modes of travel.

As a direct consequence of the COVID-19 pandemic, new social norms—coupled with growth in information technology and e-mobility (i.e., the use of electric vehicles, e-bikes, and other electric-powered options)—are spurring changes in the level and distribution of transportation demand by individuals and businesses. Many people have dramatically modified their travel behavior by working entirely from home, ordering goods and services online, and limiting out-of-home entertainment and other social activities. Businesses are shifting transportation use to meet changed consumer preferences and demand.

Other changes include curtailed long-distance travel, shifts in time of day or purpose of travel, and increased use of certain modes such as bicycling and walking. New, related challenges have emerged from competing priorities for public rights-of-way, including interest in wider sidewalks and bike lanes, curbside accommodations and consideration of nontransportation uses for curb areas (e.g., outdoor restaurant seating).

Highlights of the panelists' comments follow.

Photo: Cathy Frye, Flickr

Public sidewalks, like this one in New York City, have been transformed during the COVID-19 pandemic to provide socially distanced outdoor dining options that range in size and configuration. Some contain amenities like heating or cooling. Is this use of public space here to stay?

KEY TAKEAWAYS

Recent Changes in Travel Demand
Brian Taylor, University of California, Los Angeles

- Demographers talk about three types of effects on the behaviors and beliefs of generations: 1) life cycle (how people make life-stage changes and how that changes over time), 2) cohort (preferences and traits that are unique to generations or demographics), and 3) period (major shocks that affect all people and have residual effects over time).
- There are multiple ways to think about the longer-term COVID-19 period effect on transportation. Pre-pandemic patterns and trends may be amplified, return (hence, 2020–2021 is merely "a blip"), be reversed, or be replaced by entirely new trends that emerge.

The Future of Cities
Jed Kolko, Indeed

- The type of work we do has shifted from services to goods during COVID-19. This is the first services-led recession in modern history, but we will likely return to a services-led economy.
- Remote work levels of 90, 95, and 99 percent each have different implications for residential choice. With a job that is 90 percent remote, people will still want to stay within reasonable reach of offices. Remote work of 99 percent can mean more dispersed residential locations.
- Remote work is likely to be less appealing to younger generations who have less established professional capital and greater desire for face time with superiors.
- Business travel may become a complement to, or a substitute for, going into an office. Many companies may reconfigure office space for internal conferencing, with solitary work occurring at home.

Teleworking and Travel Behavior
Pat Mokhtarian, Georgia Institute of Technology

- "Teleworking" is a broad term that encompasses self-employed individuals, salaried employees working at home instead of commuting, workers putting in overtime or completing partial-day work at home, people who are moonlighting, those working while traveling, and more.
- Before COVID-19, when people worked from home, they did so for an average of 1.5 days per week and for a relatively short period of time (often less than one year).
- During COVID-19, average work-from-home frequencies seem to be "only" three days per week. This is a significant increase from before but less than headlines may indicate.
- After COVID-19, the share of workers who do some work from home may increase, but workers are still likely to do so 1.5 days per week. Many past extreme events led to speculation on increases in working from home, but work-from-home patterns returned to near normal.

The Future of Commerce
Jannine Miller, Georgia Department of Transportation

- Georgia Interstate freight traffic declined at the beginning of the pandemic, but as of late 2020, year-over-year truck traffic was up, indicating increased demand for delivered goods.
- Goods deliveries to homes over the "last mile," which in the United States actually ranges from six to nine miles, has shifted to small freight vehicles instead of personal autos.
- There was an immense increase in online procurement and delivery of food items during COVID-19. In particular, suburban food delivery saw growth.
- Warehouses got smaller but more numerous. As a result, freight length-of-haul declined, leading to tighter long-haul capacity and making pay increases for long-haul drivers likely.

The Future of Travel Behavior
Jon Ciarletta and Jennifer Chase, Toyota North America

- In tracking consumer sentiment, Toyota found that the size of groups who are very worried about the pandemic versus those who are not has varied over time based on current events.
- The U.S. population is much less mobile than it was at the beginning of 2020, and that mobility has shifted away from airlines and transit to walking and bicycling. The degree to which those shifts will remain post-pandemic is very uncertain, but Toyota is interested in understanding this.
- In tracking consumer trends relevant to the automotive industry, Toyota found that 1) presence-free living, or living digitally, increased clearly and is likely to drive deurbanization; 2) suburban drivers drive more sport utility vehicles and pickup trucks than do city drivers; 3) healthy habitats and being in settings that protect health caused people to move away from transit and toward car ownership and travel; 4) sustainable living paused during the pandemic but is still on the minds of consumers; and 5) life-stage delays are likely to result in reduced vehicle sales as family formation lags.

Making Good Decisions Without Good Predictions
Robert Lempert, RAND Corporation

- Traditional transportation planning uses forecasts to develop plans of action, but these forecasts and planning methods may no longer be relevant, accurate, or adequate.
- Robust decision making is a framework that identifies actions and tests them against multiple possible futures to determine which actions succeed in the broadest range of possible futures.
- Robust decision making allows officials and decision makers to agree on decisions without focusing—or needing to agree—on the underlying forecasts.
- Traditional planning employs normative scenarios, identifying preferred outcomes and then developing plans to reach them. Robust decision making employs exploratory scenarios, examining the results of a wide range of possible outcomes.

CONSENSUS REPORT 341

Are Wheelchair Securement Systems Feasible for Airline Travel?

A PRELIMINARY ASSESSMENT

MELISSA WELCH-ROSS

The author served as the study director and is a senior program officer at the Transportation Research Board, National Academies of Sciences, Engineering, and Medicine in Washington, D.C.

Wheelchair securement systems for passenger use in airplane cabins are intuitively appealing as a solution to many of the hardships that people with disabilities and who are nonambulatory face when flying. Such systems are currently used and designed in accordance with widely accepted safety standards for public and private modes of surface transportation, including cars, vans, and transit buses. Using these systems, people who are nonambulatory can board the vehicle in their personal wheelchair, stay seated in the wheelchair for the duration of the trip, and wheel off the vehicle. Airline transportation is an exception—it invariably requires nonambulatory people to fly in an airplane seat.

In the FAA Reauthorization Act of 2018, Congress called for the U.S. Access Board to examine the feasibility of wheelchair securement systems for passenger use in airplane cabins and the ways in which people with significant disabilities who use wheelchairs can be accommodated by such systems, if feasible. In response, the U.S. Access Board commissioned a National Academies of Sciences, Engineering, and Medicine study. *Consensus Report 341: Technical Feasibility of a Wheelchair Securement Concept for Airline Travel—A Preliminary Assessment* is the result of this study.

Photo: James Williams, Unsplash

Although many wheelchair users can exercise independent mobility to get to and through an airport, these passengers must transfer from wheelchair to airplane seat for the flight, and they often deplane last.

Conclusions

The report's expert committee found major technical considerations most relevant to this technical assessment were whether

- Airplanes common to airline service have enough doorway and interior space to enable a power or manual wheelchair to enter and exit the passenger cabin and maneuver to and from a securement location with sufficient room for the securement system and medically essential wheelchair position adjustments to function;
- An airplane floor and its structure can accommodate the loadings imparted by an occupied power wheelchair; and
- A secured personal wheelchair can meet FAA crashworthiness, occupant injury protection, and other relevant air transportation safety requirements.

For more information on *Consensus Report 341: Technical Feasibility of a Wheelchair Securement Concept for Airline Travel—A Preliminary Assessment*, visit www.nap.edu/catalog/26323.

In each case, the committee identified no issues likely to call into question the technical feasibility of an in-cabin wheelchair securement system and the value of exploring the concept further. In particular, the report documents that the majority of airplanes have a main boarding door wide enough for most personal wheelchairs. Also noted was that the most common cabin interior dimensions and layouts for the two most ubiquitous families of airplanes—the Boeing 737 and Airbus A320—should require only modest interior modifications to create a wheelchair securement area located at the front

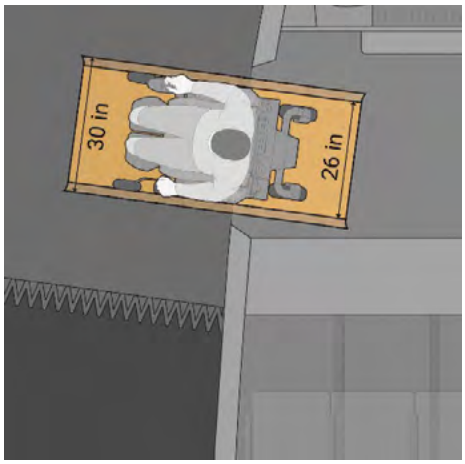


Image: Courtesy Melissa Welch-Ross

Including armrests, most wheelchairs have a maximum overall width of 30 inches or less and a wheelbase of 26 inches.

of the cabin near the turn from the main boarding door.

In particular, the removal of two successive rows of seats in a cabin location near the boarding door should provide

- Sufficient room in most airplanes for a securement location spacious enough to allow the occupant of a wheelchair to maneuver into—and out of—the location and, once secured, to use physically and medically essential wheelchair position functions without impinging on the space of other passengers;
- Enough airplane floor structure to accommodate the load imparted by the heaviest of occupied power wheelchairs using load distribution systems that are commonly employed for seat assembly attachments, including pallet systems; and
- Sufficient clear space to satisfy FAA criteria that the wheelchair occupant and nearby passengers do not risk serious head and leg injuries from striking objects or structure during a survivable crash or emergency event as long as the wheelchair remains secured and its occupant restrained.

Further, many personal wheelchairs, including power wheelchairs, comply with WC19 standards covering motor vehicle transportation safety and crash performance for wheelchairs as established by the Rehabilitation Engineering and Assistive Technology Society of North America. This provides a widely available and standardized interface for an in-cabin wheelchair tie-down and occupant-restraint system.

The report explains that more work is needed to understand how secured personal wheelchairs are likely to perform relative to certain FAA safety criteria in restraining and protecting occupants during a survivable airplane crash or emergency landing. The report also identifies several important airline operational and passenger accommodation issues that warrant careful consideration as part of any initiative to develop and introduce an in-cabin wheelchair securement system intended to provide reliable and meaningful levels of flight service to nonambulatory passengers, including those with significant disabilities. These include providing needed passenger assistance and service, fare reservation system capabilities, procedures for validating wheelchair boarding eligibility, and protocols and power management for controlling wheelchair seating functions while in flight.

Conclusions

To fill information gaps identified, the report included the following for consideration:

- The U.S. Department of Transportation (U.S. DOT) and FAA may establish a program of research, in collaboration with the Rehabilitation Engineering and Assistive Technology Society of North America and the assistive technology industry, to test and evaluate an appropriate selection of WC19-compliant wheelchairs in accordance with applicable FAA crashworthiness and safety performance criteria.
- The U.S. Access Board may sponsor studies that assess the likely demand for air travel by people who are nonambulatory if they could remain seated in their personal wheelchairs while in flight. The studies may assess both the extent to which, and how, people with different disabilities are likely to use the securement systems, which could better define the space needed in the airplane cabin for wheelchair maneuvering and securement, provide insight into passenger support and service assistance requirements, and inform airline decisions about needed levels of fleet coverage and flight availability.

The report concludes by observing that the next steps of research, testing, and evaluation would be informed by the suggested research, then planned and programmed in accordance with a high-level roadmap defining and prioritizing decisions to be made and follow-on work.

U.S. DOT would be the logical lead for the development of such a roadmap in collaboration with the agencies and entities identified and with consultation and input from a wide range of interests and experts, including the airlines and their passenger service personnel, airframe manufacturers and interior component suppliers, people with disabilities and their advocates, and the assistive technology industry.

There are no issues likely to call into question the technical feasibility of an in-cabin wheelchair securement system.

Transit for All

Transit Equity & Environmental Health in Baltimore City examines the relationship between the public transit system of Baltimore, Maryland, and health impacts. The Baltimore Transit Equity Coalition worked with Baltimore community members and the Johns Hopkins University Bloomberg School of Public Health to identify and analyze data mapped by study theme using the smallest geographic unit from the Census Bureau.

When superimposed over each other, the study's social vulnerability and health maps revealed Baltimore's "White L and Black Butterfly" shapes. The White L is where high-income, predominantly white communities are located. The Black Butterfly encompasses areas with low-income, minority-populated communities.

Among other findings, the transit map revealed that farther away from the city center, the gap between time to commute by transit and personal vehicle widened, and there were less frequent transit stops. An overlay of data from the transit and social vulnerability themes showed that "those who are more socially vulnerable also have less access to high-quality transit."

Findings like these "can be used to determine which communities might benefit the most from investments in transit."

Photo: Elvert Barnes, Flickr

Where does this bus go? It could be a lifeline getting disadvantaged—and often essential—workers to their jobs, or it might provide affluent communities with a transit choice. Ensuring transit equity means fairly balancing needs with dollars.

For more information, go to https://www.youtube.com/watch?v=ST84sVqaUqA or read the report at https://americanhealth.jhu.edu/sites/default/files/2021-09/JHU-016%20Transit%20Equity%20Report-FINAL_0.pdf.

Photo: Bridgestone

This all-metal tire is designed for the moon's harsh environment, where temperatures range from -274°F to 248°F, the surface is a sandy substance called regolith, and the gravity is one-sixth of that on Earth.

Custom Tires for the Lunar Rover

Bridgestone, which is taking part in an international space exploration mission with the Japan Aerospace Exploration Agency and Toyota Motor Corporation, is developing tires that can deliver traction on the rough surface of the moon, where none of the company's previously developed tires are able to function.

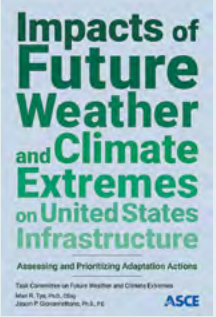
Standard tires support the weight of vehicles with internal air pressure. However, according to Bridgestone, air cannot be used this way in space. Bridgestone's all-metal tire employs an elastic metal skeleton construction designed to bend flexibly while offering the resilience necessary to make trips of more than 10,000 kilometers required of moon exploration missions.

Used in pairs like truck tires—commonly known as dualies—the prototype lunar tires increase the surface area of the tire's contact patch, which is about six times that of standard passenger car tires. These tires are encased with special tread material to disperse the contact pressure. Made from an elastic metal akin to steel wool, this tread material was inspired by the pads on the feet of camels. Like camels, the lunar rover will need to carry heavy loads across long expanses of desert-like terrain with ease.

Learn more at https://www.bridgestone.com/technology_innovation/moon_tires.

Minimum Design Loads and Associated Criteria for Buildings and Other Structures, ASCE/SEI 7-22 Standard
American Society of Civil Engineers, 2022, 888 pp., ASCE member, $232.50; nonmember, $310; 978-0-784-48349-7.

The American Society of Civil Engineers' most widely used standard is an integral part of building codes in the United States and around the globe. The 2022 edition includes first-ever criteria for tornado-resistant design and substantial improvements to the design criteria for atmospheric icing, earthquake, tsunami, rain, snow, and wind. Available as a two-volume softcover or as PDF files.



Impacts of Future Weather and Climate Extremes on United States Infrastructure: Assessing and Prioritizing Adaptation Actions
Mari R. Tye and Jason P. Giovannettone. ASCE, 2021, 174 pp., ASCE member, $60; nonmember, $80; 978-0-784-41586-3.

The authors summarize the likely changes in selected extreme meteorological and hydrological events, assess the vulnerabilities of infrastructure within critical sectors and their collective interdependencies, and review frameworks that decision makers can use to prioritize limited budgetary resources.

Autonorama: The Illusory Promise of High-Tech Driving
Peter Norton. Island Press, 2021, 320 pp., $27; 978-1-642-83240-2.

The author investigates the push for autonomous driving, from GM's 1939 Futurama exhibit to connected highways and vehicles.

Performance-Based Decision Making for Asset Management: Lessons Learned and Practitioner Toolkit
Transportation Association of Canada, 2021, 156 pp. For more information, visit https://www.tac-atc.ca/sites/default/files/site/doc/publications/2021/ptm-pbdm-e.pdf.

This new synthesis summarizes current practices, describes lessons learned by pioneering Canadian agencies, and presents a toolkit to help practitioners make better asset management decisions. It is available as a free download.

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

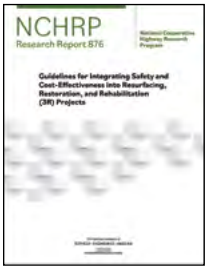
TRB PUBLICATIONS

Transportation Research Record 2675
Issue 9

The authors present research on the nanotechnology of cement and concrete, optimization of takeoff departure procedures for airport noise mitigation, vehicle delay estimation at signalized intersections using machine learning algorithms, and more.

2021; 1,729 pp. For more information, visit http://journals.sagepub.com/home/trr.

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



Guidelines for Integrating Safety and Cost-Effectiveness into Resurfacing, Restoration, and Rehabilitation (3R) Projects
NCHRP Research Report 876

The Federal-Aid Highway Act of 1976 allowed the use of federal aid for resurfacing, restoration, and rehabilitation (3R) projects on federal-aid highways. This report presents a rational approach for

estimating the cost-effectiveness of incorporating safety and operational improvements into 3R projects.

2021; 234 pp.; TRB affiliates, $74.25; nonaffiliates, $99. Subscriber category: design.

LED Roadway Lighting: Impact on Driver Sleep Health and Alertness
NCHRP Research Report 968

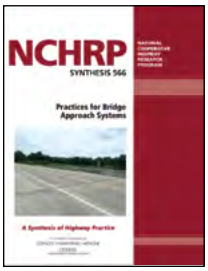
This report seeks to determine the impact of LED roadway lighting on driver sleep health and alertness.

2021; 56 pp.; TRB affiliates, $48; nonaffiliates, $64. Subscriber categories: safety and human factors.

Revised Clear-Water and Live-Bed Contraction Scour Analysis
NCHRP Research Report 971

This report develops live-bed and clear-water contraction scour equations suitable for use in risk-based bridge design encompassing a wide range of hydraulic conditions, including varying contraction ratios.

2021; 174 pp.; TRB affiliates, $70.50; nonaffiliates, $94. Subscriber categories: design, hydraulics and hydrology, bridges and other structures.



Practices for Bridge Approach Systems
NCHRP Synthesis 566

This synthesis documents the current state of the practice at state departments of transportation (DOTs) related to the design, construction, and maintenance of bridge approach systems. State DOT design guides and standard specifications were reviewed as part of the information-gathering process.

2021; 212 pp.; TRB affiliates, $72; nonaffiliates, $96. Subscriber categories: bridges and other structures, construction, design.

Summary State DOT Practices for Developing and Implementing TSMO Plans
NCHRP Synthesis 567

This synthesis documents current practices used by state DOTs related to the development and implementation of Transportation Systems Management and Operations (TSMO) plans. An overview presents the current state of TSMO plan development and methodology.

2021; 152 pp.; TRB affiliates, $66; TRB nonaffiliates, $88. Subscriber categories: operations and traffic management.

Portland Cement Concrete Pavement Joint Sealant Practices and Performance
NCHRP Synthesis 568

This synthesis compiles and documents information regarding the current state of practice of joint sealing portland cement concrete by state DOTs.

2021; 98 pp.; TRB affiliates, $55.50; nonaffiliates, $74. Subscriber categories: materials, pavements.

Guidebook for Developing a Zero- or Low-Emissions Roadmap at Airports
ACRP Research Report 220

This guidebook articulates steps for creating an airport-specific emissions roadmap. Roadmap development is discussed from start to finish using conceptual diagrams, examples, best practices, and links to external tools and resources.

2021; 104 pp.; TRB affiliates, $55.50; nonaffiliates, $74. Subscriber categories: aviation, environment.

Rapid Slab Repair and Replacement of Airfield Concrete Pavement
ACRP Research Report 234

This report is designed to assist airport personnel and engineering consultants in selecting and executing rapid slab repair and replacement (RSRR) projects and to provide relevant information for airport maintenance personnel performing RSRR work.

2021; 134 pp.; TRB affiliates, $62.25; nonaffiliates, $83. Subscriber categories: aviation, design, pavements.

Prioritization of Public Transportation Investments: A Guide for Decision-Makers
TCRP Research Report 227

This report provides practical advice for transportation agencies looking to improve their prioritization practice for public transportation projects.

2021; 90 pp.; TRB affiliates, $55.50; nonaffiliates, $74. Subscriber categories: passenger transportation, planning and forecasting.

Joint Development Agreements Using FTA Funds or FTA-Funded Assets
TCRP Legal Research Digest 56

This digest aims to clarify the FTA-assisted joint development process and attempts to separate public perceptions (and misperceptions) about transit-oriented development from reality.

2021; 29 pp.; TRB affiliates, $39; nonaffiliates, $52. Subscriber categories: planning and forecasting, law, finance.

Fix It, Sign It, or Close It: State of Good Repair in an Era of Budget Constraints
TCRP Legal Research Digest 57/NCHRP Legal Research Digest 84

This digest addresses the legal ramifications to transportation agencies that have to decide whether to repair, improve, or rebuild assets that are in poor repair.

2021; 32 pp.; TRB affiliates, $31.50; nonaffiliates, $42. Subscriber categories: highways, law.

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

MEETINGS, WEBINARS, AND WORKSHOPS

March

14 **TRB Webinar: Innovations in Bridge Foundation Load Testing and Data Integration**
For more information, contact Beth Ewoldsen, TRB, 202-334-2353, BEwoldsen@nas.edu.

15–18 **Conference on Sustainability and Emerging Transportation Technology**
Irvine, CA
For more information, contact Bill Anderson, TRB, 202-334-2514, WBAnderson@nas.edu.

20–23 **American Society of Civil Engineers (ASCE) Geo-Congress 2022***
Charlotte, NC
For more information, contact, Nancy Whiting, TRB, 202-334-2956, NWhiting@nas.edu.

22 **TRB Webinar: How Rough Is Your Pavement? Measuring Pavement Profiles for Low-Speed Roads**
For more information, contact Beth Ewoldsen, TRB, 202-334-2353, BEwoldsen@nas.edu.

22–24 **International Data Science for Pavements Symposium***
McLean, VA
For more information, contact Nelson Gibson, TRB, 202-334-2953, NGibson@nas.edu.

29 **TRB Webinar: Robot-Enabled Sensing and Augmented Learning for Bridge Inspection**
For more information, contact Deanna Sparger, TRB, 202-236-2116, DSparger@nas.edu.

April

3–6 **International Conference on Accelerated Pavement Testing***
Nantes, France
For more information, contact Stephen Maher, TRB, (202) 334-2955, SMaher@nas.edu.

5–7 **Marine Board Spring Meeting**
Irvine, CA
For more information, contact Tess Austin, TRB, (202) 334-2445, TAustin@nas.edu.

May

15–18 **International Conference on Roundabouts**
Monterey, CA
For more information, contact Nelson Gibson, TRB, 202-334-2953, NGibson@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, please visit www.nationalacademies.org/trb/events or e-mail TRBMeetings@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."

IN MEMORIAM

Richard W. Bloom, former Aviation Safety, Security, and Emergency Management Committee chair, died on June 1, 2021. He also was a longtime faculty member and administrator at Embry–Riddle Aeronautical University in Prescott, Arizona.

George Blomme, TRB Airport Terminals and Ground Access Committee member emeritus and chair from 1984 to 1988, and Aviation Group chair from 1989 to 1994, died on December 10, 2021.

VOLUNTEER VOICES

"I was drawn to the transportation community by my lifelong interest in airplanes. When I was 16, I really got into aircraft safety and incidents. I decided that I would get a mechanical engineering degree, then an aerospace degree, and then be an investigator. When I was looking at internships early in my sophomore year, I realized that there was a lot more to transportation safety than just aircraft. I got hooked on it. I tried to read as many transportation safety articles as possible. I then joined a professional organization that had a forum, and I saw people talking about issues. I see so many passionate people in the transportation community. I love that there are people who want to make the world safer and are passionate about what they do."

—TORI BROOKS
Master of Science Candidate, Engineering Data Science, University of Houston, Texas

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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