TR NEWS
September–October 2020 NUMBER 329

Embracing the Future of Transportation

100 YEARS MOVING IDEAS: ADVANCING SOCIETY
The National Academies of
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TRB
TRANSPORTATION RESEARCH BOARD

The National Academies of
SCIENCES • ENGINEERING • MEDICINE

The **National Academy of Sciences** was established in 1863 by an Act of Congress, signed by President Lincoln, as a private, nongovernmental institution to advise the nation on issues related to science and technology. Members are elected by their peers for outstanding contributions to research. Dr. Marcia McNutt is president.

The **National Academy of Engineering** was established in 1964 under the charter of the National Academy of Sciences to bring the practices of engineering to advising the nation. Members are elected by their peers for extraordinary contributions to engineering. Dr. John L. Anderson is president.

The **National Academy of Medicine** (formerly the Institute of Medicine) was established in 1970 under the charter of the National Academy of Sciences to advise the nation on medical and health issues. Members are elected by their peers for distinguished contributions to medicine and health. Dr. Victor J. Dzau is president.

The three Academies work together as the National Academies of Sciences, Engineering, and Medicine to provide independent, objective analysis and advice to the nation and conduct other activities to solve complex problems and inform public policy decisions. The National Academies also encourage education and research, recognize outstanding contributions to knowledge, and increase public understanding in matters of science, engineering, and medicine.

Learn more about the National Academies of Sciences, Engineering, and Medicine at **www.nationalacademies.org**.

The **Transportation Research Board** is one of seven major programs of the National Academies of Sciences, Engineering, and Medicine. The mission of the Transportation Research Board is to provide leadership in transportation improvements and innovation through trusted, timely, impartial, and evidence-based information exchange, research, and advice regarding all modes of transportation. The Board's varied activities annually engage about 8,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state departments of transportation, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.

Learn more about the Transportation Research Board at **www.TRB.org.**

TRB

TRANSPORTATION RESEARCH BOARD 2020 EXECUTIVE COMMITTEE*

* Membership as of August 2020.

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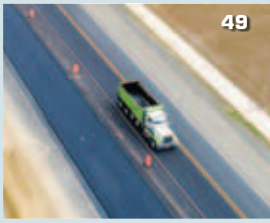

COVER As humans continue to aspire to ease and efficiency in transportation, what will tomorrow bring? Will New York City taxis, for example, take to the skies as passenger drones to transport us to our destinations? The skies, roads, and rails are the limit for the future of transportation. (Image: andrey_l, Shutterstock)

Coming Next Issue

The November–December 2020 issue of *TR News* will feature articles on topics including incorporating resiliency into freight mobility, living with transformational technologies, and pollution-reducing highway barriers.

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 novel coronavirus 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.

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 Transportation Research Board Publications Staff**
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EMBRACING THE FUTURE OF TRANSPORTATION

Photo: iStock

In one concept of the future, maglev trains will zip below rails, cars will be airborne, and holograms will compete with stars in the night sky.

SANDRA LARSON

The author is Transportation Innovation Strategies Leader, Stanley Consultants, Des Moines, Iowa.

The articles in this issue are predictions of possible outcomes meant to be thought- and discussion-provoking, not necessarily a statement of a desirable future state. As such, these ideas are subject to change, revision, and rethinking at any time. The views and opinions expressed in this issue are those of the authors and do not necessarily reflect the official policies, positions, or point of view of any other organization or entity, including their employers or related companies.

Welcome to this issue of *TR News* on "Embracing the Future of Transportation." It is part of the yearlong Transportation Research Board (TRB) Centennial celebration, which concludes January 2021. Like many *TR News* readers, I have been blessed to work in transportation my entire career. Little did I know that this would be such an exciting and dynamic career choice.

This theme issue captures and conveys the enthusiasm we as professionals hold for the future of transportation. We solve problems by seeking solutions, and transportation offers us opportunities to make a difference in the world around us via debate, collaboration, and cooperation. In this issue, we focus not only on where we have been and where we are now but, especially, on where we are going.

My heartfelt thanks go to the team of authors who wrote these articles. They were presented with the unique opportunity to forecast the future of transportation with a visionary discussion on the trends that will inform future debates. They were asked to be multimodal, creative, diverse,

Photo: Unsplash

Transportation offers opportunities to collaborate, using the past and present to inform the future.

Photo: Event Photography of North America

A group photo of some of the TRB committee members, friends, staff, and 2020 Annual Meeting attendees shows the growth and diversity of the transportation profession in the 100 years since TRB was founded.

inclusive, and thought-provoking—no small task. We wanted these articles to create a pause point in our deliberations, to give us room to examine and contemplate the what-ifs and potential future transportation scenarios.

My thanks also go to the TRB staff I have enjoyed working with on planning TRB's Centennial, including Neil Pedersen, Russell Houston, and Katherine Kortum. TRB staff are among the most talented and dedicated professionals I have had the pleasure of working with over the course of my career.

Areas of Focus

We chose nine main areas of focus in this issue: safety, transformational technologies, climate change and resiliency, infrastructure, funding, socioeconomic trends, freight, streets, and aviation. Additionally, we have included a retrospective on TRB staff contributions to the success of TRB; a forward-looking perspective from young professionals; and a crystal-ball transportation vision on the past, present, and future.

I hope that, as you are reading this issue, we are emerging globally from the nightmare that this COVID-19 pandemic has been for our communities, countries, and livelihoods. Restricted movement has brought new appreciation of and perspective to transportation in its many modes and forms. I will no longer take a restorative morning walk for granted, and I yearn to travel freely and visit my favorite places.

Safe, affordable, and equitably available transportation is key to our physical, emotional, and economic well-being. As we look to the future, I hope we all

Photo: Elvert Barnes, Flickr

A sign in a Washington Metropolitan Area Transit Authority station advises riders to wear masks amid the COVID-19 pandemic, which has upended every transportation mode—and most other aspects of life, as well.

have a renewed dedication to solving our challenges and searching for solutions to keep us all healthy and able to live a life we choose. No matter where we live, our ability to get where we must go and find the goods we need to live is keenly felt, now more than ever. Crisis has a way of focusing our attention.

Our choices are many, and our opportunities are diverse. Here's to another 100 years of TRB as a foundation for transportation research—convening people, ideas, and solutions for the future.

The *TR News* Editorial Board thanks Katherine Kortum, Transportation Research Board, for her work assembling and developing this issue.

Photo: Risdon Photography

TRB Executive Director Neil Pedersen listens as the author Sandra Larson delivers a presentation to the TRB Executive Committee at the 2019 TRB Annual Meeting.

CENTENNIAL QUOTE

"One hundred years from now at the Transportation Research Board's (TRB's) 200th Anniversary, people will look back and wonder about today's vehicles and think, "How inefficient!" Single-owner vehicles will be replaced by a transportation system that will be fast, efficient, clean, accessible to all, and on demand. The emphasis on transportation planning will be on alignments and rights-of-way, not built infrastructure. The ways we work and teach also will be on demand and open to all. Universities will replace their traditional undergraduate and graduate programs with lifelong learning that can be accessed from anywhere. Artificial intelligence will dominate our lives, and humans will learn to work and live alongside machine staff and companions. Space travel for nonastronauts is only just beginning. But, in a century, vacationing in space stations will be the hot ticket. TRB's role is to imagine this reality sooner rather than later and to ensure that it is leading the way for the next 100 years. My vision for TRB is not what it will be like in 100 years but what it should be like starting tomorrow—and every day thereafter until we reach our 200th year.

—GERALDINE KNATZ
Professor of the Practice of Policy and Engineering,
University of Southern California, Los Angeles

BEHIND THE SCENES

Photo: Russell Houston

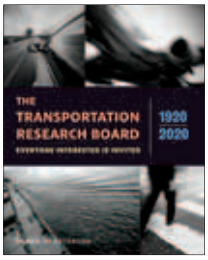
ROBERT E. SKINNER, JR.

The author served as Executive Director of the Transportation Research Board from 1994 to 2015.

Above: As a division of the National Academies of Sciences, Engineering, and Medicine, TRB helps the National Academies fulfill its mission of independent, objective analysis and advice to the nation.

No one talks more about the Transportation Research Board (TRB) than its executive director, a position I held for more than 20 years. TRB is a complicated organization like none other. It combines elements of a professional society, a consulting firm, and a think tank, and it is located within the National Academies of Sciences, Engineering, and Medicine—another complicated institution. So, explanations are needed for folks who are new to TRB, whether they are graduate students or newly appointed heads of transportation organizations. At this point, however, there is not much room for me to say anything new and important that I haven't already said.

In the past, I have spoken about factors that have contributed to TRB's success and longevity. Most recently, I did so with Tom Deen, TRB's executive director from 1980 to 1994, in a foreword to the newly published history of TRB, *The Transportation Research Board, 1920–2020: Everyone Interested Is Invited*. The factors include such things as TRB's placement within the National Academies' National Research Council, its mix of researchers and practitioners, its lack of credentials or other requirements for participation, its means of empowering its many committees, and the long-term sponsors who share the vision of what TRB can accomplish.



For more information on *The Transportation Research Board, 1920–2020: Everyone Interested Is Invited*, visit https://trbcentennial.nationalacademies.org/centennial-book.

All of these are very important. But, on reflection, I have overlooked another crucial success factor, maybe because it seemed a bit self-serving: the talented and dedicated staff members who have implemented TRB's programs, supported its committees, and served its sponsors from the very beginning.

TRB staff gathered for a group photo in early 2020. Staff members join TRB at various points in their careers, but the welcoming environment and rewarding work mean that many stay for a long time.

For the most part, TRB staff members—particularly those with transportation specialties—come to TRB midcareer, after working elsewhere. The jobs they take on are unusual, frequently involving committees and panels and supporting communities of volunteers and sponsors working in a particular subject area or on a particular task. Some staff members support continuing dialogues and information exchanges among researchers and practitioners; others manage research projects or consensus studies; and still others run various information and business systems, along with other support activities needed to make the organization function.

Some staff members come to TRB, contribute, and then move on to positions elsewhere. One executive director, Grant Mickle, returned to the Automotive Safety Foundation in 1966 after helping steer TRB through some difficult challenges. Later, he chaired the Board's Executive Committee, thus coming full circle from volunteer to staff member and then to volunteer again. This pattern benefits TRB and has been repeated not infrequently—including by the current executive director, Neil Pedersen, who first served as a volunteer before joining TRB's staff. But, more often than not, staff members stay and make TRB the capstone of their careers.

Why do they stay on at an organization that offers relatively few paths for promotion and increased remuneration and requires staff to stay in the background, working behind the scenes and receiving limited credit for their work? No doubt the reasons vary, but high on the list for many must be the opportunity to work closely with experts—the shining stars—in their particular technical areas. The institution itself—both TRB and the National Academies—is prestigious and committed to excellence; it offers a congenial workplace doing work that benefits the nation. This must be an attraction, as well. And, for many, there is a great deal of autonomy in the work. Individual staff members are often the face of TRB for specific technical areas and communities.

Serendipity has been a factor in TRB's success. Part of that serendipity is that the value proposition offered by TRB has been good enough to attract and retain truly excellent people. And without excellent people, TRB would not have survived long enough to celebrate 100 years of service to the nation.

The author guides the TRB Executive Committee through its agenda at the 2014 TRB Annual Meeting.

Photo: Risdon Photography

TRB is a complicated organization like none other. It combines elements of a professional society, a consulting firm, and a think tank.

Young Professionals Lead Transportation Innovations

Photo: Risdon Photography

KATHERINE KORTUM AND NANCY AGUIRRE

Kortum is Senior Program Officer, Transportation Research Board, Washington, D.C., and Aguirre is Program Manager, Highways and Airports, Cement Council of Texas, Hurst.

Above: University of Hawai'i at Mānoa senior Diana Moana Nomura presents her paper, Traffic Problems at Popular Rural Tourist Attractions, at the 2020 TRB Annual Meeting Black, Indigenous, and People of Color poster session. Young professionals are stepping forward to develop technology and solutions that will carry the transportation industry into the future.

Transportation is suddenly an "it" industry full of dynamism. New services, including ride hailing, e-scooters, mobility-as-a-service business models, and more, are expanding rapidly. Automation—to varying degrees—is under way. On top of it all, the urgency of climate change and equity make the need to address our transportation system's flaws more pressing than ever.

As innovative solutions evolve to address complex transportation challenges, a new generation of professionals is taking on these concerns. Students and young professionals are aware that they are working to create a better system for their own future use. Transportation agencies and all levels of government have crafted strategic plans that often propose using innovative technologies to provide safe, reliable, and effective transportation to meet the traveling public's needs. However, many of these strategic plans do little to address the need for higher levels and more varied types of education and research in transportation. There is a great deal of demand for interdisciplinary work in the public, private, nonprofit, and academic sectors.

Photo: Marco Verch, Flickr

Filling a gap for commuters when destinations are too far to walk, e-scooters are an alternative to cars and have taken off in urban areas.

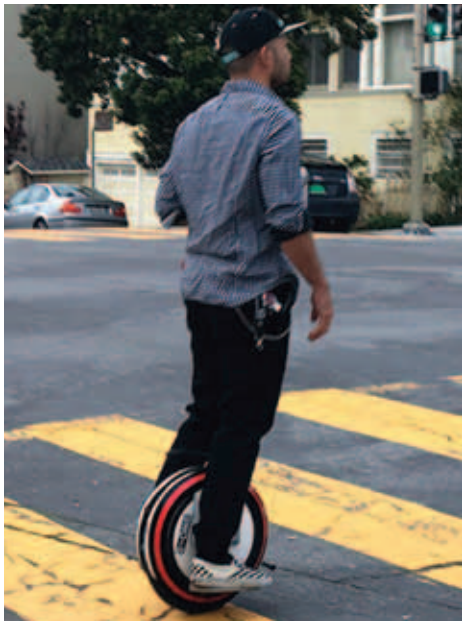


Photo: Lynn Friedman, Flickr

Rare enough to turn heads on city streets, electric unicycles are innovative, self-balancing, personal transports. Riders use foot motions to steer and lean backward and forward to control speed, maneuvers made possible by gyroscopes and accelerometers.

Photo: Pixabay

Expertise from diverse fields—such as medicine, biology, immunology, and epidemiology—can contribute to the connection between transportation and public health.

Traditional fields of study are no longer enough to address the challenges of our transportation system. To address safety, equity, public health, environmental sustainability, funding and financing, and more, the transportation industry needs to attract a wider array of perspectives and expertise. Many of those currently in transportation describe their career progression as having "fallen into" transportation. Encouraging this "falling" should continue, but the industry also needs to continue to reach out to and invest in seemingly unrelated fields.

Adding greater diversity of fields and individuals to any industry provides a wide array of benefits. Those from less traditional educational fields bring new concepts and creative solutions to longstanding issues. Many fields—perhaps, most notoriously, engineering—suffer from a lack of strong communication skills, especially in communicating with the public. Increasing the number of professionals from nonengineering backgrounds is likely to improve that significant gap in understanding. However, communication is not the only skill set that the transportation industry could strengthen by broadening its reach.

Connections between transportation and public health require medical expertise, as well as knowledge of biology, immunology, and epidemiology. Safety improvements require physicists, material scientists, and human behavior experts. Funding and financing issues require analysis by economists, statisticians, and political scientists. And an increased need for data analysis, programming, and systems engineering is a thread running through all of these.

Young professionals will join the transportation industry from all directions, and this influx can only benefit the industry. High schools, colleges, and graduate schools all will plant the seeds and develop the incoming leaders that we need to address the many challenges the world faces. From climate change to pandemics, transportation is quite literally what brings the world together. Plenty of challenges await us. But, with a highly diverse workforce in the future, we are in the best position to address them.

As innovative solutions evolve to address complex transportation challenges, a new generation of professionals is taking on these concerns.

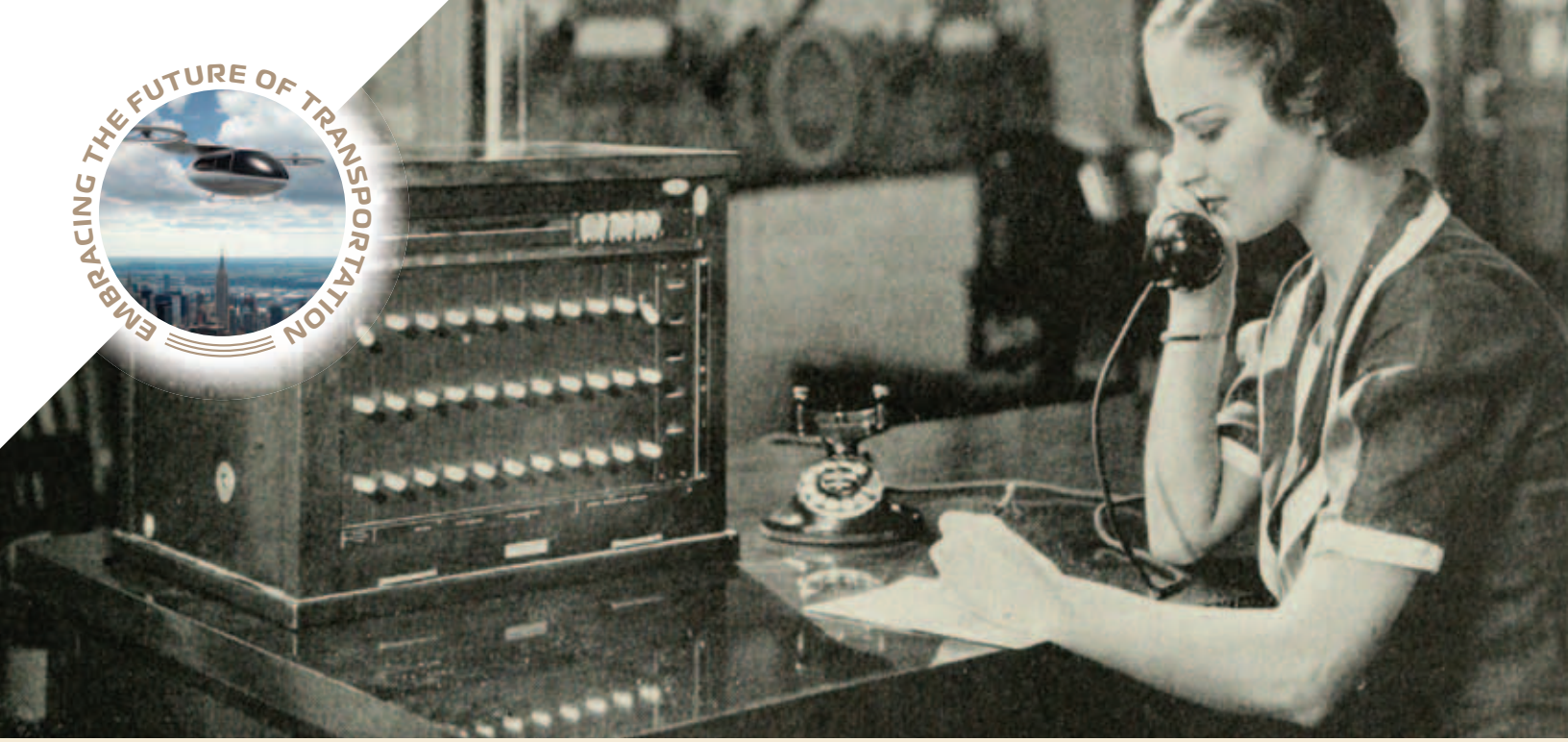


Photo courtesy of Prelinger Library

That Was Then, This Is Now, Tomorrow Will Be Amazing!

KATHERINE TURNBULL

Turnbull is Executive Associate Director, Texas A&M Transportation Institute, Texas A&M University System, College Station.

Take a stroll down memory lane, then gaze into a crystal ball with us. As we celebrate the TRB Centennial, let's take a look back at life in 1920, contemplate where we are today, and then consider what 2120 might hold.

In the Stands

The year 1920 was the inaugural season of the American Professional Football Association (the precursor of the National Football League) with the Akron Pros winning the title—and managing to do so without something called a halftime show. The Kansas City Chiefs won Super Bowl LIV in 2020, with Shakira and Jennifer Lopez performing the halftime extravaganza. The 2120 virtual Super Bowl was won for the first time by the Mars Martians, with the Ceres Rock Miners headlining the halftime show.

Above: "Mr. Loney on Line 1!" In 1920s offices across the country, receptionists—largely female—used multiline switchboards to route calls. Flip switches were assigned to a phone in each private office or department. The receptionist flipped one switch to answer the call, another to route it, and yet another to disconnect on her end.

Keeping in Touch

Making a telephone call in 1920 involved connections through a manual switchboard and—likely—a party line with up to four phone numbers belonging to your neighbors (please don't listen in on those other conversations). Today, smartphones can do it all—talking, texting, video streaming, taking photos, and much more. By 2120, communication arrays the size of a pinhead are implanted at birth, providing truly 24/7 hands-free calling throughout life.

Staying Informed

You needed 2 cents to mail a first class letter in 1920, compared with 55 cents today. In 2120, what is a letter? And what is a postage stamp? The morning mail arrives electronically, drones deliver small packages, and large shipments are sent via autonomous freight pods.

Playtime

Crossword puzzles were the rage in 1920, with newspapers using the word games to boost daily sales. Children played with pogo sticks and yo-yos. Virtual gaming is the craze today, with e-sport leagues, tournaments, and championships. The hot game in 2120? Virtual curling, of course! The hot toy? Cabbage Patch robots reminiscent of the dolls of the late 1970s!

Photo: Pixabay

In today's virtual world, the castle can fall with the king in a game of chess.

Snack Time

The 1920s brought us Wonder Bread, Baby Ruth candy bars, Reese's Peanut Butter Cups, Welch's Grape Jelly, Wheaties, and Yoo-Hoo chocolate drinks. New in 2020 are White Reese's Peanut Butter Cups Thins, KRAVE Plant-Based Jerky, Chocolate Marshmallow Oreos, Life's Grape Peanut Butter-Dipped Grapes, Post Hostess Twinkie Cereal, and Goldfish Veggie Crackers. New taste treats in 2120 include peanut butter jerky, grape jelly goldfish, and chocolate-covered seaweed cookies.

Feeding Our Minds

Books written in 1920 included *The Mysterious Affair at Styles* by Agatha Christie, *Main Street* by Sinclair Lewis, and *The Story of Doctor Doolittle: Being the History of His Peculiar Life at Home and Astonishing Adventures in Foreign Parts* by Hugh Lofting. *Walk the Wire* by David Baldacci, *If It Bleeds* by Stephen King, and *Camino Winds* by John Grisham are new in 2020. Featured e-reading in 2120 includes *COVID-19: A Look Back 100 Years Later, The Mysterious Affair on the Moon,* and *Celebrating 200 Years of TRB*. Maybe human cloning will be a reality by 2120, and we can all be part of the TRB celebration after our original selves are long gone!

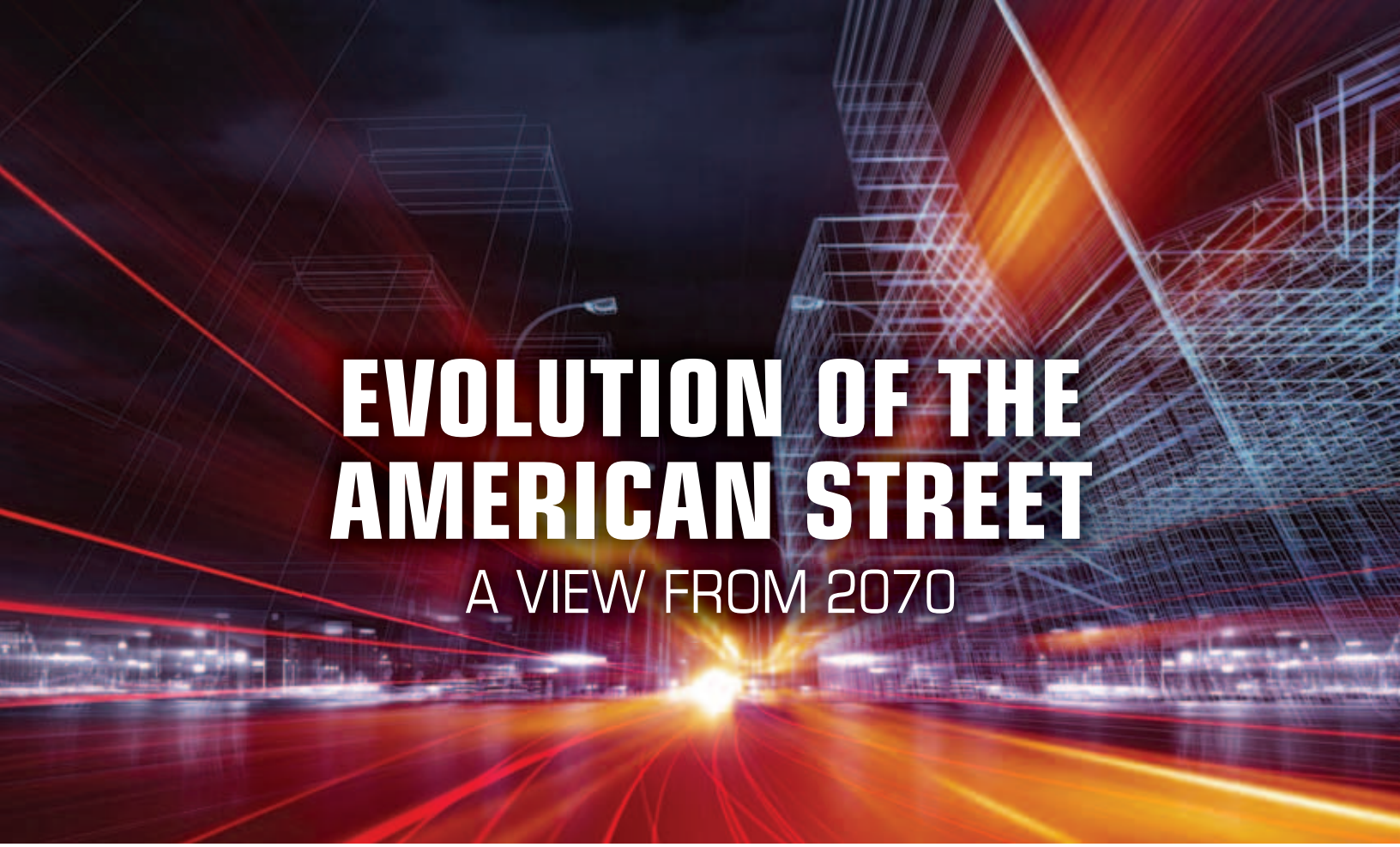
Getting Around

Men, women, and children all rode bicycles in 1920; and cycling clubs, bicycling tours, and velodrome racing were popular. The 1920 Summer Olympics in Antwerp, Belgium, included two bicycle road racing and four track racing events. Electric scooters were the rage in 2020, but e-scooter racing was not (yet) an Olympic sport. The hot transportation mode in 2120? From watching the Jetsons cartoon TV show as a kid, it has to be personal jet packs!

What do you see in *your* crystal ball?

Photo: Nationaal Archief of the Netherlands

Danger was in the details of the one-wheeled motorcycle, which took to the roads in the 1920s. This version, possibly invented by Italians Cislaghi and Goventosa, was powered by a Garelli 350 engine and reached 93 miles per hour. But, speed and precarious balance made them unsafe for travel, and the innovation eventually was relegated to entertainment vehicles in circus clown corps.



EVOLUTION OF THE AMERICAN STREET

A VIEW FROM 2070

Photo: iStock

ASHA WEINSTEIN AGRAWAL AND KEVIN FANG

Agrawal is Education Director, Mineta Transportation Institute, San Jose State University, California, and Fang is Assistant Professor, Sonoma State University, Rohnert Park, California.

Above: The innovative, livable street systems of the future are the topic of an imagined panel discussion at the 150th TRB Annual Meeting.

During a hypothetical TRB Annual Meeting, the speakers reflect on how streets have evolved from 1920 to 2070.

In the Greater Washington Aerotropolis Convention Center, Salon Z, four speakers sit in armchairs at the front of the room.

Lu Ban

"Welcome to Session 1701-D. I am Lu Ban, Executive Director of Streets.4.Everyone. Streets are shining jewels that adorn and nourish our communities and are critical infrastructure fundamental to our economy and way of life. Today, we discuss how streets have evolved over time into today's increasingly popular Efficiency Street and Freedom Streets typologies.

"As this hologram shows . . . oops, the holo-projector isn't working. Let me fix it—there. As you can see, Efficiency Streets have perfected vehicle movement, with separated lanes for rapid travel, medium speeds, and loading. By contrast, Freedom Streets accommodate diverse travel modes and activities. Both typologies have embraced engineering and social advances made over the past 50 years to improve streets, but with very different goals.

"Today, three experts join us. Dr. Morgan Garrett is Transportation History Curator at the Smithsonian's National Museum of American History. Engineer Roberta Moses received the American Association of State Highway and Transportation Officials' Lifetime Achievement Award for her seminal contributions to the Efficiency Street typology. And Professor Enaj Jacobs is a path-breaking scholar who founded the discipline of Street Sociology and Design Sciences and publishes prolifically on Freedom Streets.

"Before we walk through the history of streets from 1920 to 2070, let's discuss the characteristics of Freedom and Efficiency Streets. Roberta and Enaj, could you describe each typology in terms of three essential features: how people move, what activities occur in the street, and how the streets are laid out?"

Photo: Seattle Municipal Archives

The multimodal, free-for-all nature of pre-1920s roadways is evident in this 1911 photograph of Third and Union Streets in Seattle, Washington.

Roberta Moses

"Efficiency Streets are all about speed and safety. How people move on these streets is simple: there are just four sizes of motor vehicles. Any other travel devices or nontravel activities are prohibited. As for layout, travel is strictly organized into three lane types in each direction: one or more 10-foot lightning lanes, an 8-foot loading lane, and a 10-foot transition lane between the two.

"Oh, yes—both sides of the street are bordered by a 5-foot walk zone, just in case someone needs to move only part of a block. But, it's rare to see pedestrians on Efficiency Streets, since vehicular movement is so convenient and cheap."

Enaj Jacobs

"Freedom Streets are all about—well, freedom. Freedom to move in many different ways and freedom to engage in more than just travel. Freedom Streets accommodate a veritable Noah's Ark of travel modes, from motor vehicles of all sizes to electric and human-powered, person-sized micromobility devices to pedestrians. Freedom Streets also host activities like socializing, commerce, and play.

"In terms of layout, Freedom Streets have three zones. A modest travel zone—20 feet wide—accommodates vehicle movement. Walking and nontravel activities take place in a more spacious life space, which is 30 feet wide. Finally, a single, narrow street border—5 feet wide—provides additional pedestrian space."

Lu Ban

"Let's talk about how we got here. Morgan, take us back to 1920, TRB's birth year. What were streets like 150 years ago?"

Morgan Garrett

"The 1920s were a defining period. Before that, streets had been a free-for-all, with pedestrians, horse-drawn vehicles, street vendors, bicyclists, and streetcars all mingling together. In the 1920s, though, communities responded to mass adoption of motorized automobiles and trucks by embarking on a century of designing streets to prioritize motor vehicles. Other modes lingered on, but more and more, travel occurred in motor vehicles.

"Motorization ushered in a new vision of what activities should occur in streets. Streets came to be defined as places primarily for vehicles, not the mix of activities seen earlier. Once the primary objective became to accommodate vehicle movement, street layouts changed to facilitate large volumes of vehicles moving at high speeds.

"Notably, streets became formally divided into large vehicle zones and small people zones. Most space was allocated to moving and parked motor vehicles. Walking, cycling, and nontravel activities gradually were relegated to comparatively narrow sidewalks on busy streets—or to dodging fast traffic in streets without sidewalks. These trends intensified over the next century."

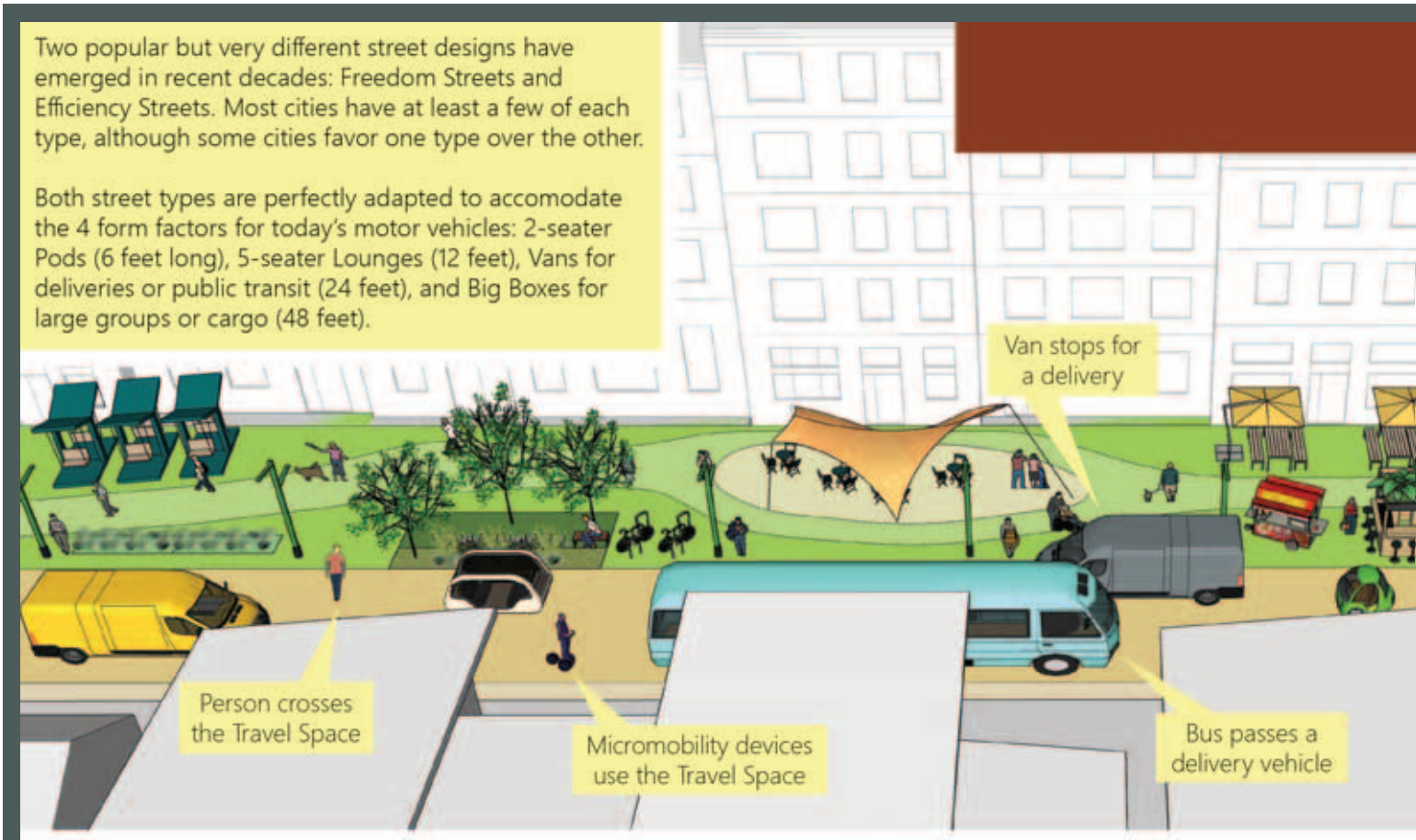
(Continued on page 16)

Photo: Pxfuel

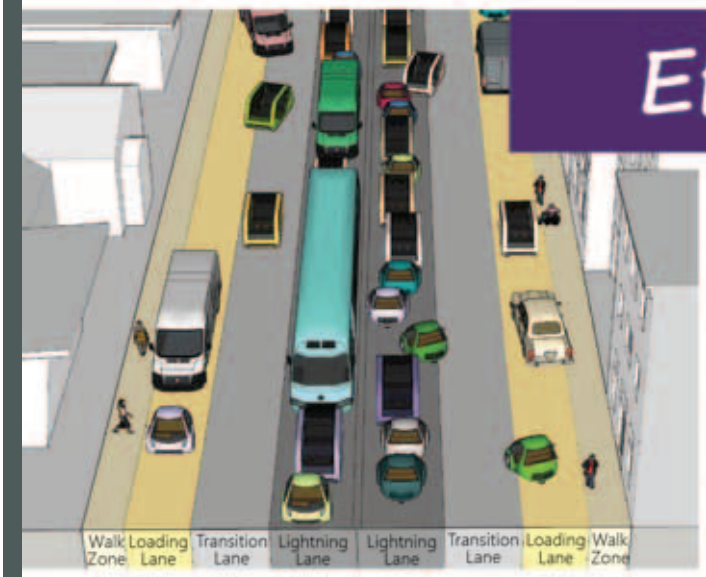
A street in Bozeman, Montana, is optimized for car throughput.

Two popular but very different street designs have emerged in recent decades: Freedom Streets and Efficiency Streets. Most cities have at least a few of each type, although some cities favor one type over the other.

Both street types are perfectly adapted to accomodate the 4 form factors for today's motor vehicles: 2-seater Pods (6 feet long), 5-seater Lounges (12 feet), Vans for deliveries or public transit (24 feet), and Big Boxes for large groups or cargo (48 feet).



Efficiency Street

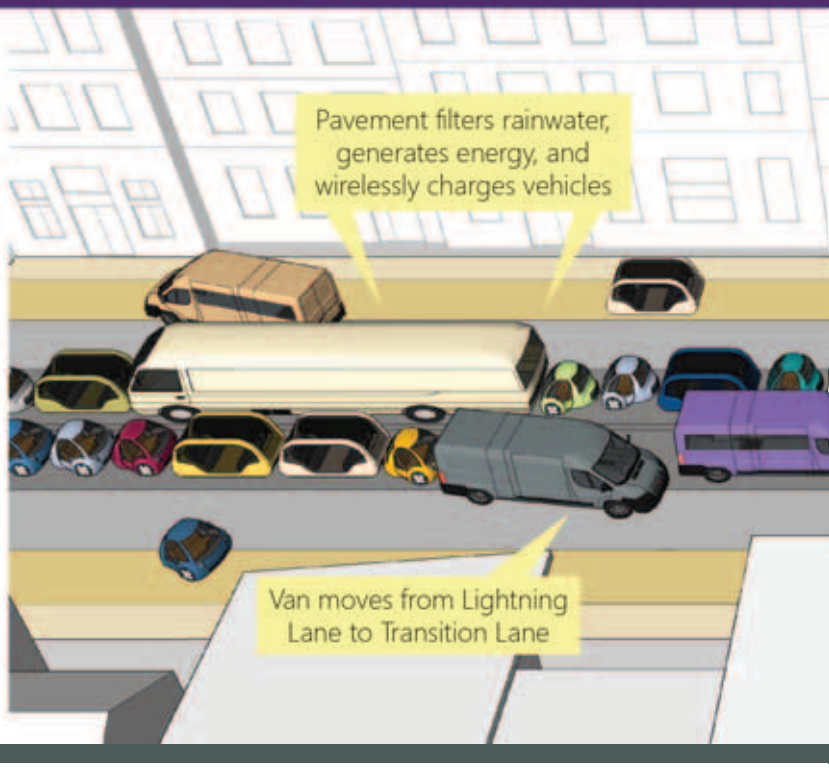


Lightning Lanes The center lanes accommodate high-speed vehicles traveling in close formation (10')

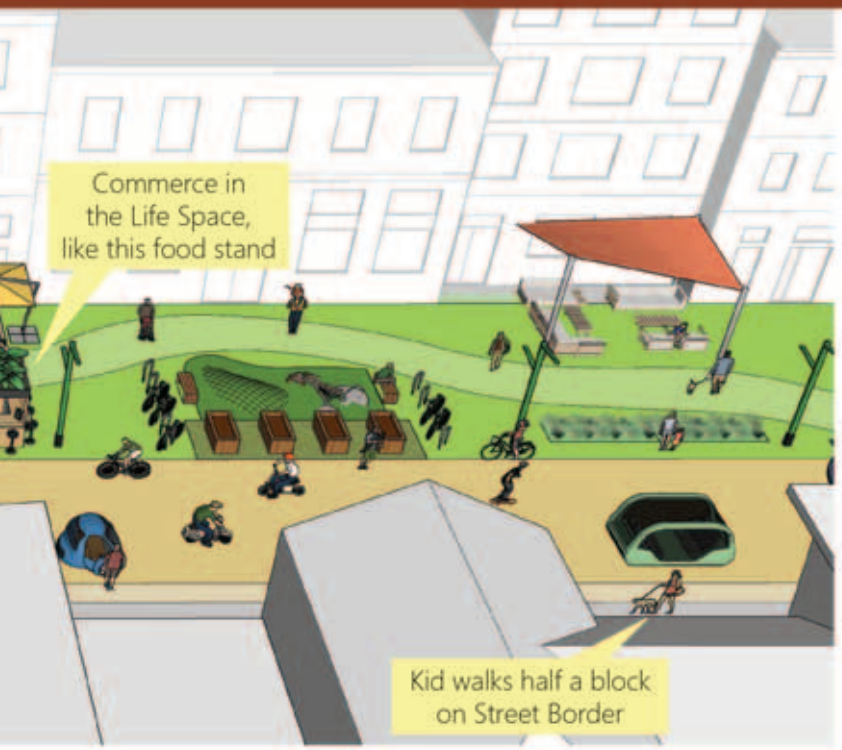
Transition Lanes The middle lanes accomodate vehicles transitioning to and from the Loading Lanes (10')

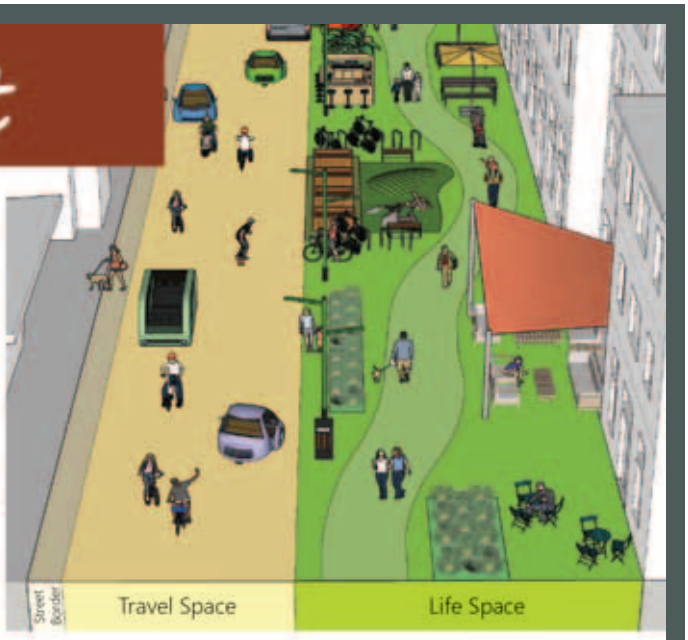
Loading Lanes The exterior lanes are for loading and unloading passengers and freight (8')

Walk Zones Space for the occasional pedestrian (3')



Freedom Street





Life Space Primary conduit for pedestrians and a place for play, socialization, and light commerce (30')

Travel Space All types of vehicles and travel devices mix freely. Pedestrians may cross anywhere. No rules for travelers other than to share space safely (20')

Street Border A pathway for pedestrians (3')

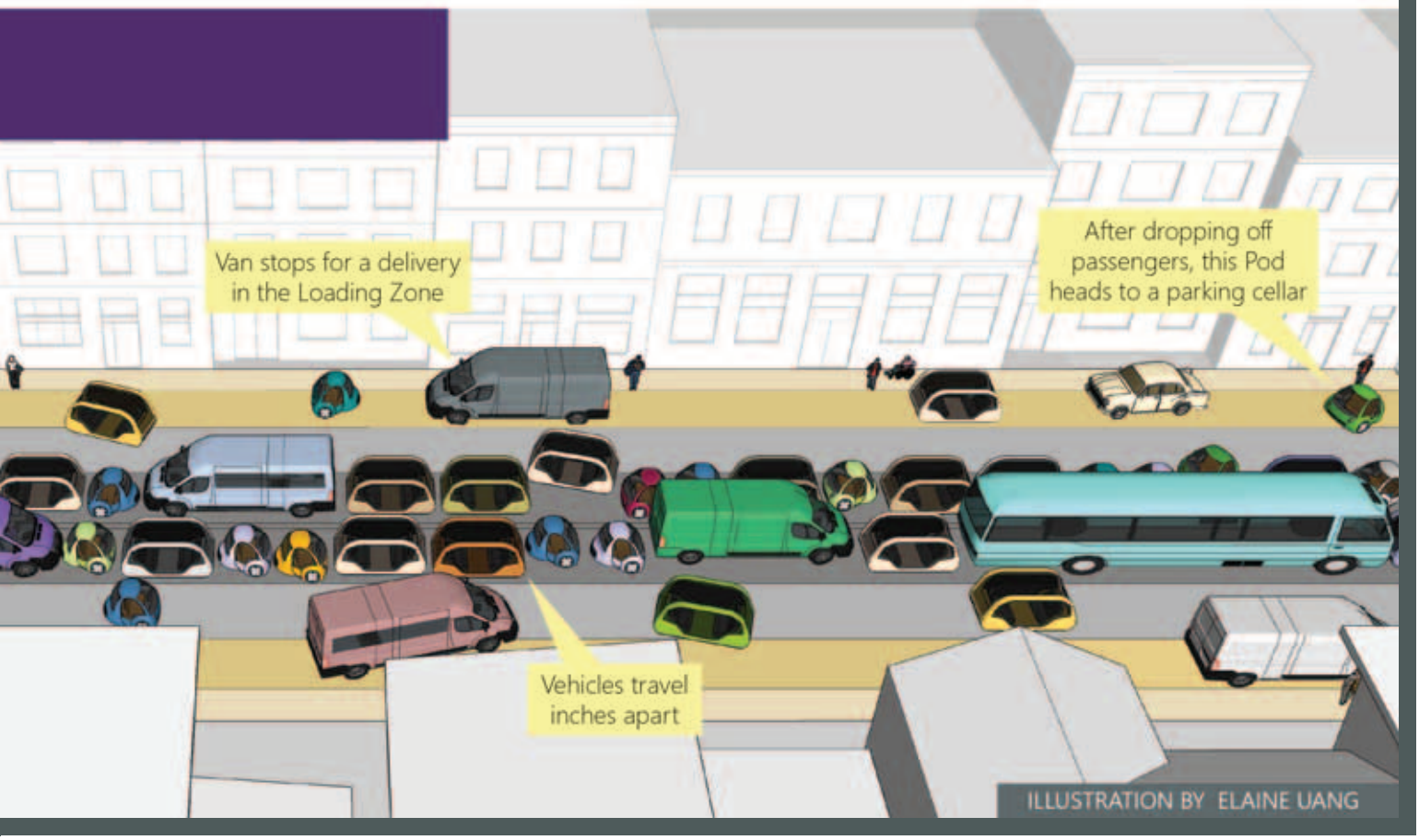


ILLUSTRATION BY ELAINE UANG

(Continued from page 13)

Photo: UNC Libraries Commons

By the 1930s—as shown in this image of a street in Salisbury, North Carolina—roadways no longer hosted a variety of modes.

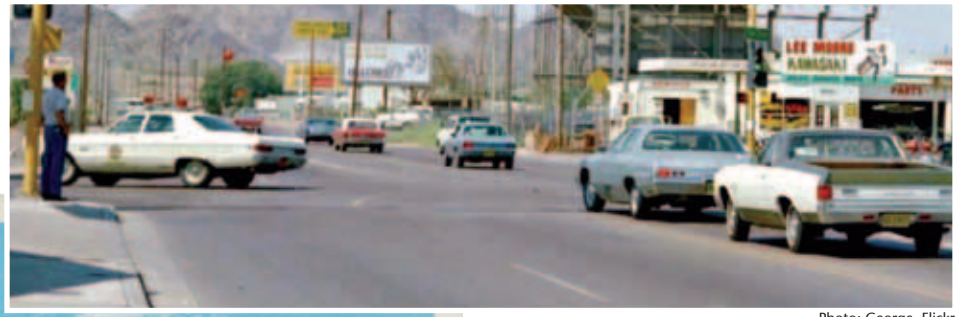


Photo: George, Flickr

Automobiles dominate the roadway—with very little room for pedestrians—in the 1970s at 7th Street and Cave Creek Road, Phoenix, Arizona.

Lu Ban

"Were the 2020s the next major pivot point?"

Morgan Garrett

"Yes. Breakthrough technologies—plus the need to manage public health crises—led to major changes that laid the foundation for today's Freedom and Efficiency Streets."

Enaj Jacobs

"Let's start with the evolution of the Freedom Street concept. The core principle is that streets function as both travel spaces and community 'living rooms,' or locations for civic, social, recreational, and even some commercial activities. But, how did we come back to this pre-1920 vision of streets?

"First, the emergence of micromobility in 2018 and ensuing Scooter Wars reminded America that travel doesn't require large, motorized vehicles. Next, the 2020 global pandemic sparked an enduring community desire to do more in streets than drive. With recreational spaces temporarily closed to flatten the infection curve, revolutionary transportation planners like Hannah Monderman repurposed streets overnight, limiting vehicle travel on key streets so people could use them for multiple functions—movement, of course, but also exercise, play, and even weddings, as this hologram shows.

"Since the pandemic, many communities have ever more strongly demanded that we move backwards 100 years, so to speak, to the pre-1920 vision of what activities streets should accommodate."

Morgan Garrett

"The 2030s brought another major change in what people thought streets were for—a new vision of streets as places for environmental services. Earlier, streets were major sources of air, noise, and water pollution; carbon emissions; and stormwater flooding. Today, we see streets as places for environmental healing, thanks to the innovations of Zoomer-generation engineers. Transformative technologies included pavements that store and filter rainwater, generate electricity, and wirelessly charge moving electric vehicles."

Roberta Moses

"To me, the most exciting advance in the 2030s was that operations researchers finally optimized vehicles for efficient

Photo: iStock

The changing use of streets—from solely travel to dining, gatherings, and even weddings—was partially hastened by the COVID-19 pandemic.

street space use. Logistics guru Pascal Blaise applied the concept of containerization—developed for cargo shipping 80 years earlier—to passenger transportation. That's why today's streets only permit vehicles 8 feet wide and of standardized lengths: two-seater Pods (6 feet), five-seater Lounges (12 feet), Vans for deliveries or larger groups of people (24 feet), and Big Boxes (48 feet) for public transit or cargo."

Enaj Jacobs

"Yet another turning point in the 2030s was that more and more Americans realized they could escape from the crushing economic burden of vehicle ownership by transitioning to subscription vehicle sharing services. Imagine, families routinely used to spend one-third of their income on vehicles!

"The shift from owning vehicles to purchasing mobility by the trip also meant the end of solo drivers lumbering to coffee shops in grossly oversized vehicles. Today, we pick the right-sized vehicle for every trip, better utilizing road space. Traveling alone? Take a space-efficient Pod. With the kids? Pick a Lounge like the *Diplomat*, that exciting luxury import from India."

Roberta Moses

"Inspired by air traffic control systems, the 2040s also saw the replacement of so-called human 'drivers' with The Brain, a centralized artificial intelligence, or AI, system that efficiently directs every single Pod, Lounge, Van, and Big Box."

Lu Ban

"It's hard to imagine that motorized vehicles were once controlled by unskilled and irrational humans. The Brain guides vehicles safely through multimodal Freedom Streets, and they can travel mere inches apart in lightning lanes on Efficiency Streets."

Enaj Jacobs

"Another benefit of centralized AI control was eliminating the need to dedicate street space for vehicle storage. The Brain moves empty vehicles directly to their next job or to storage cellars. And with no need for parking space, communities started to embrace allocating former road space for the Freedom Street life spaces."

Photo: Metropolitan Area Planning Council, Flickr

Automated and connected vehicles in standard, function-based sizes could improve traffic flow and open streets to nonvehicle uses.

Roberta Moses

"The end of street parking was a game-changer for Efficiency Streets, too, providing space for the dedicated loading lanes. Just think: when services like InstaCar and RoboDash started, their vehicles often stopped in the middle of travel lanes, blocking traffic!"

Lu Ban

"Wasn't there a technical term for this?"

Roberta Moses

"Yes, I believe it was called 'double parking.'" Moses laughs incredulously along with the audience.

Enaj Jacobs

"By 2050, everything was in place for the Efficiency and Freedom Streets we see today. Freedom Streets function as amazing community assets; Efficiency Streets move large volumes of vehicles safely and rapidly. But, since then, we've had two decades of disagreement over policy issues. For example, how many of each street type does a community need? There are profound social justice implications in choices about which neighborhoods get each typology.

"Also, problems arise when a neighborhood's land-use patterns are incompatible with its desired street type. Finally, there are questions about street management practices and costs."

Morgan Garrett

"These vexing policy issues are the perennial ones that we have faced for centuries, even as travel technologies have advanced. Indeed, I predict we will still be debating them for many more TRB Annual Meetings to come."

Lu Ban

"Let's thank our speakers for this fascinating discussion of history as a tool to help us understand the present—and plan for the future."

The speakers say goodbye and audience members direct their hoverchairs to their next session.

The authors greatly benefited from insightful comments from Sandra Rosenbloom, Sarah Jo Peterson, Martin Wachs, Sandra Larson, and several anonymous reviewers.

Transportation in a Changing Climate

Innovating to Create Resilient, Low-Carbon Systems

Photo: J. Daniel Escareño, Flickr

VICKI ARROYO AND ANNIE BENNETT

Arroyo is Executive Director, Georgetown Climate Center, and Professor from Practice, Georgetown University Law Center, and Bennett is Senior Associate, Georgetown Climate Center, Washington, D.C.

The climate is changing rapidly, bringing new temperature highs and weather extremes and affecting every individual, community, and sector of society—including transportation. Although, at times, climate change may feel like an insurmountable challenge, humanity is resilient and innovative. Transportation ultimately is about people: connecting people to places, to goods and services, and to each other. Because of its central role in the functioning of society, the transportation system—including its infrastructure, networks, and workforce—is an essential part of addressing and responding to climate change.

This article discusses challenges and opportunities for building resilient and low-carbon transportation solutions in the United States.

The Challenge of Climate Change

Each year brings more changes and extremes in storms, floods, wildfires, and other climate-related impacts. January through May 2020 brought heavy rainfall and flooding to much of the United States, leading to road damage and closures, a

Photo: John McQuaid, Flickr

U.S. Coast Guard and volunteer boats bring Hurricane Katrina evacuees to dry land in New Orleans, Louisiana, in 2005. In the years since the devastating storm, climate change has only made hurricanes more frequent.

Above: All lanes along this stretch of SH-288 in Houston, Texas, flooded during Hurricane Harvey in 2017. Damage from stronger and more unpredictable hurricanes is among the many effects of climate change on transportation infrastructure.

Photo: Infrogmation of New Orleans

The New Orleans City-Assisted Evacuation Program set up designated hurricane or disaster evacuation pickup spots, such as this one on Read Road.

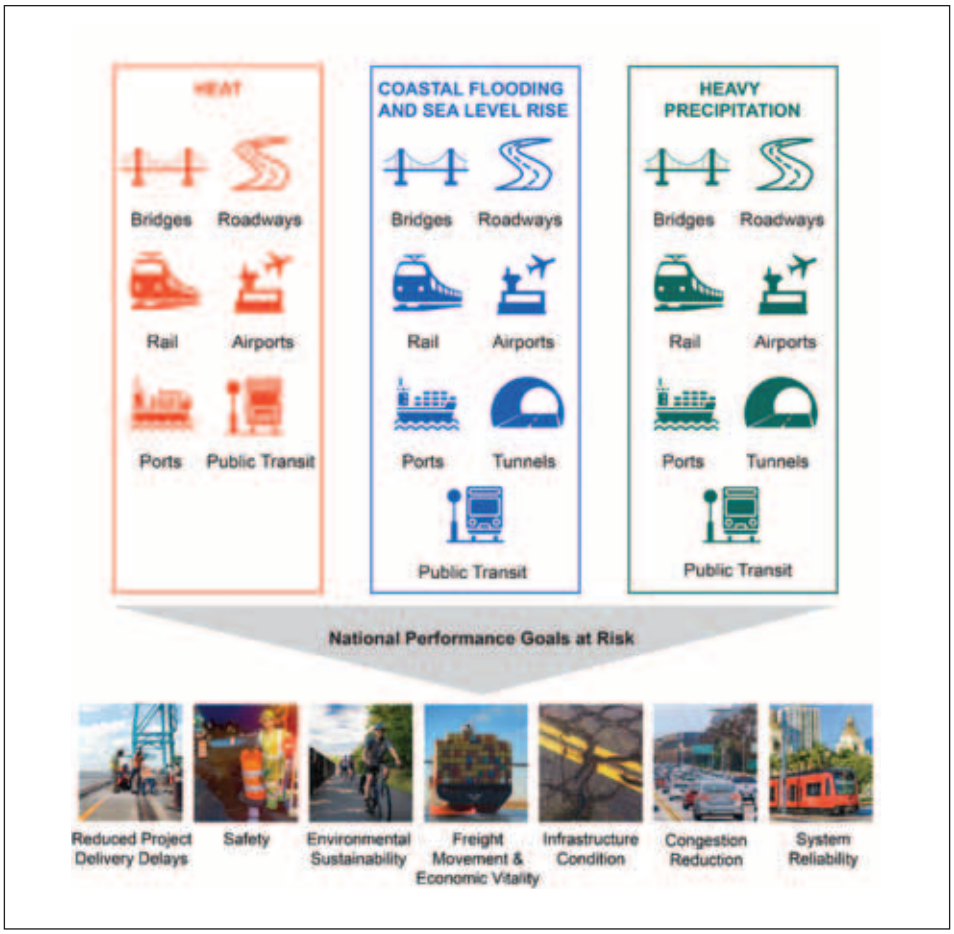


FIGURE 1 Climate change transportation vulnerabilities. (Source: Fourth National Climate Assessment, 2018.)

train derailment, and other transportation system impacts (*1*). Temperature averages are shifting as well: globally, January 2020 was the warmest January ever recorded, and July 2019 was the hottest *month* ever recorded (*2*–*3*). The combined effects of aging infrastructure, system complexity, and cross-sector interdependencies make it all the more important to begin planning for and addressing climate-related risks.

The 2018 National Climate Assessment found that, in addition to the physical risks to infrastructure from increasing temperatures and extremes, climate change will cause or exacerbate transportation disruptions, resulting in societal and economic impacts (*4*; Figure 1). These impacts are especially pronounced for individuals at higher risk because of mobility limitations, preexisting health conditions, age, income, and other factors.

These varied physical, societal, economic, and cross-sectoral risks pose significant challenges for making decisions about the legal standards, design, construction, and operation and maintenance of transportation systems. Although work to understand system vulnerabilities and risks is under way at TRB and throughout the transportation field, there are constraints in applying new information in constructing and operating transportation systems.

For example, climate projections often are not translated into actionable terms for infrastructure design; additionally, agencies may struggle to justify higher upfront adaptation costs because of practical or political realities. Policy makers, researchers, engineers, communities, and other stakeholders must work together to build more resilient, low-carbon transportation solutions that foster a more sustainable, equitable, and connected society.

Building Climate-Smart Systems

The resilience and security of transportation infrastructure, networks, systems, and the workforce are of increasing concern in the context of a changing climate. Physical assets are at risk from extreme heat; flooding from precipitation, sea-level rise, and storm events; wildfires; landslides; and more. Weather extremes, rising seas, and other impacts pose challenges for system performance and management, affecting life-cycle costs of maintaining and operating infrastructure.

Risks to the transportation workforce also are of growing concern (e.g., increasing exposure to extreme heat and other dangerous outdoor conditions), highlighting just one of the many safety and public health considerations relating to climate change (*5*). Interdependencies between transportation and energy, telecommunications, healthcare, and other critical sectors bring risks of cascading failures.

Transportation resilience is a rapidly growing field. Research, planning, design, and policy have advanced significantly since

the 2008 release of *TRB Special Report 290: Potential Impacts of Climate Change on U.S. Transportation*. Some of this progress has occurred in response to federal support and incentives, such as funding for pilot projects and tools and technical assistance for vulnerability assessment and planning, or because of federal guidelines and requirements, such as the integration of resilience into long-range planning.[1] Transportation agencies work to understand vulnerabilities at the network, corridor, and asset levels and to improve resilience through changes in programming, design, and operations and maintenance practices.[2]

Other progress has been made as a result of multisectoral or governmentwide approaches, including climate change task forces, statewide adaptation plans, and laws and policies that require the consideration of climate change in decision making regarding public investments.[3] These are important steps toward incorporating climate change considerations within decision making, which is needed to foster more holistic approaches to building resilience. Still, more innovation is needed to bridge interdisciplinary gaps, center equity considerations, and consider broader landscape-scale challenges (e.g., encroaching seas, wildfire zones, and ecosystem migration) in transportation decision making.

Reducing Greenhouse Gas Emissions

Transportation also must be part of any strategy to reduce the emissions that are fueling climate change. In 2017, the transportation sector surpassed the electricity sector as the single largest source of greenhouse gas (GHG) emissions (*6*) (Figure 2). A GHG reduction strategy in the transportation sector is key to action on energy and sustainability.

To transition to a more sustainable future, policy makers at all levels must adopt policies and solutions that facilitate a rapid shift to low- and zero-emission travel. Widespread public and private investments in electric vehicle charging stations are needed, as well as incentives to develop transformational technologies in areas such as battery storage. Such efforts should be paired with policies designed to affect traveler behavior and ultimately reduce overall vehicle miles traveled, including through greater investments in transit and alternatives to single occupancy vehicles. Emissions from freight and other modes—such as aviation and marine travel—should also be addressed, including through electrification, efficiency requirements, and the use of zero- and low-carbon liquid fuels.

Electric vehicles already provide significant emissions reductions relative to petroleum-fueled vehicles—even when accounting for electricity production—and electric vehicles will become even lower-emitting over time as the power sector continues to decarbonize. State, regional, federal, and international initiatives are designed to facilitate the transition to transportation electrification. These include California's Zero-Emission Vehicles (ZEV) sales mandate for auto manufacturers; incentives for the purchase of electric vehicles (EVs); the 10-state ZEV Task Force and the international ZEV Alliance; federal policy designating and funding EV corridors; regional corridor planning [such as through the Transportation and Climate Initiative of the Northeast and Mid-Atlantic States (TCI),

(Continued on page 22)

Photo: Waltarrrrr, Flickr

A haze—indicating poor air quality—hovers over Los Angeles, California. The health impacts of air pollution include increased risk of asthma, cardiovascular disease, and premature death.

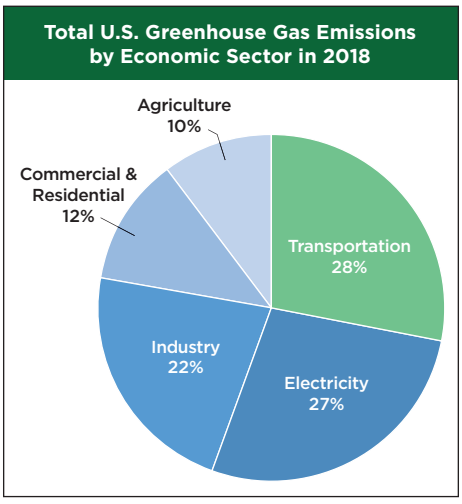


FIGURE 2 Transportation accounts for more than a quarter of U.S. GHG emissions. (Source: U.S. Environmental Protection Agency.)

[1] See, for example, a map compiled by the Federal Highway Administration of resilience pilot projects: https://www.fhwa.dot.gov/environment/sustainability/resilience/pilots/.

[2] For examples of how transportation agencies are integrating climate change considerations into assessments, planning, design, construction, and operations and maintenance, see Transportation Sector Case Studies, Adaptation Clearinghouse, Georgetown Climate Center: https://www.adaptationclearinghouse.org/sectors/transportation/case-studies-a.html.

[3] For an overview of U.S. state-by-state adaptation efforts across multiple sectors, see State and Local Adaptation Plans, Georgetown Climate Center: https://www.georgetownclimate.org/adaptation/plans.html.

Working Toward a Sustainable Future

TRB Committees Address Climate Change

Over the years, the Transportation Research Board (TRB) has advanced research on climate change resiliency and mitigation via its standing committees, task forces, and panels. Even with the recent restructuring of committees in TRB's Technical Activities Division, many committees will continue to address climate change through activities such as paper reviews, session and workshop planning for the TRB Annual Meeting, other conferences, and webinars.

The Transportation Energy and Alternative Transportation Fuels and Technologies committees will continue to pursue research that assesses options for reducing energy demand, increasing efficiency, advancing alternative fuels and technologies, and moving to lower-carbon and cleaner transportation systems. To better harmonize air quality and climate research and planning efforts, greenhouse gas mitigation is now also included in the scope of the Air Quality and Greenhouse Gas Mitigation Committee. These three committees now reside in the Transportation and Sustainability Section. This structure places climate change and decarbonization in the broader context of sustainability, economic development, and resource conservation.

Research on the critical issues of adaptation, resilience, and security is addressed in the Transportation Systems Resilience Section. Of particular note is the creation of a new committee: the Extreme Weather and Climate Change Adaptation Committee, which resides alongside other groups addressing issues of infrastructure preparedness and disaster response.

Photo: Risdon Photography

Rebecca Dodder (*at right*) guides a meeting of the Transportation Energy Committee at the 2020 TRB Annual Meeting in January.

Climate change cuts across all modes and aspects of transportation, meaning that other committees—whether they are related to public transit, roadways, aviation, marine, or rail—will also have a role. Few areas can be entirely disconnected from climate change, as it is a multimodal, systemwide challenge. With the support of their many volunteers, members, and friends, TRB committees will serve a key role by pursuing and leading research and innovation to create resilient and low-carbon transportation systems.

For more information on TRB's standing committees, including those addressing environment and energy, visit www.trb.org/AboutTRB/StandingCommitteesMT.aspx.

Photo: Oregon DOT

As part of the West Coast Electric Highway, an EV corridor stretching from Canada to Mexico, Oregon Department of Transportation offers charging stations for EV drivers.

(Continued from page 20)

the West Coast Electric Highway, and the Regional Electric Vehicle Plan for the West]; and in-state efforts to increase EV charging infrastructure through direct investments, local development requirements, and more. Additional and expanded policy action is needed to meet science-based decarbonization targets, however.

New approaches in funding and investment in innovative strategies include multistate coalitions like TCI, which is developing regional market-based approaches to reduce carbon and other air pollution through investment in low-carbon transportation alternatives (*7*). Some states are exploring mileage-based fee options, which would fund transportation investments while offering incentives for individuals to reduce vehicle travel and opt for transit, active transportation, or other alternatives. Many cities are exploring congestion pricing options to reduce traffic, improve air quality, generate revenue, and influence travel behavior.

In addition to state and local policies, more-stringent federal fuel economy standards and greenhouse gas standards for cars and trucks are critical to reducing transportation-sector emissions. Federal vehicle standards are cost-effective and save trillions of dollars for drivers while reducing emissions. Leadership from federal and state governments could help provide stronger policy drivers and incentives for innovation. Renewed U.S. participation and leadership in the Paris Agreement and future international efforts to combat climate change would generate additional accountability and motivation for climate action in the transportation sector, in the United States and beyond.

Innovating for Resilient and Low-Carbon Transportation

Climate change is a challenge that affects all people and aspects of society. Adequate solutions will require international collaboration, public engagement, private innovation, and a whole-of-government approach.

As a sector that is critical to economies and livelihoods, transportation is an important piece of this puzzle; our systems must promote a more sustainable future and be resilient to the changes to come. We need policies that incorporate climate change considerations in decision making and practices that foster a culture promoting resilience and sustainability within government and more broadly. We also need research to advance public and private solutions that achieve multiple benefits for the environment, the economy, health, equity, and mobility.

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THE FUTURE OF ROADWAY SAFETY

Photo: Pixabay

ALEXANDER EPSTEIN AND DANIEL V. MCGEHEE

Epstein is Former Director, Transportation Safety, National Safety Council, Los Angeles, California, and McGehee is Director, National Advanced Driving Simulator, and Associate Professor, University of Iowa, Iowa City.

Above: In 2070, as artificial intelligence–controlled vehicles share roadway networks with human drivers, researchers must meet the challenge of making the roads safe for all concerned.

From the Year 2070: My car will die for me once again, as it did decades ago.

Looking back from our vantage point in 2070, certain big events shaped roadway safety in the United States. Here is a summary:

By 2040, fully automated driving systems (ADS) were deployed in increasing numbers but in very limited operational design domains (ODDs). In the increasingly rare crash scenario involving an ADS, it became apparent that we could no longer rely on prior safety assumptions that vehicles would crumple to maximize occupant protection. Instead, artificial intelligence (AI)–controlled evasive actions in preventing crashes tended to minimize physical damage to the vehicle. Why? Sensors evolved and expanded awareness to onboard AI controllers, which acted to preserve the vehicle as opposed to the passenger. It turned out that there was an unintended software bias. Most early AI software was developed for fleets and ride-hailing companies and inadvertently optimized for vehicle, rather than passenger, survivability. This unduly influenced the entire roadway ecosystem. Humans eventually adjusted the imbedded software systems and AI controllers to optimize passenger and roadway user safety.

Well into 2070, individual vehicle ownership still persists as fleet owners bump into the truth that 150 years of aspirational automotive marketing cannot be easily undone. At first, continued vehicle ownership was explained away as a generational phenomenon. Then, sociologists and marketers found large numbers of people preferred to drive their own vehicle because it is convenient and configured according to each owner's preferences and with each owner's personal belongings on board. In short, the vehicle as appliance worked best in mass transit or commodity delivery.

In 2070, a mixed fleet of automated and human driver–required vehicles coexist. All vehicles must conform to an appropriate level of vehicle-to-vehicle and vehicle-to-infrastructure communication and must strictly follow traffic laws to optimize

Photo: Pixabay

By 2040, when AI software showed bias toward protecting the vehicle over the passenger during a crash, humans interceded and adjusted systems to give themselves more control over personal safety.

safety and flow. Figure 1 describes the levels of driving automation found in the current fleet mix.

Levels 4 and 5 vehicles, whether personal or commercial, are still primarily deployed to transport humans in limited areas such as airports, retirement homes, college and hospital campuses, and smaller cities or suburbs. In commercial transport, Levels 4 and 5 vehicles either ferry goods on limited-access Interstate highways; are truck trains on trips to and from large terminals adjacent to those highways; are local, slow moving, specially designed buses or delivery vehicles; or are operated by businesses moving or extracting bulk commodities. The few Level 5 cars owned individually are treated as exotic cars. In urban areas, vehicles classified as SAE Level 0 and Level 1 long ago were relegated to specific roadways on Sundays only, giving new meaning to the term "Sunday driver."

The Road to Zero Coalition produced a report in 2018 that suggested roadway safety should focus on three areas (*1*). This framework proved prophetic. We reached zero fatalities on the road in 2060 by 1) doubling down on what works, 2) encouraging automation, and 3) improving safety culture and safe systems. However, injuries from crashes—while less numerous and severe than when that report was written—are still a major problem for the United States. As the auto industry slowly recovered from the COVID-19 crisis in the early 2020s, advanced driver assistance systems quickly gained market share and further helped reduce the frequency and severity of the crashes.

Double Down on What Works

In 2070, effective, research-based behavioral and infrastructure countermeasures are still emphasized and employed, primarily for the millions of Levels 0, 1, and 2 vehicles still on the road. In addition, vehicles' average age and reliability continues to increase (hitting 16-plus years by 2070). Along the road to more highly automated driving, people learned how to interrupt ADS operation through a variety of means—from spoofing to hacking to interference techniques such as altering street signs to fool AI algorithms or driving recklessly to deliberately cause a crash. These interruptions resulted in short-term and limited chaotic situations, and, as a result, Americans lessened their resistance to automated enforcement and reduced privacy concerns. Automated enforcement then became widespread and included speed cameras, red light cameras, cameras

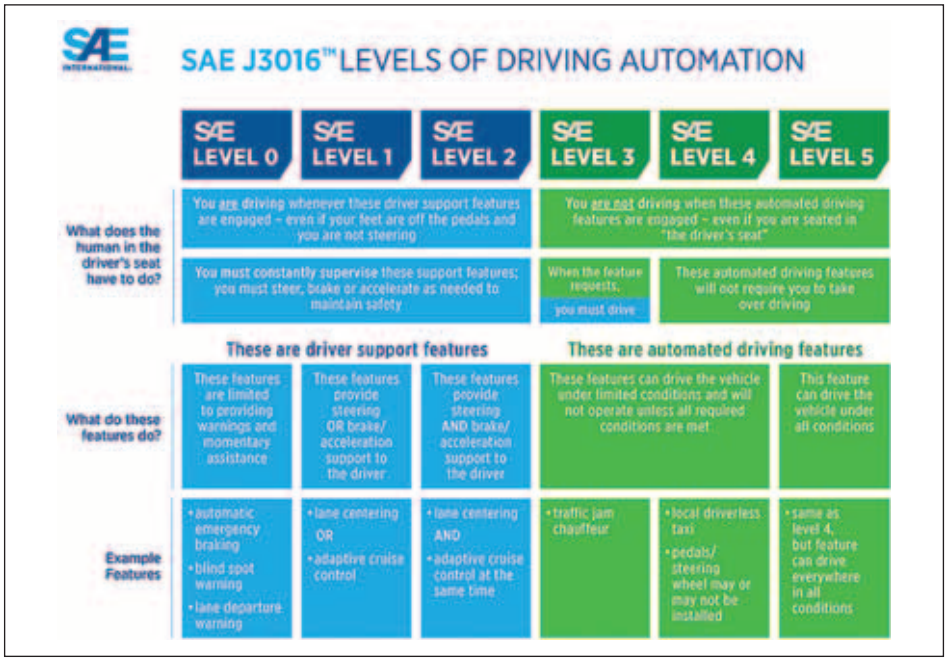

FIGURE 1 The SAE J3016 levels of driving automation look at the actions and features supported by the human driver and the automated driver. (Source: SAE International.)

Smartphones of the future will use apps that track driver behavior, mandatory metrics that are then shared with automakers, local authorities, and insurance companies. In this case, safe driving results in an insurance discount.

in work zones, and new detection means for reckless driving.

Accelerate Advanced Technology

Here, the game changers were physical and digital infrastructure bills passed and signed in the 2020s. A bold initiative, on the scale of the planning and construction of the Eisenhower Interstate Highway System in the 1950s, was implemented and known as Eisenhower 2.0. Along with upgrading physical assets to provide for common recognition necessities of automation, the bills also included significant digital infrastructure to permit vehicle-to-infrastructure and vehicle-to-vehicle communications.

By 2070, vehicle purchase agreements, driver's license renewals, and motor vehicle registrations all include end user licensing agreements that grant permission to record and monitor driving behavior and permit the licensing and resale of the data. Driver state monitoring becomes ubiquitous, and data sharing with local authorities, automakers, and insurance companies is a requirement for use of the roads. If the vehicle has no telematics capabilities, then drivers are rated and identified through apps on their smartphones. Much like an individual's credit status, a driving safety score follows each individual driver or ADS. Individual contextual rules for the operation of the car place hard limits on destination, route, and other variables, depending on whether the driver—human or AI—has permission to operate in various ODDs.

Vehicle manufacturers that developed automated technologies spent little time with SAE Level 3 and went to Level 4 relatively quickly. However, Level 4 ODDs are still limited and greatly nuanced. Promised in-vehicle passenger productivity never reached projected levels, in part because approximately one-third of passengers are affected by virtual reality, motion sickness, or both. They and others prefer having ADS as their driving assistant and back-up, rather than being chauffeured by an AI-powered vehicle. ADS ubiquity is still just over the horizon, as universal environmental coping and ODD issues prove harder to overcome than first imagined.

New educational and driving challenges arise with increasing over-the-air updates in partially self-driving vehicles. Gamification of driver state monitoring is adopted as a way to increase relevant understanding of vehicle software updates

Photo: Sylvain Leprovost, Flickr

One of California's most popular motor-free zones, Third Street Promenade in Santa Monica, started as the open-air Santa Monica Mall in 1965. Twenty-four years later, it entered its second generation as the pedestrian-only Third Street Promenade, heralding a golden age of drawing people to landscaped outdoor spaces lined with bustling cafés, shops, and movie theaters. However, the venue continues to evolve. In 2020, the COVID-19 pandemic delayed plans for a move to a future of programmable space for farmers' markets, food festivals, and book fairs.

and new capabilities, as well as to help human drivers focus attention on the road.

Prioritize Safety

Infrastructure designed to reduce driver error that leads to fatal crashes continues to improve. Cities utilize shared data to maximize safety and mobility, adapt infrastructure, and implement intelligent design of corridors and transit. Decades ago, even as advanced modes of personal transport deployed, equity in safety and access to transportation became issues. Local jurisdictions stepped in to ensure that vulnerable and economically disadvantaged communities had access to the safest mode of transit. In addition, public transit partnered with increasing numbers of first-/last-mile solutions. Infrastructure inducements for automation, such as access to carpool lanes, proved largely untenable, as other classes of roadway users (e.g., electric vehicles and multiple-passenger vehicles) had already clogged the lanes. Tolling for those lanes further exacerbates the equity issue. Pedestrians and bicycles are effectively separated from the roadways to minimize vehicle interactions.

In urban areas, infrastructure owners mandated vehicle-to-everything communication, as vehicles and drivers acting as independent agents did not maximize benefits for the entire system. The solution was to implement transmitters and receivers that worked with multiple bands to accommodate legacy (e.g., DSRC and 5G, 6G, and 7G) and newer technologies.

Cities enacted more green space and motor-free—including electric—zones to encourage health and well-being of inhabitants, but it was not because the vehicle population vanished. It turned out that the vehicle as appliance flourished for first-/last-mile transit and commodity delivery and clogged city streets. Cities simply limited ride-hailing and deliveries as they once limited taxis through a permit or medallion system. Rural areas were the last to feel the effects of automation, as it was not cost-effective for fleet owners to deploy in limited-population areas.

Driving privileges continue to be earned each year by demonstrating safe and successful driving records, both by humans and Level 4 and Level 5 vehicles. Data shared with governmental agencies, manufacturers, law enforcement, insurance companies, and agreed-upon rating systems decide these privileges. Routes driven by those with spotty records, serious infractions, or repeat offenses are limited via automated enforcement of ODDs. Real-time feedback to traffic monitoring and fleet deployment centers occurs. Coaching to human drivers and ADS systems is provided via automated systems at the end of each day, week, or month with direct feedback to DMVs and insurance companies. Those who do not show improvement are limited in their access to the system.

Conclusion

The uniquely American notion of unfettered access to unlimited territory via unrestricted personal mobility will change slowly over time. In exchange for permission to use public infrastructure, human or machine drivers will comply with laws that ensure safety, equitable use, and maximized efficiency. The very technologies that enable machine driving will find multiple uses as elements of control for access, speed, and environmental preservation. Humans and machines will drive the same roads for a long time. The learnings achieved through data sharing, study, experimentation, practice, transparency, and continuous improvement make our roads safe for all users.

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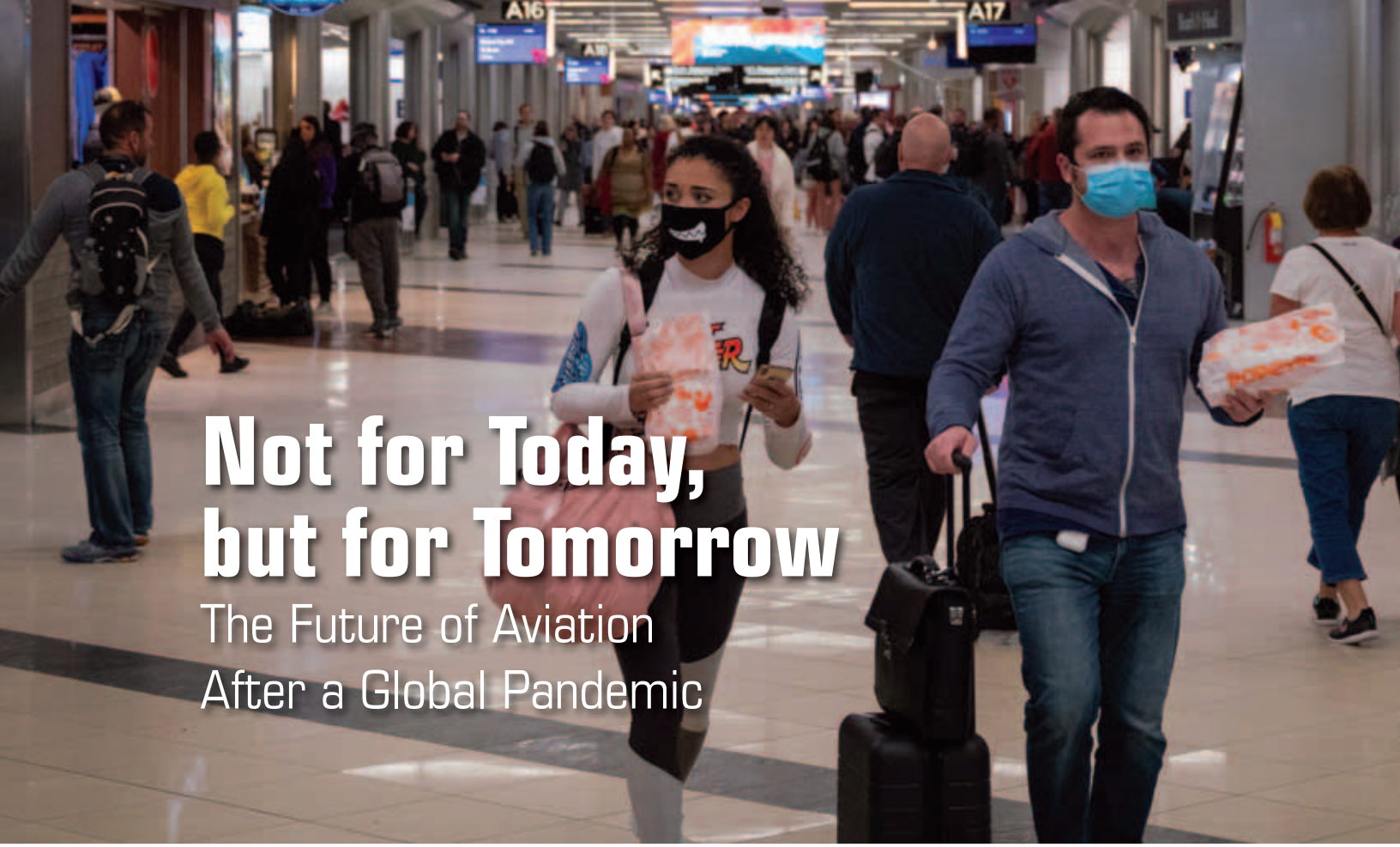

Not for Today, but for Tomorrow

The Future of Aviation After a Global Pandemic

Photo: Chad Davis, Flickr

JOHN FISCHER AND MATTHEW BEAMER

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Above: Masked travelers maneuver through Hartsfield–Jackson Atlanta International Airport in Georgia in early March 2020, just before the COVID-19 pandemic halted a majority of U.S. domestic and international air travel.

Writing about the future of aviation during the COVID-19 global pandemic is a bit like contemplating the next meal after just finishing Thanksgiving dinner: you know you will eat again, but the question is when and how.

The pandemic arrived at a time when almost the entire aviation industry was operating at a peak level of activity and quickly brought some sectors of the industry down to levels of activity not seen in decades. Commercial passenger air travel has been battered in a way that was unseen in past system shocks. At the same time, other segments of the industry—such as air cargo—are seeing growth. The past tells us that the industry will recover, though the length of that recovery is unguessable. Recovery will be painful for some industry participants, but it will provide opportunity for others—especially those using new technologies.

Looking Ahead by Looking Back

Aviation became one of the areas of study at the Transportation Research Board (TRB) in the mid-1970s. Originally allotted only to a couple of committees, aviation had to earn its place in the organization. It did so by continuously increasing its membership, scholarship, and breadth of activities. This was especially the case after the Airport Cooperative Research Program was created in 2005 with dedicated federal funding.

Now nine committees strong, the Aviation Group—including the new, forward-looking New Users of Shared Airspace Committee—is well-placed to serve TRB for the years ahead. Historically, TRB's aviation committees have reacted to events and studied rising issues and forecast trends. Some of the forecasts have been spot on; others have not.

Photo: That Hartford Guy, Flickr

The Mohawk Airlines terminal at Connecticut's Bradley Airport awaits an airplane arrival in the early 1970s. Like many other passenger airlines, particularly following deregulation in 1978, Mohawk was acquired by another company.

AIRLINE OPERATIONS AND ECONOMICS

When aviation became a part of TRB, it was a heavily regulated industry. That changed dramatically in 1978, when much of the domestic economic regulation of the airline industry was eliminated.

Since deregulation, airlines have come and gone and a whole new system of global alliances has been created. In the process, airline travel has become much more available to regular people, rather than only to the wealthy, as it had been previously. The increased accessibility of air travel is demonstrated by data showing that U.S. airline passenger enplanements increased from 274.7 million in 1978 to 976.7 million in 2019.

This increase in traffic has come with its own problems. For example, high levels of industry concentration in just a relatively few major air carriers (and alliance groups) are raising concerns about competition in the future.

AVIATION SAFETY

One of the most remarkable achievements of the past 40 years has been an exceptional improvement in airline safety. No commercial U.S. airliner has crashed since 2009. New and retrofitted aircraft with enhanced technologies have mostly eliminated the once-constant dangers of collision and wind shear.

Recent problems with the new-generation Boeing 737 MAX, however, serve to remind the industry that it cannot be lulled into complacency on the subject. Although passenger airline safety is the window through which the public views the aviation sector, it is important to note that safety has improved for all sectors of the aviation industry, not just airlines.

PHYSICAL INFRASTRUCTURE

Recent decades have seen a pervasive mismatch between where aircraft operators want to go and where sufficient airport and other capacity exists. Attempts to solve this issue—either by regulation or economic means or both—have so far been unsuccessful. This ongoing problem still seeks new solutions.

AIRSPACE SYSTEM CAPACITY AND AIR TRAFFIC CONTROL

In 1981, U.S. air traffic controllers went on strike. All of the striking workers were fired, leaving the system partially crippled for several years as new employees were hired and trained.

Photo: Jeff Stvan, Flickr

The air traffic control tower at Fort Worth Alliance Airport in Texas was built in 1992, with a cone-shaped feature to hide microwave signal relay equipment. First proposed nearly 40 years ago, automated air traffic control is still in development.

Shortly after, the Federal Aviation Administration (FAA) announced it would create a fully automated air traffic control system within 10 years. Four decades later, that promise remains unfulfilled. The FAA's most recent plan, NextGen, remains a work in progress—some components are in use, but many promised improvements are still missing.

ENVIRONMENT

For most of the 20th century, the principal environmental issue with the widespread introduction of the jet engine was noise pollution. Over time, the introduction of new technology in jet engine design and the introduction of airport noise abatement programs reduced noise impacts—but more work was needed.

The 21st century refocused the environmental debate to encompass further noise reduction while seeking reductions in air pollutants affecting local air quality

Flights arriving at San Diego International Airport in California make for busy skies above Bankers Hill and other residential neighborhoods near the airport. Airplane noise is a primary environmental concern of the aviation industry.

around airports and global warming. Changes and improvements continue to be made, but not fast enough in the view of much of the public.

Future Challenges

The aviation sector has proved its resiliency and its unique role as the high-speed, long-distance mode of transportation by bouncing back and even growing after significant events. These include September 11, 2001; other earlier acts of terrorism; the Persian Gulf War; other regional conflicts; and multiple economic shocks, such as the Great Recession of 2008 and, most recently, the severe economic disruption resulting from COVID-19.

NEW USERS AND TRAVELERS

The largest airports are increasingly congested, while the smallest general aviation airports struggle to survive. Airports will face financial challenges such as those currently presented by ride-hailing companies, which have drastically reduced parking revenue. They require airports to rethink how to use and adapt their existing assets; for example, by turning portions of now-underused parking structures into curblike pick-up and drop-off areas.

As demand increases and space does not, airports will increasingly explore technological options to more efficiently use their assets without building more terminal space. Airports will be challenged to find ways to accommodate new entrants, including unmanned aerial vehicles (UAVs), which may require new separate facilities for servicing and enhanced air traffic control measures.

Commercial airports may change in other ways, too. As more people fly, airports—like the airlines before them—likely will need to tailor their services to different groups of passengers. Over the years, airlines increasingly have segmented their customers to better target their offerings to specific travelers. Now, the largest airports, which have the most diverse passenger base, have started to differentiate their products.

In 2017, for example, Los Angeles International Airport opened a new type of passenger lounge called "The Private Suite," providing comfort, quiet, and personal attention to passengers who can afford the thousands of dollars required for an annual membership. Other airports around the world likely will adopt similar offerings. This trend of exclusive spaces and personal attention for those who can afford it and bare-bones services for the most price-sensitive travelers—and gradations in between for everyone else—is likely to continue as airlines (and, increasingly, airports) seek new ways to maximize their revenue.

AUTOMATION

Aviation is a capital-intensive industry, and technological advances could help reduce many of its associated costs. Nonetheless, for commercial airlines, one of the largest costs is human labor. Still, flight attendants, pilots, gate agents, and even analysts could one day be replaced by robots and computers that never tire and do not make mistakes. Air traffic control system employees, too, could largely be replaced by computers that effortlessly manage an increasingly complex airspace.

Other aviation-related technology promises to forever change the industry. UAVs will be used by a diverse array of businesses to monitor infrastructure and events from the air and to deliver cargo. Advanced air mobility improvements could ease urban congestion, and spaceports can offer a way to reach the last frontier. All of these changes will result in more demand for limited airspace, requiring additional efforts to manage its use and ensure equitable access.

Climate Change

The aviation industry accounts for approximately 2% to 3% of total annual carbon dioxide emissions, and the aviation industry will continue to be on the front lines of climate change. Air cargo and passenger activity are both expected to double over the next 20 years and likely will double again in the 20 years after that. More and more, the aviation industry will be singled out for its impacts (such as through flight shaming, or *flygskam*[1]) and will be called upon to mitigate emissions through the use of carbon offsets, the adoption of alternative fuels, and the use of more efficient aircraft.

(Continued on page 31)

[1] The Swedish concept of *flygskam*, which translates as "flight shame," is an anti-flying movement that originated in Sweden in 2018. It encourages people to stop taking flights in order to lower carbon emissions.

New Aviation Group Committee on New Users of Shared Airspace

The Transportation Research Board (TRB) Aviation Group continues to deepen its coverage of air transportation issues, reflecting the research needs of a vibrant and evolving sector. A recent example of the group's responsiveness is its creation of a new committee on emerging users of the National Airspace System.

The New Users of Shared Airspace Committee focuses on emerging and growing applications in aviation, such as commercial space operations, unmanned aircraft systems (UAS), and urban (or advanced) air mobility. In many instances, these new operations will occur in airspace that is already available to and in use by existing operators and users.

Some of the research needs of this new sector include the development of rules and procedures that allow these new operations to occur harmoniously and safely among both themselves and existing airspace users. For example, in the case of UAS, National Aeronautics and Space Administration (NASA) researchers created a UAS Traffic Management (UTM) system. In June 2020, the NASA UTM was awarded the 2020 Government Invention of the Year.

The New Users of Shared Airspace Committee will also be able to present recent research to a growing practitioner community and the many advocacy and professional organizations that support the UAS and commercial space sectors. The committee will examine operations- and safety-related topics that overlap naturally with the scope of established Aviation Group committees.

Photo: Virginia Tech

Zachary Wehr, a pilot and safety officer with the Virginia Tech Mid-Atlantic Aviation Partnership, conducts test drone flights as part of a Federal Aviation Administration UTM pilot program.

The new committee's research also will address topics of interest to other TRB committees: automation, emerging opportunities in urban transportation, and legal and operational coordination challenges across modes. These shared concerns can lead to cross-cutting research projects and applications, facilitating the collaboration across committees and groups envisioned in the recent TRB Technical Activities Division strategic alignment initiative.

The timeliness of the formation of the New Users of Shared Airspace Committee is attested to by the growing numbers of TRB Annual Meeting sessions and other events addressing the committee's topics. In January 2020, these sessions were well-attended and sponsored both

(Continued from page 29)

Even with these measures, airports will face climate-related challenges. Extreme heat will lead to pavement buckling, and low-lying coastal airports will increasingly be at risk from climate change–related sea-level rises. Policy makers will need to decide how much to spend to shelter at-risk airports from the effects of climate change.

Also at question is who should pay for these mitigation measures: the public, through increased fees? Airlines, through increased taxes? Airport operators? Will some airports be abandoned because no one will undertake the Sisyphean task of paying to maintain them in the path of climate change?

Clearly, the future of aviation holds many more questions than answers, especially in uncertain times. The next 40 years promise to be exciting and challenging for airports, airport users, and the people who make the aviation industry work. If history tells us anything, it is that continuing growth in aviation, communications, and other technologies will be needed to create the interconnected world that many anticipate.

Photo: Zach Stern

High surface temperatures and extreme weather events caused by climate change will have a range of effects on airport infrastructure, from heat-buckled pavements to flooding in coastal areas.

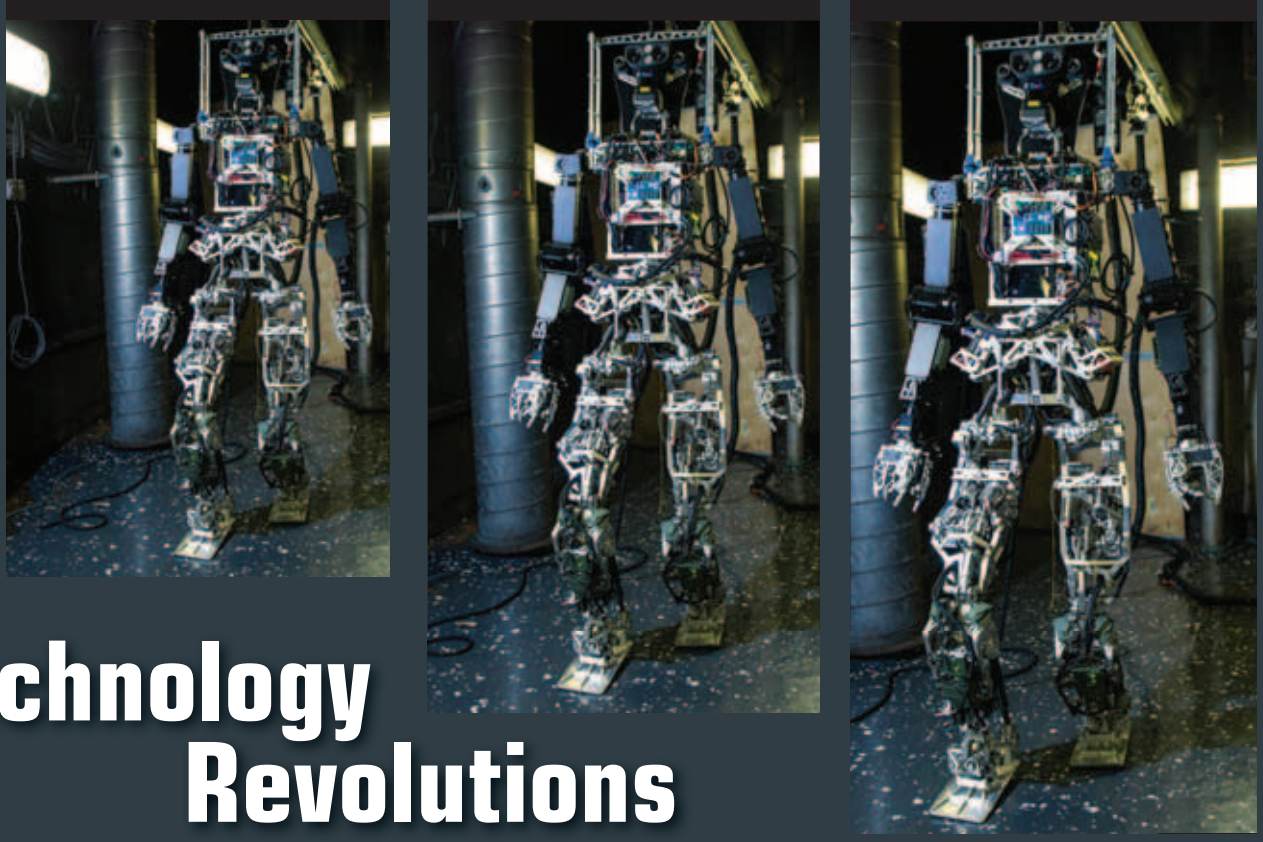
by Aviation Group committees and by committees in other groups and sections, including a very lively all-day workshop on urban air mobility. Importantly, these events were planned and attended by many younger transportation researchers and practitioners, indicating that the new committee will be able to address the concerns of tomorrow's TRB while building on the solid foundations erected over a century of research.

To search past Annual Meeting sessions by topic, visit https://annualmeeting.mytrb.org/OnlineProgramArchive/Browse?ConferenceID=999.

— David Ballard,
Jenkintown, Pennsylvania,
Member, New Users of Shared Airspace Committee

Photo: Risdon Photography

Justin Guan (*far right*), Arup, presents the challenges in planning for urban air mobility at a special workshop during the 2020 TRB Annual Meeting.



Technology Revolutions

Bringing Tomorrow Here Today

Photo: John F. Williams for the U.S. Navy

CHRIS HENDRICKSON AND JOHANNA ZMUD

Hendrickson is Hamerschlag University Professor Emeritus, Carnegie Mellon University, Pittsburgh, Pennsylvania, and Zmud is Senior Research Scientist, Texas A&M Transportation Institute, Texas A&M University System, Austin.

Above: Standing 5 feet 10 inches and weighing 143 pounds, SAFFiR—the Shipboard Autonomous Firefighting Robot—is armed with infrared stereovision sensors and a rotating laser that allows it to see through thick smoke. This futuristic technology for the U.S. Navy stands ready to keep sailors from the dangers of direct exposure to fire.

After a century of activity by the Transportation Research Board and others, transportation is experiencing several technological revolutions driven by research performed over multiple decades:

1. Alternative fuel vehicles, such as battery electric, hybrid, and hydrogen fuel cell vehicles, are available commercially and becoming more common in the vehicle fleet.
2. Automation is common in new vehicles, originally as warning systems but now including functions such as active forward-collision avoidance. Autonomous (driverless) vehicles are being tested and will eventually join the fleet.
3. Nearly ubiquitous communications are available for vehicles, individuals, and infrastructure (*1*).
4. Artificial intelligence (AI) and data analytics are improving transportation design and operations; virtually all aspects of transportation have been affected.

Photo: Pixabay

At the core of technology revolutions, AI will touch on virtually every industry in the future—even car rentals, in which vehicles may be equipped to rent themselves out, eliminating human involvement and resulting in reduced transaction costs.

5. New modes of transportation are appearing, resulting in greater choice and improved system performance for most users.

In this article, we describe likely changes from these technological revolutions for a wide variety of industry sectors that are experiencing near- and longer-term impacts: car rentals, supermarkets, wildfire fighting, and local government transportation.

Transforming the Passenger Car Rental Industry

Car rental companies were among the first fleet-based mobility providers in the early 20th century. Today, the industry is using vehicle connectivity, AI, data analytics, and automation to compete with newer players—such as Uber and Lyft—that use data analytics and mobile apps to meet consumers' personal transportation needs.

In late 2019, Avis Budget Group surpassed 200,000 connected vehicles globally, a significant marker on its journey to fully connect its 600,000-vehicle fleet to improve the customer experience while also streamlining operations and reducing costs (*2*–*4*). It is testing key-as-a-service applications that use the Avis mobile app to lock the car, unlock it, and start the engine, which allow a faster customer transaction.

Looking ahead, rental agencies will use autonomous driving features for rearranging vehicles and delivering vehicles to customers. Enterprise has entered into an agreement with self-driving vehicle startup Voyage to manage its fleet as a foray into its own autonomous operations (*5*).

Looking even farther ahead, decentralized peer-to-peer car rentals will be available for autonomous vehicles (AVs). Using AI, vehicles may be equipped to rent themselves out without human involvement, resulting in vast reductions in the transaction costs of renting a car. This has implications for not only further disrupting the car rental industry but also the future of vehicle ownership.

Photo: Melinda Young Stuart, Flickr

It may look like a cooler on wheels, but Kiwibot has become a regular on the University of California, Berkeley campus. The robot, part of a multimodal system, is one of three kinds in a fleet of 200 that has taken to the sidewalks—guided by camera sensors—and delivered more than 100,000 restaurant meals to hungry students and staff since it launched in 2017.

Transforming the Supermarket Industry

Data analytics, connectivity, automation, new modes, and battery electric vehicles are also transforming grocery inventories, delivery, and shopping. Walmart uses robots to manage stock and clean floors (*6*). Amazon has 200,000-plus robots working inside warehouses (*7*).

The e-grocery market is growing. In 2019, 37% of U.S. consumers bought groceries online, up from 23% in 2018 (*8*). Kroger has partnered with Nuro to pilot e-grocery delivery by autonomous pods from its Scottsdale, Arizona, and Houston, Texas, stores (*9*). The COVID-19 pandemic helped speed this change. New data indicate that 52% of consumers bought groceries online during COVID-19 (*10*).

AVs for delivery are appearing. Starship Technologies deployed its autonomous delivery ice chests on college campuses (*11*). Testing at the University of Pittsburgh was stopped (and later restarted) after one robot vehicle trapped a wheelchair-bound student in the street. The incident underscored the accessibility and safety challenges of delivery robots operating on crowded sidewalks and curbs.

Online ordering can also be improved. Dent Reality uses augmented reality technology, which overlays information and virtual objects on real-world scenes in real time to enhance a shopper's in-store experience, providing up-to-date stock information, highlighting nutritional and allergen information, and enabling in-store navigation (*12*).

But, this assumes that there *are* supermarkets. Supermarket travel will diminish as food retail is decentralized through just-in-time supply chains and AVs—and as AI devices "learn" when (and when not) to order replacement items. Auto ordering, searching for best prices, and comparing brands might be done by chatbots and avatars that can optimize the mode and timing of delivery.

Food supply chains may become shorter as indoor farming offers not only a potential alternative use for the large retail spaces that will become vacant but also convenient access to locally grown food. Shorter supply chains, along with AVs, may make last-mile delivery economical, environmentally viable, and ubiquitous. At the same time, these shorter supply chains may add new curb management challenges.

In the United States, food waste is responsible for roughly the same amount of greenhouse gas emissions as 37 million

Photo: Bureau of Land Management

Drones are making an impact on fighting wildfires by using thermal cameras to guide firefighters to safe exits, a task traditionally left to piloted planes. But, before long, these aerial marvels will put out fires altogether using sound physics: pressure waves from loud noise disrupt the air that surrounds the fire and, ultimately, extinguish the flames.

cars (*13*). For perspective, in the 4th quarter of 2019, some 280 million vehicles were operating on U.S. roads (*14*). Many technologies are being applied to help food last longer. They include apps that connect unsold food from supermarkets with customers, farmers who use drones and sensors to maximize crop yields, and smart food labels that get more and more bumpy as food decays and are more accurate than printed dates (*15*).

Transforming the Wildfire Fighting Industry

From Siberia to the Amazon and from California to Australia, forest fires were unprecedented in 2019 (*16*). Wildfires cause widespread damage, destroying lives, buildings, transportation infrastructure, supply chains, and agriculture.

Drones provide aerial surveillance to make sure there are safe exits for firefighting teams and residents, a role currently filled by piloted aircraft (*17*). Drones equipped with thermal cameras do the job better and more safely.

Forest fires could soon be fought by drones that direct loud noises at the trees below (*15*). Sound is comprised of pressure waves; noise can disrupt the air surrounding a fire, cutting off the oxygen supply. Drones could be especially useful for fighting fires at night when winds die down and fires theoretically become easier to control (*18*).

Not only flying robots but also surface-based ones battle wildfires in extreme conditions that are unsafe for humans (*19*). These robots can be remotely controlled or autonomous.

The fire truck of the future is electric with advanced functionality (*20*). Its chassis can be raised for driving and lowered for service at the scene. Electrical energy provides power for the extinguishing water pump, thus eliminating the need to carry a power generator. The fire truck is equipped with haptic feedback and rearview cameras, making it safer for firefighters while driving and on the scene.

Transforming Local Government

Local governments often provide public transportation service and manage transportation infrastructure. The ongoing technology revolutions will thus affect them in significant ways by prompting new modal considerations, rather than just buses and rail; riskier investments, such as private partnerships and, possibly, regulation of hydrogen stations for fuel cell vehicles; and transformative process changes.

Parking and traffic violation fees are significant sources of revenue for many counties and municipalities. The advent of new modes—such as private helicopters, ride-hailing, e-scooters, and driverless surface and aerial vehicles—not only increases mobility options but also reduces parking revenues substantially. Rather than parking a highly automated vehicle, it can be sent to a distant location and recalled as needed. Also, highly automated vehicles are typically programmed to obey all traffic restrictions, reducing fees for violations. Local governments will need new sources of revenue. Some localities are testing dynamic pricing of curb space, which could expand to airspace used by drones (*21*).

At the same time, there are possibilities for more efficient municipal services. Wi-Fi and 5G may be ubiquitous, enabling smart infrastructure and devices to work together seamlessly. Based on monitored real-time data, Internet-connected infrastructure may monitor public safety and adjust traffic flow, energy usage, street sweeping, and waste collection.

Regulations also require reconsiderations and changes. Building codes requiring a certain number of parking spaces should be reappraised. Land uses will also be rethought as the demand and space required for parking drops.

Photo: Carnegie Mellon University

Ready to go for a spin, Pennsylvania Governor Tom Wolf and other passengers test the features of a fully autonomous vehicle.

Research Needs and Policy Decisions

In addition to the likely changes and possible scenarios described in several industries, as well as the new technologies of transportation stakeholders introduced, a variety of research needs and policy changes are also apparent. Vehicle regulations, infrastructure standards, and vehicle operation policies should be reexamined. Resilience, sustainability, and nonvehicle transportation can be enhanced. Research to best integrate new modes and new technologies is now timely, especially to promote improved equity and performance for all travelers and for a variety of conditions.

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CENTENNIAL QUOTE

"In 2120, the Transportation Research Board's activities will be, in many respects, unrecognizable from today's mostly three-dimensional transportation structure—that is, two spatial dimensions plus a third temporal dimension. One hundred years from now, it will be primarily a four-dimensional structure—or three spatial dimensions plus a fourth temporal dimension. As a consequence, all transportation activities will be structured and carried out within a four-dimensional grid. More importantly, because of the speed required, humans will be assisted by artificially intelligent robots. Additionally, movements and communications will be nearly instantaneous, and accidents or conflicts over the four dimensions should be minimal.

—JAMES M. TIEN

International Secretary, National Academy of Engineering;
Distinguished Professor, Dean Emeritus, and Faculty Ombudsperson,
University of Miami, Coral Gables

Embracing the General Fund Future

Turning Revenue Constraints into Opportunities

Photo: Oregon Department of Transportation

PAUL LEWIS AND MARLA WESTERVELT

Lewis is Vice President, Policy and Finance, Eno Center for Transportation, Washington, D.C., and Westervelt is Head of Community and Partnerships for North America and Asia–Pacific, MobilityData IO, Chicago, Illinois.

Above: The changeable message sign on I-5 near Medford, Oregon, relays a safety message early in the COVID-19 pandemic—one that many drivers seem to be heeding. Funding shortages hastened by the pandemic have roots in longstanding user-based funding mechanisms.

Predicting the future for transportation revenues is always challenging. Doing so in the midst of a global pandemic is even more difficult. Trends from the past few decades, combined with the current situation, can provide an indication of where public policy is headed, however. By codifying a policy of general funds paying for transportation programs, policy makers can cover COVID-19–related shortfalls and align spending toward investments best suited to today's needs.

Historically, the Highway Trust Fund (HTF), supported by user-based excise taxes on gasoline and diesel, has been the gold standard for paying for federal transportation programs. Through contract authority, Congress typically authorizes 5 years of funding, offering multiyear predictability for construction projects. That model has proven to be unsustainable, however, as Congress refuses to increase user-based revenues.

According to data from the Federal Highway Administration, revenues used for highways at all levels of government

Photo: Scott J. Ferrell, Library of Congress

Cars travel I-99 south of Altoona, Pennsylvania, in the late 1990s. Over the past 25 years, the share of federal and state user-based revenues has dropped from more than 60% to less than 40%.

over the past 25 years have trended toward general fund sources. In 1994, federal and state fuel taxes, tolls, and other user-based revenues accounted for more than 60% of all funding nationwide. Fast-forward to 2017, and that share has fallen to less than 40%.

Meanwhile, the use of general funds for highways has more than quadrupled. Public transit, which always relied heavily on general taxation, has increasingly turned to ballot-box measures for local funding. In the 2018 midterm elections, voters approved more than $6.5 billion in new taxes for roadway investment, $9.3 billion for transit investments, and $24 billion for multimodal investments (*1*).

Unexpected Challenges

COVID-19 has left government budgets in tatters. Sudden changes in consumer behavior have dramatically decreased revenues flowing into support expenditures, particularly for transportation programs. Transit agencies, highway departments, and the U.S. Department of Transportation all have seen a sudden and significant fall in fares, tolls, fuel excise taxes, and sales tax revenues. This unanticipated revenue shortfall is causing transportation agencies to question the continued operation and construction of capital projects.

Although the novel coronavirus pandemic exacerbated the funding challenges associated with the HTF, it certainly wasn't the catalyst. With federal gas and diesel excise tax rates fixed since 1993, inflation and improved fuel economy have chipped away steadily at the purchasing power of these funds. Since 2008, Congress has transferred $143 billion in general funds to the HTF. In fiscal year 2019, general funds supported more than 22% of HTF outlays.

As revenue streams have stalled across the board, Congress is contemplating an infrastructure stimulus and reauthorization of the HTF. Long-term sustainability of revenue sources will be critical to ensuring that funds exist for the full term of the policy. But, none of the major proposals circulating on Capitol Hill involve increasing fuel taxes to fund a stimulus or reauthorization, even while fuel tax receipts and truck sales tax revenues plummet.

Photo: Trevor Wrayton, Virginia DOT

Virginia Department of Transportation completed an improvement project on I-81 exit 150 to improve the safety and traffic flow. Often, transportation agencies use HTF revenues for capital projects.

Meanwhile, a broad coalition comprised of engineers, infrastructure builders, public agencies, and the business community has been unified in pressing Congress to increase fuel taxes dedicated to the HTF. In many respects, user-based revenues are an obvious choice for funding transportation investment.

As with utilities, paying at the pump or by the mile theoretically enables users to pay only for what they use, provides planners with an indication of need, and helps to manage demand. Whether these theories are even true is the subject of substantial, decades-long debate. But, from a political standpoint, increasing federal fuel taxes and implementing a vehicle miles traveled (VMT) charge face stiff resistance.

As states have increased dedicated fuel taxes, added toll lanes, and piloted other user-based sources like VMT fees, nearly all congressional representatives and senators have opposed user-based revenues at the federal level. After years of lobbying efforts to "restore trust to the trust fund," the prospects for federal fuel tax increases are no greater now than they were 15 years ago—and perhaps are even dimmer today, as America attempts to recover from an economic crisis.

General Fund Solution

Dipping into general funds to bail out transportation programs might seem like a temporary fix, but it actually has been the de facto financial approach for transportation for more than a decade. Codifying a policy that purposefully leverages gas tax revenues and general funds also could shift the policy conversation at a macro level. Rather than focusing on increasing the federal gas tax for transportation investment generally, policy makers instead could refocus their energy on *how* that money is spent.

CHANGING NEEDS

Currently, HTF money is spent in a way that pays homage to its 1956 roots. The HTF was created to support the physical expansion of the Interstate Highway System. Transportation agencies at the state and local levels were organized in part to allocate money toward projects that supported that goal. In 1982, Congress included public transit as part of the trust fund, allocating 20% of expenditures toward that mode. Public transit has since retained its 20% share and the program remains focused on providing capital funding for up to 80% of highway project costs.

Photo: Robert Dyess, Flickr

Cars and a Dallas Area Rapid Transit train pass under the Collins Boulevard bridge over I-75 in Dallas, Texas. Moving to a general fund structure rather than the HTF can facilitate greater attention to public transit projects.

But, the transportation needs of the 21st century are different from the capital projects that the federal program was set up to fund. General funds offer state transportation agencies the opportunity to enhance adaptability, plan multimodally, emphasize operational investments, and reform governance.

GREATER FLEXIBILITY

A generally funded federal program provides greater flexibility to states on how to spend their share of formula funding. Although states do have some ability to flex their funding between modes, in a system without user-based revenues, no mode can lay claim to the revenues or be fixed to an arbitrary division of these funds. Investment needs in New York might be different from those in Nebraska. States may also have funding needs that have no relationship to what they historically have paid into the HTF or to the funding apportionments set in stone since 2008 (*2*).

A refocused federal program could also allow policy makers to place more emphasis on maintenance and operations over capital expansion. According to the U.S. Congressional Budget Office, state and local governments today spend more than 70% of their budgets on maintenance and operating expenses. This has not yet fixed America's oft-cited crumbling infrastructure, however. Recent laws have advanced requirements and incentives for asset management, but a reimagined federal program that directly funds high-quality asset management on federal-aid highways and major transit networks can answer nationwide calls to bring existing infrastructure up to a state of good repair.

REVISION AND RECONCEPTUALIZATION

What's more, strategically investing in operations instead of in capital can meet the goals typically associated with capital investments. For example, increased technology in operations can expand capacity, increase access, and improve safety. A shift in the revenue paradigm will make it more feasible to shift the program goals and focus.

A revamped federal program also provides an opportunity to reconceptualize our transportation institutions. Historically, these institutions were shaped by the federal-aid program and supported by the HTF. Although general funds are not directly tied to governance reform, a shift away from raising fuel taxes and toward broader policy can invite much-needed new thinking on how the federal program can help states and localities reorganize their institutions to meet modern challenges (*3*).

Embracing general funds does not mean abandoning user-based revenues. States and localities will and should increase

Photo: Roger DuPuis, Flickr

In 2019, Lake County, Ohio, voters approved a 0.25% sales tax increase to fund Laketran services. Ballot box measures to support multimodal and transit projects will continue to be a necessary component of robust transportation funding programs.

fuel taxes and continue to expand dynamic tolling. The federal government can incentivize state- and local-based congestion pricing, VMT-based fees, and other user-based revenues to increase revenue and manage demand. Ballot-box measures will continue to be a key source of local multimodal transportation investment. Fuel taxes can support state-of-good-repair initiatives or can be used as other policy mechanisms.

Evidence from abroad also supports a relationship between better transportation outcomes and a generally funded transportation program at the national level. For the most part, developed countries have long abandoned dedicated fuel taxes in favor of general funds for national transportation programs. These countries have higher fuel taxes, but those are used for environmental policy and are not viewed as user fees. They also have better maintenance outcomes, employ a greater use of public–private partnerships to deliver key infrastructure projects, and have found ways to provide long-term, predictable funding (*4*).

Although embracing general funds can create flexibility and foster innovation, the HTF, through contract authority, has been touted as critical in ensuring long-term predictability of funding. And, although contract authority officially has to be connected to a trust fund that is sustained through user fees, that requirement hasn't been enforced. In short, there is no reason that Congress cannot write new rules to replicate the funding predictability that the HTF has created.

Shifting the funding policy from user fees to general funds undoubtedly represents a huge political challenge—the HTF is valuable because it already exists. And, general funds won't necessarily help legislators reimagine the federal program. But, by effectively severing the connection to the capital expansion vision, there is good reason to believe that such a shift can become the impetus for a reimagining. By changing the funding mechanism, policy makers may be able to overcome long-standing inertia and reorient funding streams and institutional structures toward today's goals.

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CENTENNIAL QUOTE

"Many individuals from all over the world attend the Transportation Research Board Annual Meeting. One hundred years from now, large hotels like space vehicles will fly delegates from the United States to other parts of the world to host the Annual Meeting. This will help get everyone in the transportation industry to one place to discuss the future. In 100 years, most vehicles will have flying capabilities. People will be able to travel anywhere in the world at very low cost and within a couple of hours. Such advancements will allow more professionals to attend meetings and contribute to the growth of the transportation sector. Some will choose to attend via videoconferencing. But, since remote—or virtual—technologies isolate people from real social interaction, in the future we will have meetings with an emphasis on physical presence.

—UPUL ATTANAYAKE

Associate Professor, Civil and Construction Engineering,
Director, Center of Excellence for Structural Durability,
Western Michigan University, Kalamazoo

A Gray Swan Decade

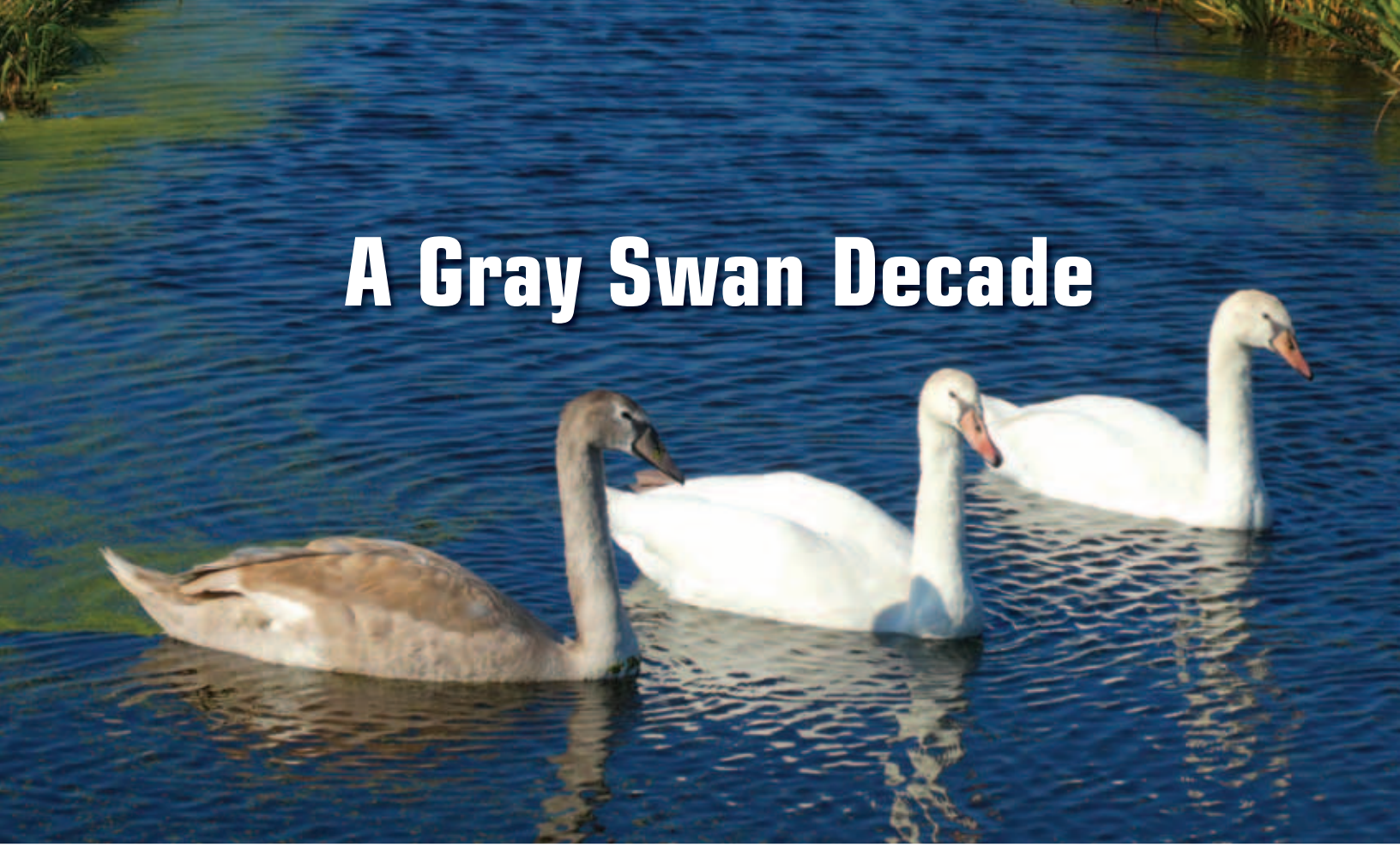

Photo: Pixabay

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Above: Potentially of high significance, a gray swan event is unlikely to happen but still within the realm of possibility. Even the slightest chance that it can occur means that it should be anticipated.

The outlook for travel in the coming decades is probably the most difficult to predict since forecasting gained prominence. What do those working on long-range transportation plans foresee as issues that will influence travel? What considerations will affect planning for the future? It may be an era of tremendous uncertainty. Travel activity in the 2020s will be driven by pronounced demographic changes, with millennials moving toward peak travel ages, while the aging baby boom generation travels less. At the same time, dramatic technological changes will affect transportation during what appears destined to be a contentious policy environment. It is a Petri dish culture ripe for complex—perhaps, unforeseen—interactions. However, some insights can be gleaned from history.

Travel Activity in an Uncertain Future

As evidenced by the changes since 2000, and perhaps most clearly from the arrival of COVID-19, uncertainty is increasingly shaping transportation planning, investment, and policy. The relatively stable trends in the last half of the previous century are giving way to more dynamic and diverse transportation trends across the country. Whether because of demographics, technology, natural phenomena, economics, or changes in culture and values, travel patterns, needs, and solutions are taking different directions in different contexts and locations. It is not a black swan event (extremely rare with potentially severe consequences) but, rather, a bevy of gray and black swans—and maybe a few white swans—that may confront us. Planning for uncertainty, epitomized by emerging attempts to predict the effects of autonomous vehicles, is challenging transportation professionals and potentially impeding the role and credibility of planning as they struggle to answer fundamental questions about demand, supply, and impacts. This uncertainty risk is exacerbated as transportation is increasingly reactive because needs backlogs, investment resource constraints, and the

lack of a shared motivating vision have collectively limited proactive investments for the future.

Demographics

The significance of the magnitude of demographic changes remains underappreciated among policy makers and planners. As the last of the baby boomers reach the age of 65, many continue to work. For the first time in U.S. history, the population older than 65 will outnumber those younger than 18. This means fewer new drivers, less travel serving the young, and more serving the elderly. One of the key concerns raised by U.S. Census population projections is the lower number of new working-age population in this decade to serve society's dependent populations (Figure 1).

The phenomenon of the baby boomers rapidly increasing the working age cohort and women's historic post–World War II surge into the formal workforce will not be replicated. Before the COVID-19 threat, national forecasts from the American Association of State Highway and Transportation Officials estimated vehicle miles of travel growth in the range of 1% per year—well below past levels. Now, even that level of growth is in question. Immigration, the only demographic factor that can change at the stroke of a pen, likely will be a greater factor in population growth than natural increases for the first time in our history. The magnitude of immigration, along with the age profile, skill levels, and destinations of those arriving, may be different than historic patterns. The level of immigration is more likely to be driven by U.S. policy and economic drivers than by factors in other countries.

Photo: Cushing Memorial Library and Archives, Texas A&M University

After serving their country in factories during World War II, American women began to enter the workforce in earnest in the 1950s—and in a number of roles, including in clerical pools, on factory assembly lines, and as computer keypunch operators, as with these women at Texas A&M University.

One of the capacity challenges of transportation infrastructure is caused by the redistribution of the population (Figure 2). Since 2000, approximately half of U.S. counties have lost population. Those areas with significant declines struggle to have the economic capacity to maintain and upgrade their transportation infrastructure, while those fast-growing, primarily metropolitan areas in the South and Southwest are challenged to keep capacity growing with increasing demands.

Transportation is fundamentally about the bridge between people and place, influenced by technology, the economy, and social values. Evolving patterns of residence, work, and activity location may, therefore, be as challenging as demographics. Will people cluster in larger and larger metropolitan areas to ensure access to employment opportunities? Or, given the forced natural experiment of the pandemic, will being able to communicate over long distances lead to a "work-anywhere" world for larger parts of the skilled workforce, in which access to the Internet, a road, and an airport may be the key? In a world driven by knowledge-based industries and a limited supply of skilled labor, an increasing number of workers can choose to live most anywhere—and the jobs will follow. Pandemic concerns have added a new dimension to debates of center city versus

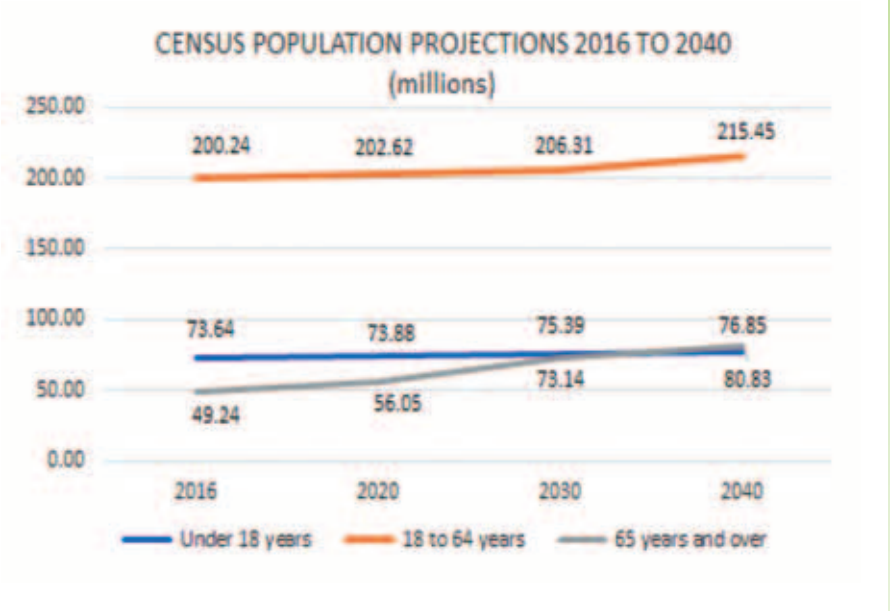

FIGURE 1 U.S. Census Bureau projections from 2017 show that—between 2020 and 2030—the number of Americans older than 65 will grow dramatically. However, a decreasing number of new working-age population during the same decade may not be sufficient to support both the young and the older dependent populations. (Source: U.S Department of Commerce.)

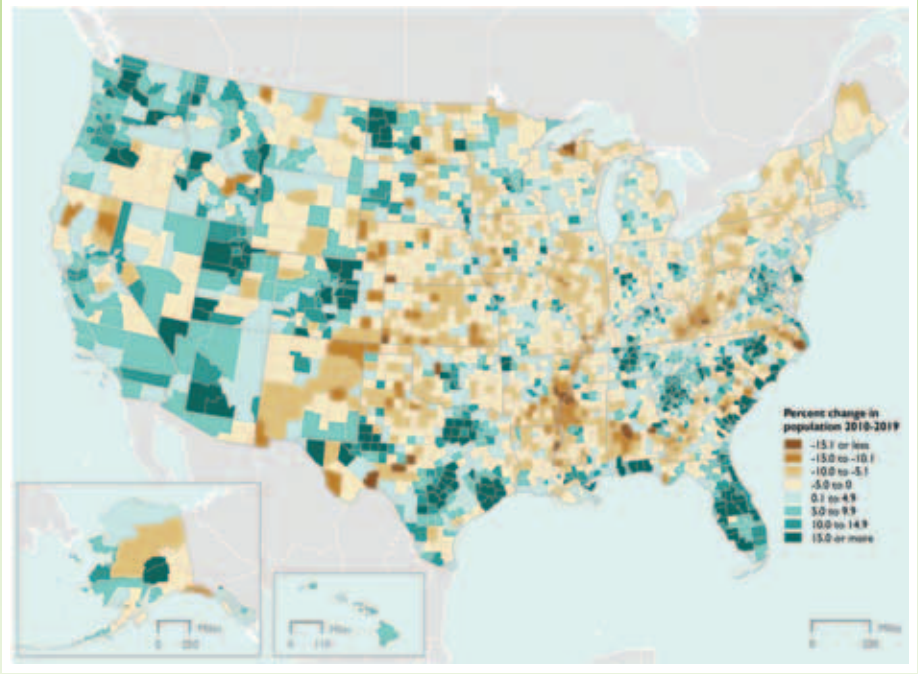

FIGURE 2 Disparate population growth trends across U.S. counties. (Source: U.S. Department of Transportation, Bureau of Transportation Statistics.)

suburban or rural densities and lifestyles. It is conceivable that both trends can prosper.

How growing diversity will play out is an open question. Diversity in race, ethnicity, age, and gender are important, but so are diversity of preferred locations, skills, and the times and places in which we work and play. As the explanatory power of traditional social factors diminishes in the highly diverse world of the future, those factors will be replaced by emphasis on levels of education and skills, age, income, and geographic availability as determinants of travel demand. Varying work schedules, work-at-home opportunities, and balancing family life with work will be central factors.

Technological Influences

Although the importance of technology has garnered attention in the context of autonomous vehicles, it remains underappreciated regarding its current influence on transportation. It is technology—not policy—that deserves the lion's share of recognition for improvements in safety, energy efficiency, and environmental impact mitigation. Wireless communications, near-universal computer capabilities, web access, and sophisticated sensors—among other technologies—provide the basis for ongoing changes in transportation. Enhanced logistics, multimodal integration, convenient trip planning, scheduling, ticketing, and payment are revolutionizing travel choices and the reliability, convenience, cost, and safety of travel options—all of which influence travel choices, many in ways not fully understood or predictable.

Among the least appreciated changes is the ability of enhanced communications to substitute for travel in the form of telecommuting, e-commerce, distance learning, telebanking, and related logistics changes and capabilities. Technologies enable sequential and concurrent vehicle sharing, and new business models are generating private-sector interest in transportation services such as ride-hailing, bikeshare, e-scooters, and robotic or drone deliveries. Mobility-as-a-service scenarios may eventually capitalize on these features and ultimately complement the travel choice set with autonomous vehicles.

For now, future travel planning will have travelers faced with more travel choices with more nuanced characteristics and choice attributes. In addition to traditional cost and speed attributes, other factors such as reliability, flexibility, convenience, comfort, safety, and image will further differentiate travel choices. Trip rates, trip destinations, mode choices, travel paths, and logistics will be influenced in new ways as technology evolves.

Traveler Values and Culture

In addition to changes in the density profile and settlement patterns of travelers and the range and traits of personal travel options, future transportation will be influenced by the values and cultures of those making travel decisions. It will also be affected by those making decisions about the investment priorities and policies that guide public- and private-sector involvement in transportation.

Photo: Pixabay

The COVID-19 pandemic has forced office buildings to close and introduced teleworking as the new normal. A computer, Internet access, and a comfortable workspace are all that are required to get the job done—anywhere and anytime.

Photo: Pixabay

Strapping on a backpack, millennials are characterized as a generation inclined toward experiencing people and places over possessing property. But, it is anyone's guess whether their love of adventure and experiential travel will persist as they grow older.

Generational value shifts may play a role. Millennials are characterized as valuing experiences—which implies travel—over ownership. Will this persist with time? Or, will they arrive at similar places as previous generations, just taking longer to get there? Whether their values translate to their transportation choices in the years ahead remains to be seen.

Similarly, the next generation of seniors may behave differently, including remaining in the workforce longer than previous generations. A large, healthy, retired population—and the rise of two-retired-person households—could still yield a potential boom in long-distance travel and other new patterns. Licensure levels, particularly among older females, will be higher than in previous generations, resulting in more independent travel decisions. A more diverse and more urban-centric population may also have different priorities and make different travel decisions than previous generations. Carbon footprints and active living considerations—or, perhaps, the ability to isolate during travel—may weigh on transportation decisions in ways that diminish the historical dominance of cost, time, and safety in making choices.

Among the influences of the COVID-19 pandemic will be the support it generated for a dispersed workforce. Working at home has been the fastest growing commute mode for decades (Figure 3). The patterns and habits acquired this year will only expand and inform that trend. More negative and difficult to assess will be the pace at which the public regains willingness to assemble in large groups. The major long-distance travel modes depend on clustering people in close quarters for long periods, often to reach venues—such as concerts, conferences, and sporting events—where people will again convene in large numbers. How long we will take in returning to the acceptance of those constraining situations is an open question. The pace of COVID-19 recovery and the fear of future pandemics will govern whether the new normal is close to the old normal.

People's confidence in technology will be tested as autonomous vehicles approach broader deployment. The willingness of individuals to be dependent on either government or private sector provision and regulation of technologies and shared services remains to be determined. Also unknown is people's willingness to rely on a user-pays–based funding tradition for transportation and how to prioritize transportation among the plethora of social and infrastructure needs. Repercussions of events such as the COVID-19 pandemic or other gray swans not yet revealed may shape the values and behaviors of the next generation of travelers and decision makers, as well as the resources available for travel and associated infrastructure.

These patterns and trends demand careful monitoring in the coming decade. The COVID-19 pandemic has taught us powerful lessons about the influence of transportation on not just our lifestyles but our very well-being and existence. These forces playing out will lead to a fascinating and challenging future for planning, building, and operating transportation. It is a rich and exciting time for transportation research and analysis.

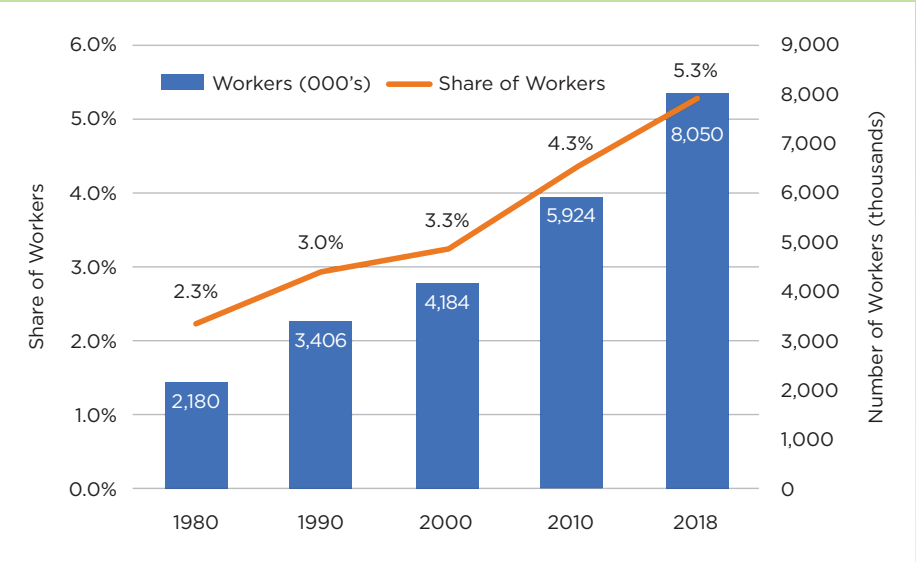

FIGURE 3 Long-term working-at-home trend, based on the usual mode used during the prior week. (Source: Commuting in America series from Decennial Censuses and American Community Survey.)

MOVING THE GOODS

Photo: versageek, Flickr

ROLF R. SCHMITT AND EDWARD L. STROCKO

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Above: Trucks share the lanes with other vehicles as heavy traffic approaches George Washington Bridge into New York City. With so many trucks delivering goods locally and across the country, managing the mix of passenger travel and freight on the same infrastructure remains a challenge.

Freight has been a key enabler of economic development and a major driver for the expansion of the transportation system since before the founding of the United States. With a vast geography within the nation's borders and oceans separating the nation from key international markets, freight infrastructure and technology has been critical to our country's success.

Freight keeps moving even through pandemics. Although passenger travel in 2020 declined by half—and for some modes, by more than 90%—some freight movements increased to keep essential businesses stocked, to move medical supplies to hospitals, and to deliver groceries and consumer goods to households where members formerly transported such commodities.

The Freight System Today

In the United States, freight travels over a complex, multimodal system that serves a growing volume of goods and complicated supply chains and carries about 51 million tons of freight valued at more than $52 billion every day (*1*). The freight system is actually two overlapping

Photo: Ted McGrath, Flickr

Loaded and offloaded with giant cranes, the container ship *Maersk Saigon* is processed at Florida's Port of Miami. In the future, cranes as well as vessels may be controlled remotely.

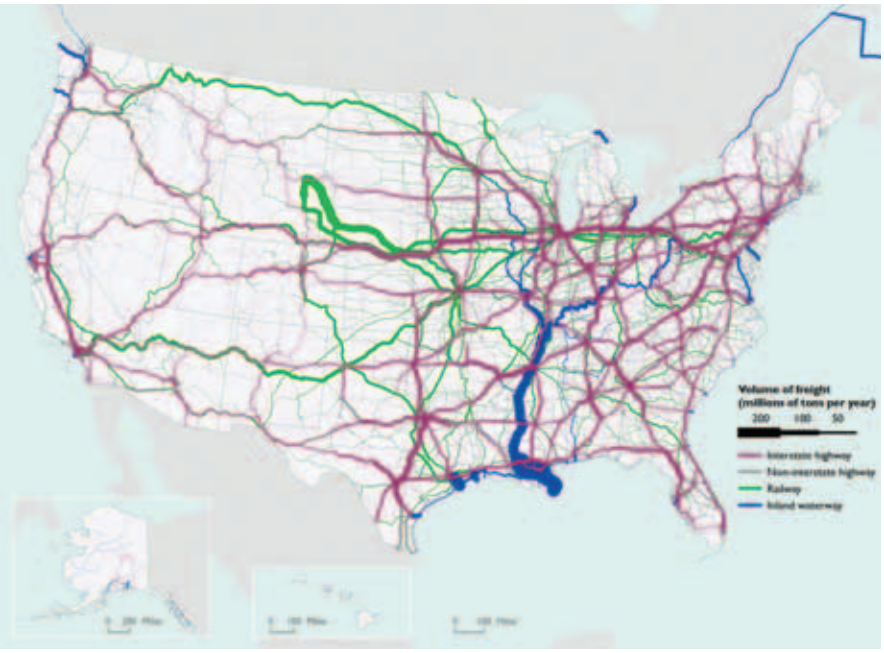

FIGURE 1 Freight flows by highway, railway, and waterway, 2018. (Source: Bureau of Transportation Statistics.)

systems, one optimized to move bulk products such as grain and coal and the other optimized to provide connections between industry and consumers for manufactured goods and perishables. The freight system for bulk goods is dominated by energy and grain movements on barges, unit trains carrying a single type of commodity that are all bound for the same destination, and pipelines providing a low cost per mile of transport. The faster and more expensive freight system for manufactured goods and perishables is dominated by truck and air movements and by container movements on railroads and ships (Figure 1).

Although freight transportation is typically associated with long-distance supply chains, most shipments are relatively localized. Half of the weight and one-third of the value of all freight shipments in 2018 moved less than 100 miles (*2*). In some cases, the local shipment is the "last mile" from a regional distribution center for goods imported from other regions and other countries. Freight can also be local in source and destination; for example, raw materials like sand and gravel being transported by truck from a nearby quarry to a construction site.

Whether facilitating long-distance or local shipments, a skilled and diversified workforce is necessary to move freight. This multidisciplinary workforce includes employees of transportation companies, from vehicle operators and aircraft crews to accountants and computer programmers; employees of transportation equipment manufacturers; workers in the transportation infrastructure construction industry; and workers in transportation occupations who are employed in other industries, such as truck drivers for grocery chains. Truck driving is by far the largest freight transportation occupation in the United States. Of the 3 million truck drivers in 2017, about 57% drove heavy trucks such as tractor trailers, about 29% drove light trucks and delivery vehicles, and about 14% are driver sales workers (*3*).

Forces of Change in the Demand for Freight Movement

The freight system for bulk shipments responds to the nation's production and use of energy, agricultural products, and construction material. According to the Energy Information Administration, U.S. energy production will grow significantly over the next 30 years. But, domestic consumption will grow slowly, and the United States will continue to be a net exporter of energy products. The mix of energy products will change as the use of coal carried by railroads declines, the use of natural gas carried in pipelines increases, and renewable energy sources replace coal and gas movements with electrons in wires transmitted from wind turbines and solar panels (*4*).

Slowing population growth, increases in extreme weather, and global trade tensions

Photo: Ron Clausen, Wikimedia Commons

Fresh milk comes straight to the door in Auburn, Washington. Such localized shipments make up the majority of U.S. freight transportation.

Photo: Washington State Department of Natural Resources

Converting wind to renewable energy, stands of wind turbines rise from a plain in Washington State. Such renewable energy sources are expected to find their place in the energy mix as coal transported by train declines and gas movement through pipelines increases.

will influence the amount, location, and type of agricultural products requiring transport. The latest U.S. Department of Agriculture (USDA) projections indicate that the United States will continue to be a competitive agricultural exporter but that slowing global economic growth is expected to suppress growth in U.S. agricultural exports over the next decade (*5*). However, flooding, drought, intense storms, atypical heat waves, and cold snaps affect agriculture production and the availability of inland waterways for moving grain.

Slowing population growth also will affect the demand for construction materials, as will changes in the types of materials used in new buildings. The Federal Highway Administration has noted that in many parts of the United States, supply of acceptable-quality aggregates is very limited and aggregates are imported from neighboring states, Canada, and Mexico (*6*).

The freight system for manufactured goods faces its own daunting changes. Decisions to locate factories outside of the United States—or to bring them back—typically are predicated on labor costs and the state of international relations. Some goods become obsolete and disappear, while new goods emerge and production processes evolve between concentrated and decentralized strategies. T.R. Lakshmanan, the first director of the Bureau of Transportation Statistics, observed in the 1990s that the nation's economy is "dematerializing" and the weight of individual products to be moved is declining. The most dramatic example of dematerializing is recorded music, which evolved from heavy vinyl disks to lighter CDs to downloads that are transmitted rather than transported. Will 3-D printers do the same for other goods? Or, will 3-D printers replace lighter shipments of finished products with heavier shipments of the resins and other materials needed to print those products?

Forces of Change in Delivering the Goods

The demand for velocity and visibility in moving goods continues to accelerate, even in the face of disruptions from the pandemic. Just-in-time delivery of components for manufacturing has expanded to overnight delivery of almost anything to businesses and consumers. The nearly universal availability of overnight delivery throughout the United States is redefining our traditional view of accessibility, replacing concern with access to shopping opportunities with concern over congestion related to last-mile deliveries as e-commerce brings the store to the consumer. The e-commerce mantra of variety, velocity, and visibility, which began with high-value manufactured goods and perishables, has permeated bulk and low-value goods

movement, resulting in a new responsiveness from shippers and carriers across the goods movement spectrum.

The importance of information technology continues to increase across the supply chain. Backroom management, tracking and communication, and use of Internet applications—all highlighted in *TRB Special Report 274: Cybersecurity of Freight Information Systems: A Scoping Study*—are no longer reserved for best-in-class companies but are now fundamental for entry (*7*). Information technologies from location-based services to blockchain-enabled distributed ledgers accessible by all partners in a supply chain are becoming critical tools in the movement of goods. These information technologies raise new issues for participants in goods movement, ranging from cybersecurity and data privacy to resiliency concerns related to power outages.

The National Cooperative Freight Research Program (NCFRP) noted in *NCFRP Research Report 39: Freight Transportation Resilience in Response to Supply Chain Disruptions* that large-scale disruptions to transportation systems are a reality of today's goods movements, and, although not new, the frequency and magnitude of severe weather, attacks on physical infrastructure, and cyberattacks on information technology continue to grow (*8*). At the same time, communities continue to raise public health concerns regarding pollution from freight transportation (*9*). Investor, regulator, and consumer demands will drive environmental practices for greening the supply chain and will push public- and private-sector action to strengthen resiliency of the freight system and supply chains. Done smartly, these actions have the potential to reduce freight transportation environmental impacts and corporate risks, while enhancing long-term company viability and profitability.

An Autonomous Future?

Products delivered by the transportation system of the future will likely be moved at least part of the way by automated conveyances. Automation can be expected to transform freight transportation from long haul to last mile for moving bulk and manufactured goods.

Photo: HadasBandel, Wiki Commons

Looking ahead, freight will take to the skies as drones deliver packages in urban and suburban areas, even claiming air space above transportation facilities.

Automated platforms already move products around warehouses, within seaports, and through intermodal terminal yards. Experiments with package delivery by small autonomous vehicles and drones are under way. Automation on highway networks may include platoons of trucks operated by one driver. Pipelines are already operated by remote control, and railroad automation is likely to expand from hump yards to the main line. Automation in the maritime system may include remotely controlled vessels and cranes.

In urban and suburban settings, where surface right-of-way is heavily constrained, freight will exploit the *z*-axis. Drones can use air rights above transportation facilities, while shallow-depth, narrow-diameter cargo tunnels can allow uncrewed cargo vehicles below the surface right-of-way. The early vision of freight delivery by underground pneumatic tube, only achieved for mail in New York City, may finally realize broader implementation.

On the surface, freight will look to operational solutions coupled with select right-of-way expansions. Time, precision, and flexibility will serve as hallmarks of these solutions. Automated freight conveyances will be scheduled for 24-hour use of a right-of-way that morphs in function throughout the day. When coupled with smart city concepts, last-mile and last-50-feet deliveries can be made at off hours without humans. Precision railroading and trucking with automated freight conveyances will allow for increased density and a mix of freight vehicles to operate in a synchronous dance on the infrastructure. Whether crewed or automated, freight delivery will need to balance safety, infrastructure availability, temporal and security requirements of the move, costs, and environmental concerns.

Future Challenges

Although the mix of commodities may change, volumes of freight to be moved are likely to increase with overall economic activity as the nation emerges from the pandemic. Future growth in volumes—especially for goods requiring expedited delivery—exacerbates several traditional issues:

- How do we manage the mix of passenger travel and freight on shared infrastructure, whether balancing freight and passenger train schedules on the railroad network or developing truck size and weight policies that

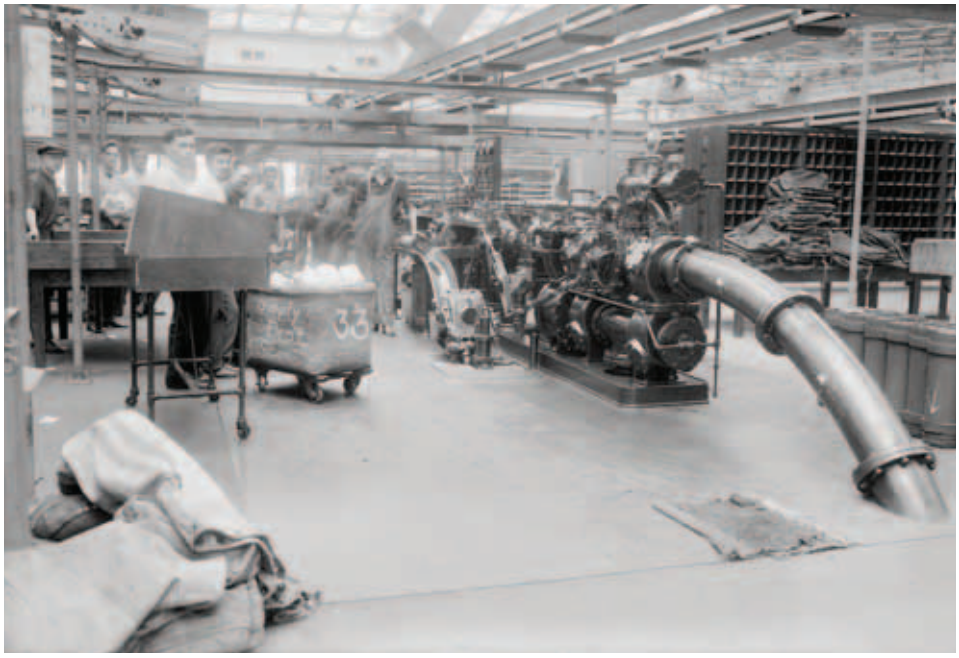

Photo: Library of Congress

More than 100 years ago, New York City embraced an innovation: delivering mail via underground pneumatic tubes, as shown in this 1910 image of the Pennsylvania Terminal Post Office, now the James A. Farley Building on Eighth Avenue. In the future, perhaps other freight will be delivered the same way.

balance motorist safety concerns with carrier productivity concerns?

- How do we manage the flow of interregional freight through or near local communities when dealing with truck routes through neighborhoods, railroad grade crossings occupied by long freight trains, or pipelines carrying hazardous material through populated areas?
- How do we develop and attract the freight and logistics workforce of the future that may replace the need for thousands of truck drivers with skilled workers in information technology and other occupations?

The evolving world of transportation will require new approaches to transportation planning to deal with longstanding and new issues. For many years, transportation planners treated freight as an extension of passenger travel, often using traditional travel demand models with different variables to estimate freight flows. New models and analytical techniques are needed because freight is very different from passenger travel. Unlike passenger travel that varies relatively little among income groups and communities and changes primarily in response to demographic trends, freight movement varies substantially by economic sector and short-term changes in economic factors. The supply chain for an automobile plant is very different than for a clothing boutique, yet all must be served by state and local transportation plans.

Evolving manufacturing technology, new approaches to logistics, and changes in consumer behavior will continue to challenge the transportation community in the years ahead. As we look toward tomorrow, a sustained commitment to build our next-generation workforce, invest in our infrastructure, and implement advanced technology will create the freight transportation system needed to connect the economy with resources and markets across the continent and beyond.

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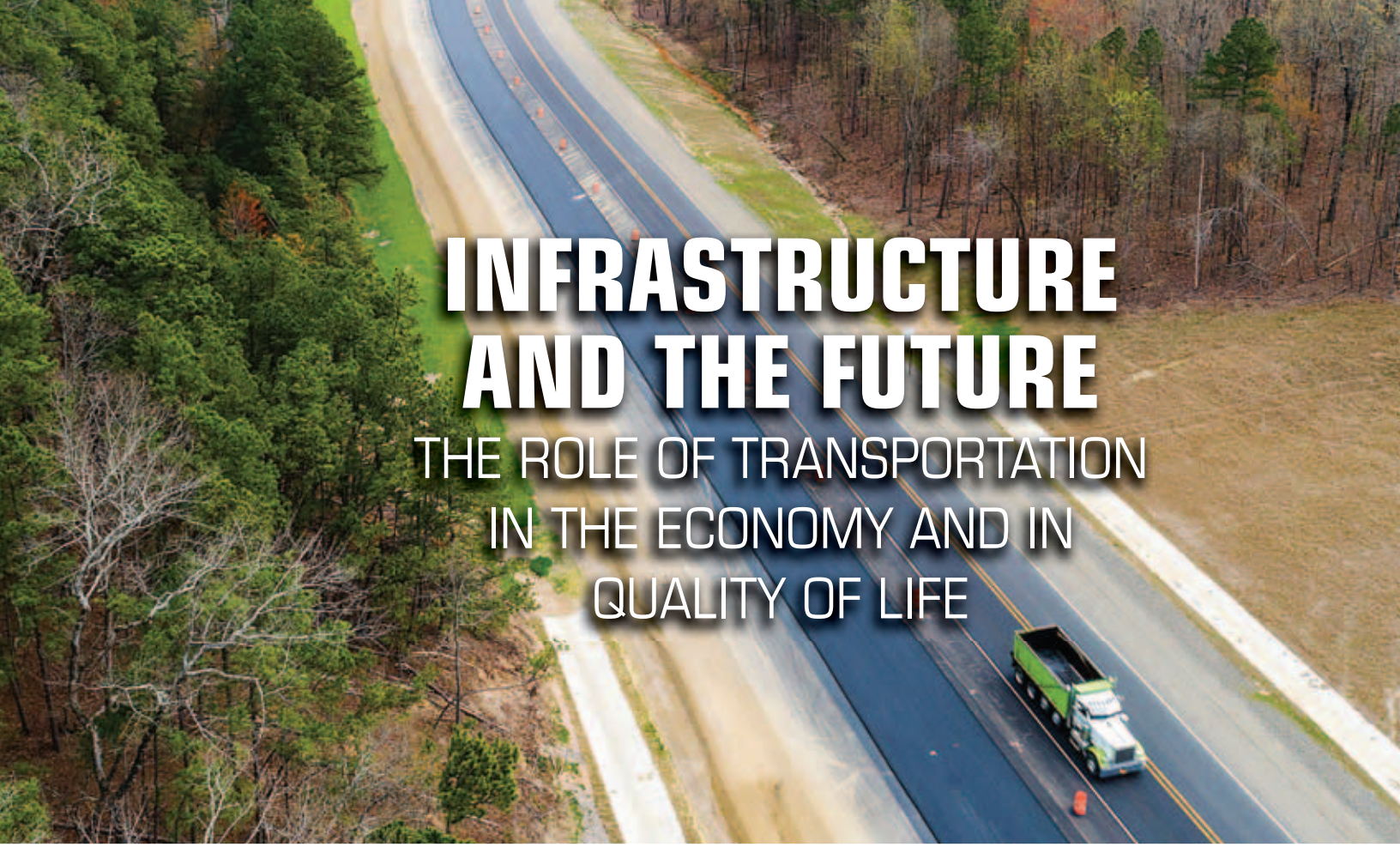

INFRASTRUCTURE AND THE FUTURE

THE ROLE OF TRANSPORTATION IN THE ECONOMY AND IN QUALITY OF LIFE

Photo: Flickr

CARLOS BRACERAS AND ELIZABETH WEIGHT

Braceras is Chair, Transportation Research Board Executive Committee, and Executive Director, Utah Department of Transportation, Salt Lake City, and Weight is Director, Strategic Communications, Utah Department of Transportation, Salt Lake City.

Above: A lone green truck threads along a forested stretch of US-70, one in an intricate network of the nation's roadways. Such transportation infrastructure keeps communities connected and provides a supply line for the food, fuel, and other commodities we all need.

Humans have intuitively recognized the importance of transportation infrastructure throughout history. The transportation system is like the circulatory system: when it works, it is central to thriving. It can easily be taken for granted because the basic expectation is that it will work. When it doesn't, the effects can be catastrophic.

We rely on infrastructure. Roads, trails, and paths have served societies throughout all of history. They are a marker among anthropologists indicating the sophistication of societies. For example, the Roman Empire was known for its advanced road system that was vital to its military success and the growth of an empire. This road system was robust and logical, with one of the first known examples of milestones—mile markers literally etched in stones. In another example, the Silk Road was a crucial enabler of economic development, allowing travelers from East Asia, Africa, and southern Europe to trade goods and leading to the creation of today's economic structure using standard currency. Perhaps even more importantly, the Silk

Photo: Júlio Reis, Wikimedia Commons

The Roman Empire did it first: it erected carved stone mile markers—such as Milestone XXIX along Via Romana XVIII in what is now Portugal—along roads throughout its vast domain. The Empire's growth and military success was due, in part, to its advanced road system.

Photo: Famartin, Wikimedia Commons

When the COVID-19 pandemic first took hold in the United States in March 2020, panic shopping stripped grocery shelves bare of essential products—particularly toilet paper, as in this Virginia store. Once production caught up, trucks took to the roads to restock stores across the nation.

Road connected different cultures, leading to more diverse populations, new political and religious ideas, and advancements in education and innovation.

In more recent history, military defense was a primary impetus for building the Interstate Highway System. The Interstate System's value has extended far beyond the military, however. It has enabled benefits ranging from broad economic opportunities to little luxuries, such as access to strawberries at any time of year. And, at this moment in history, as we face the COVID-19 pandemic, the essential nature of our infrastructure system is acutely apparent. We rely on freight for access to medical equipment, food supplies, personal protective equipment, sanitizing products, and, yes, even toilet paper.

It is evident that the primary purposes of transportation have been economy, defense, and the ability to connect. Today, we can view ourselves as facilitators of connection, like travel agents who understand that it is not about arriving at a destination; it's about providing value in the journey. As we broaden our perspective, we understand that transportation infrastructure ultimately serves one all-important cause: enhancing quality of life. Infrastructure strongly influences quality of life, and we are fortunate to work in a profession in which we deliver a system that serves the well-being of the public.

System Performance

FUNDING AND PRIORITIZATION

One unintended consequence of the current pandemic and its associated physical distancing is a precipitous decline in vehicle miles traveled throughout the United States. Because roadway funding relies in large part upon fuel taxes, already-stretched transportation budgets face increased threat. It is vital that we appropriately prioritize taxpayer dollars to deliver the greatest possible good. This means we must conscientiously consider how we measure the return on investment for every project and activity we complete. As stewards of public money, full transparency and how we spend that money matters.

In the past, our industry has focused on metrics such as delay, congestion, and pavement condition. To be sure, these outcomes will always be important. However, if our primary purpose is to enhance quality of life, then we should also measure value and performance accordingly. Our entire perspective about what we build and why we build it is shifting, and that paradigm change subtly—but absolutely—reframes how we approach our work.

If we are to identify the most important metrics for prioritizing and evaluating our work, the transportation industry has a responsibility to become more conversant in factors that influence quality of life. The body of research on quality of life is growing. It has been identified internationally as being on par with—if not more important than—gross domestic product for measuring the success of the world's populations. One of the most respected frameworks for measuring quality of life is the Organisation for Economic Co-operation and Development's Better Life Index, which is benchmarked to the United Nations' Sustainable Development Goals. This index includes factors such as income and wealth, jobs and earnings, housing, health status, work–life balance, education and skills, civic engagement and governance, environmental quality, personal security, subjective well-being, and social connection. As we review this list, we intuitively understand that transportation affects these factors in ways that are both obvious and subtle, and both direct and indirect. The challenge at hand is to make a clear and quantifiable connection between these factors and the investments we make. This task can feel overwhelming, but tools are available to help us achieve the goal of connecting the previously mentioned factors with our transportation investments.

TECHNOLOGY

Technology is among the most powerful resources at our disposal to measure performance, and it is advancing at a mind-boggling rate. In tandem with the development of various technologies, the data available for analysis have proliferated

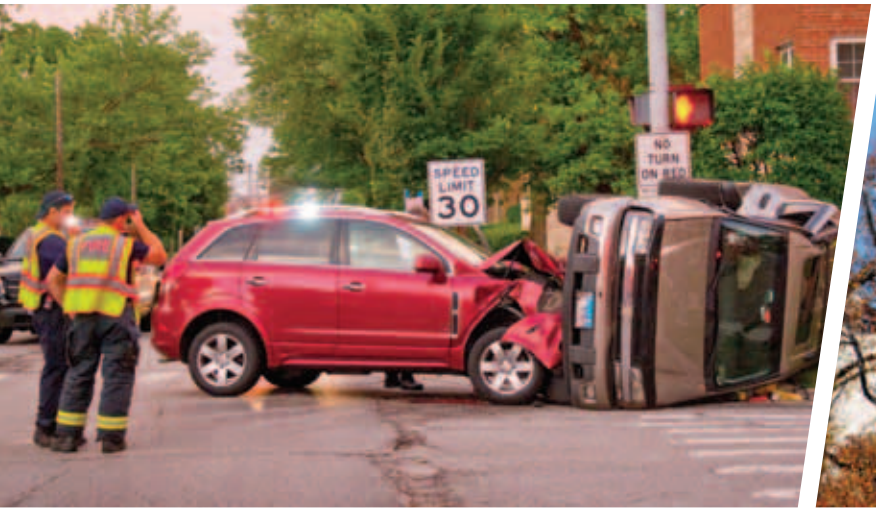

Photo: Charles Edward Miller, Wikimedia Commons

Despite traffic signs as deterrents, car crashes still happen. In the United States, as many as 94% of crashes are caused by humans. But, the time is on the horizon when autonomous technologies will reduce human influence, resulting in safer roads.

Photo: BeyondDC, Flickr

Buses get priority at traffic lights in Washington, D.C., and other U.S. cities. GPS-based computer software programmed with a bus's schedule calculates its expected arrival time at an intersection. It then extends the green light or shortens the wait at the red light, reducing idling and keeping buses running on time.

to an incomprehensible degree. We are faced with a double-edged sword: we can use data and technology for almost anything we can imagine; yet, the tsunami of options can be distracting, even paralyzing. The solution is to focus our attention on the priorities that matter most. Chief among these is safety. The clear goal is to achieve a system that delivers zero fatalities, zero injuries, and zero crashes. Many have pushed back against the idea of a zero-fatality goal, believing it is unattainable. When you consider the technology that is on our doorstep today and the technology we will have in the near future, many of us would have considered those advances unattainable, as well. With the myriad potential advances that will improve safety, why would we reach for anything other than zero?

Cooperative autonomous technologies are among the most promising when it comes to decreasing roadway fatalities. The National Highway Traffic Safety Association has identified that up to 94% of crashes are caused by humans. By removing some—and, perhaps, one day, all—human influence over vehicle operations, we will be able to make our roads safer. This may be the only viable path to zero fatalities. For nearly two decades, our industry has worked with vehicle and equipment manufacturers, legislators, and government agencies to advance the necessary technological and roadway infrastructure. We still face challenges, including unstable policy and uncertainty surrounding the availability of key resources, such as the 5.9 GHz wavelength—also known as the safety band.

Even so, opportunities exist today for us to begin implementation of autonomous technology in the field. For example, the Utah Department of Transportation has partnered with local governments and the state's largest transit authority to provide traffic signal priority, known as "signal preemption," for buses. Schedules are now more reliable, making public transit a more attractive option in a multimodal transportation system. Signal preemption is also provided for snow plows, enabling improved snow removal and safer roads. These efforts may seem relatively small, but they are meaningful and accessible today.

The acceleration of such innovation would not have occurred if we waited for federal direction. In order to create an environment in which autonomous technology

FCC Proposal Puts High-Speed Safety Band at Risk

Connected autonomous systems rely on the 5.9 GHz wireless spectrum—also known as the Safety Band—specifically allocated to facilitate ultrafast data transfer. This high-speed communication is crucial to preventing crashes between moving vehicles. The Federal Communications Commission (FCC) proposes to reduce the width of the Safety Band to make more room for traditional wireless communications. Federal, state, and local transportation agencies, automakers, and other stakeholders have raised concerns that the FCC's proposed actions to reduce the spectrum would severely restrict or eliminate the ability of unique, connected vehicle systems to prevent crashes and save lives.

Photo: Tony Alter, Flickr

Biking, walking, and other modes of human-powered transportation are a major focus of Utah's Transportation Vision, a cooperative effort that promotes improved mobility and quality of life. Such activities are even more important to maintaining good health during the COVID-19 pandemic, prompting partners to develop the Safe, Healthy, and Active Streets Initiative. The reduction in traffic and demand for more space to bike and walk have resulted in temporary allocation of some roadways to give the public more access to the outdoors.

can continue to advance, we will need extraordinary trust and collaboration in partnership among states, cities, counties, and the private sector. The federal government has an important responsibility as an enabler of advancements in deployment of connected autonomous technology.

New Perspectives and Workforce Development

Successful delivery of an effective transportation system in today's complex world will require exceptional creativity, resilience, and performance. Our workforce must adapt. Research consistently indicates that more-diverse workplaces produce better results, from increased productivity to better financial outcomes. Traditionally, we have focused on engineering and other technical disciplines, and the skills we have valued and hired for reflect that emphasis. In 2019, Forbes identified 10 skills that are vital for the future workforce: creativity, emotional intelligence, critical thinking, active learning, judgment and decision making, interpersonal communication skills, leadership, diversity and cultural intelligence, technology skills, and embracing change (*1*). Many of these soft skills do not describe the stereotypical transportation engineer. We should aim to develop more diverse skills among our technical experts and seek new talent that brings expertise into these areas.

Partnerships and Inclusivity

The value of diversity extends beyond any individual workplace. Transportation systems, communities, and the economy benefit most from teams who represent varied interests, sectors, and industries. In 2018, new state legislation tasked the Utah Department of Transportation with identifying statewide initiatives for transportation, and the effort was to be collaborative. This led to the creation of Utah's Transportation Vision (UVision), which intentionally brought together partners who have been frequent stakeholders but who have rarely been at the same table for a shared conversation. Development of the vision included partners such as the state's Department of Health; the Office of Tourism; Chambers of Commerce; economic development agencies; and Get Healthy Utah, a local nonprofit. The group identified quality of life as the primary objective, creating a framework with four key dimensions: improved health, better mobility, connected communities, and a strong economy. The resulting quality of life framework reflects a more comprehensive set of perspectives than traditional mobility metrics, leading to more holistic solutions to improve well-being for communities and individuals than we have developed in the past.

In recent months, we have been reminded of the need to be more inclusive in our conversations and expansive in our thinking. If we were to start this process again today, we would include even more perspectives—specifically from underserved and minority communities. In order to build infrastructure that improves quality of life for communities of diverse needs, we must take on the significant work ahead to adequately include a truly diverse range of voices.

Conclusion

As an industry, we have been moving in the right direction. We are building upon the notable achievements of the past—after all, many ancient Roman roads are still with us today. We continue making incredible advancements in the quality of the new infrastructure we build. As our collective knowledge grows and our opportunities expand, we will be able to do even more and we will be able to do it better. To avoid getting sidetracked or bogged down, we can focus our energy on developing projects and technologies that will most improve the quality of life of the people we serve. What we do is, indeed, essential. But we can—and should—think even bigger. We have the opportunity to do what seems nearly unimaginable. We can save lives. We can make communities stronger. We can—and do—change the world.

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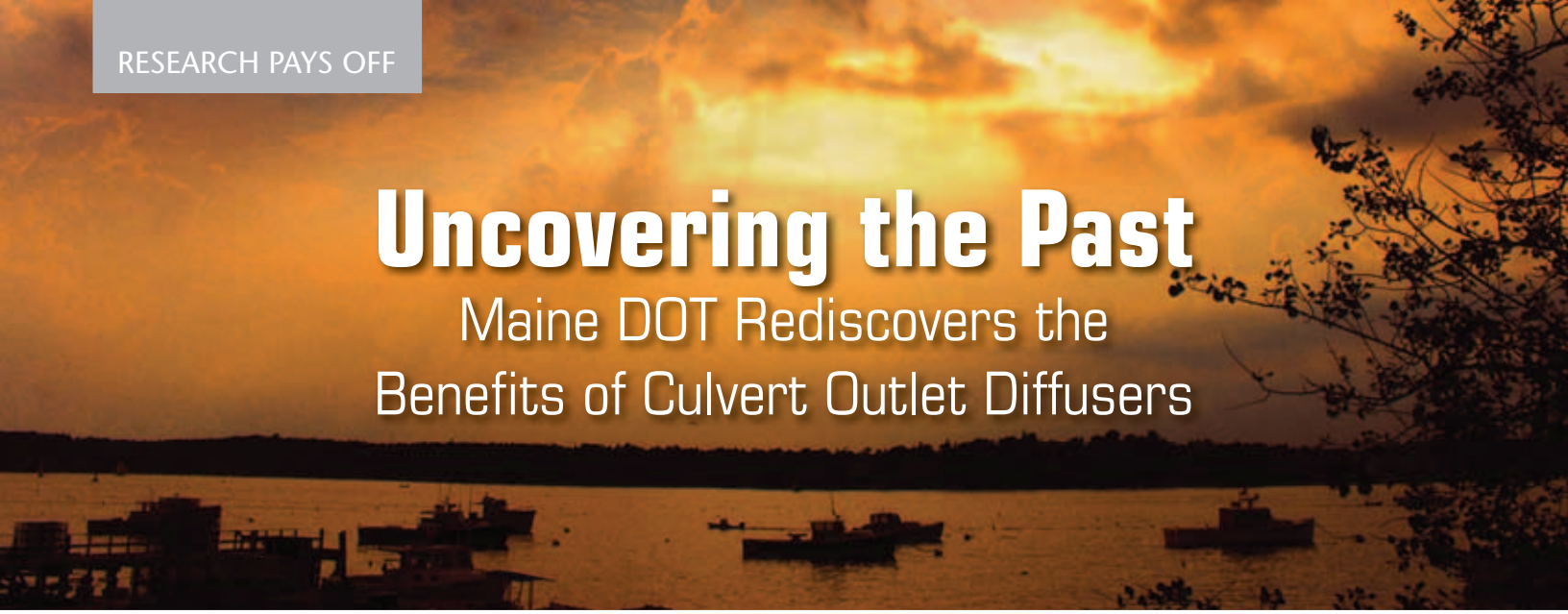

Uncovering the Past

Maine DOT Rediscovers the Benefits of Culvert Outlet Diffusers

Photo: atomahoke, Flickr

ALEXANDER W. MANN

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Above: A striking sunset follows a heavy rainstorm in Boothbay, Maine. The rediscovery of research conducted in the 1920s helped Maine DOT implement a more efficient system for culvert rehabilitation, which is critical in stormwater management.

A novel method for increasing culvert capacity has been rediscovered at the Maine Department of Transportation (DOT). During a literature search on the use of outlet diffusers in highway culverts, Maine DOT researchers came across extensive laboratory testing of diffusers by David Yarnell in the 1920s (*1*). Both Yarnell's work and Maine DOT research indicate that adding a diffuser reduces outlet losses, markedly increasing the culvert's efficiency.

Outlet losses, or the loss of energy that occurs at the exit of a culvert, are related to the square of the velocity of the exiting water (*2*). Decreased losses mean increased capacity for a culvert. Although much attention has been focused on improving culvert inlets, outlet losses largely have been ignored. The addition of a diffuser allows more water to flow through a culvert, reducing the inlet water level and, therefore, reducing flooding.

Culverts that are experiencing higher flows—because of changes in land use, climate change, or both—can be easily modified to increase their capacity. Similarly, aging culverts in need of repair can be rehabilitated without the decrease in capacity that is associated with most methods of rehabilitation.

Problem

Many years have passed since the post–World War II highway construction boom that created the Interstate Highway System and adapted many of the older roads for modern traffic. It has been even longer since the public works highway boom of the 1930s. Many of the culverts that were installed during these two periods have exceeded their useful life. These culverts now need to be rehabilitated or replaced.

Unfortunately, increases in state and federal highway budgets have not kept pace with this need—and the backlog of projects increases every year. Therefore, culvert rehabilitation methods are becoming more common. According to *National Cooperative Highway Research Program (NCHRP) Synthesis 519: The Renewal of Stormwater Systems Using Trenchless Technologies,* 88% of the state agencies surveyed had used trenchless renewal techniques to rehabilitate pipes, and these techniques are used on 16% of stormwater projects. Slip lining is the most common form of trenchless renewal (*3*).

An unpublished analysis of data from Maine DOT indicates that deeply buried culverts are approximately four-and-a-half times as expensive to replace as they are to slip line. Maine DOT has more than 4,000 culverts in fills that are more than 10 feet deep. These culverts are expensive and disruptive to replace and, ultimately, would be good candidates for slip lining; however, this method of rehabilitation typically reduces the size of both the culvert and the inlet. In addition, rehabilitated culverts are smoother, reducing friction and increasing the water velocity, resulting in greater outlet losses.

Smaller inlet size and increased outlet losses result in a significant decrease in culvert efficiency and capacity. In *NCHRP Synthesis 519*, the primary reason given for replacing culverts instead of rehabilitating them is the decrease in culvert capacity resulting from rehabilitation.

Solution

Maine DOT research has shown that culvert outlet diffusers significantly reduce outlet losses and increase culvert capacity and efficiency (*4*). In the early 1920s, similar research was conducted by Yarnell, who at the time worked for the Bureau of Public Roads. He experimented with culvert and diffuser designs at the University of Iowa Hydraulics Lab (*1*). For an analysis of Yarnell's data and analysis of the benefits of diffuser outlets, see Larson and Morris (*5*). Yarnell's experiments and the Maine DOT research study both found that a 40% increase in culvert capacity can be reliably achieved by properly designed diffuser systems.

A complete diffuser system includes an improved inlet, a culvert, a flared diffuser outlet, and an outlet weir. Unimproved inlets restrict flow into culverts. By contrast, bell, re-entrant, or side-tapered inlets are more efficient and allow culverts to fill completely—a condition necessary for optimal diffuser functioning. Typically, an outlet weir is necessary to submerge the diffuser outlet; submersion is necessary to establish the partial vacuum that has been documented at the entrance of the outlet diffuser (*1*). This decreased pressure (or recovered head) is responsible for the increased capacity and efficiency of the culvert system.

The central feature is the outlet diffuser, a slightly flared section of pipe, and its design is critical to the functioning of the diffuser system. If the flare angle is too great and the expansion too rapid, the flow detaches from the diffuser wall, the partial vacuum is not established, and the diffuser fails to be effective. Figure 1 shows the design of the prototype diffuser that was installed in Thorndike, Maine.

Maine DOT research required a way to determine flow rates and monitor the operation of the diffuser system during high-flow events. The drawdown technique developed to meet this need involved plugging the culvert with a mooring ball, allowing the inlet water to pond until it reached an adequate depth, and pulling the mooring ball out of the culvert inlet with an attached chain and come-along. At selected water elevations, the instantaneous change in water level was combined with the surface area of the ponded water to determine the flow rate. This method simulated a high-flow event, allowing the diffuser operation to be observed and tested safely at a predetermined time.

Maine DOT published the design details, protocol, and method of calculation in the research report *Outlet Diffusers to Increase Culvert Capacity* and holds a patent for the diffuser system (*4*). This keeps the research in the public sphere, facilitating the continued deployment of diffusers on highway culverts by state and federal agencies.

(a) (b)

FIGURE 2 Thorndike diffuser in operation during high-flow events.

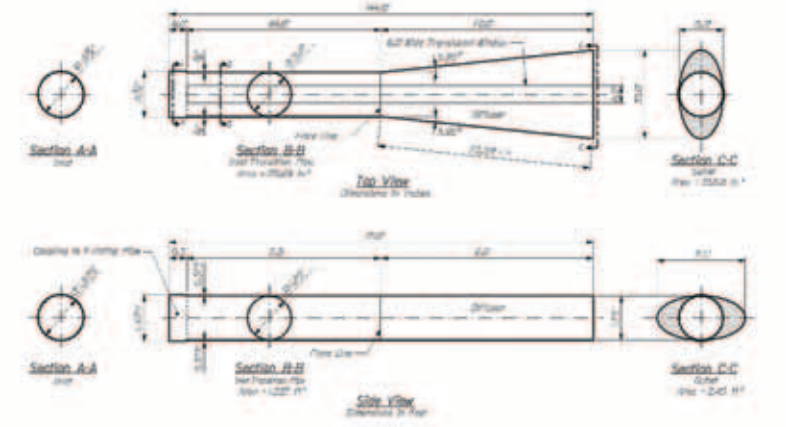

FIGURE 1 Design of the diffuser installed in Thorndike, Maine.

Application

Diffusers have been built, installed, and tested in Thorndike and Mattawamkeag, Maine. The Thorndike diffuser was installed in September 2015, tested in 2016, and has been monitored since then. Figures 2a and 2b show the Thorndike diffuser in operation and illustrate the necessary submergence of the outlet. This diffuser was left uncovered to allow the observation of attached flow—indicative of effective operation—through the translucent window at the top of the pipe and diffuser (Figure 2a).

The Mattawamkeag diffuser was installed in September 2018 (Figure 3). This culvert was tested before and after installation.

The Federal Highway Administration created a culvert analysis program, HY-8, to analyze culverts and create performance curves (*6*). The graph in Figure 4 shows

FIGURE 3 Mattawamkeag, Maine, diffuser installation.

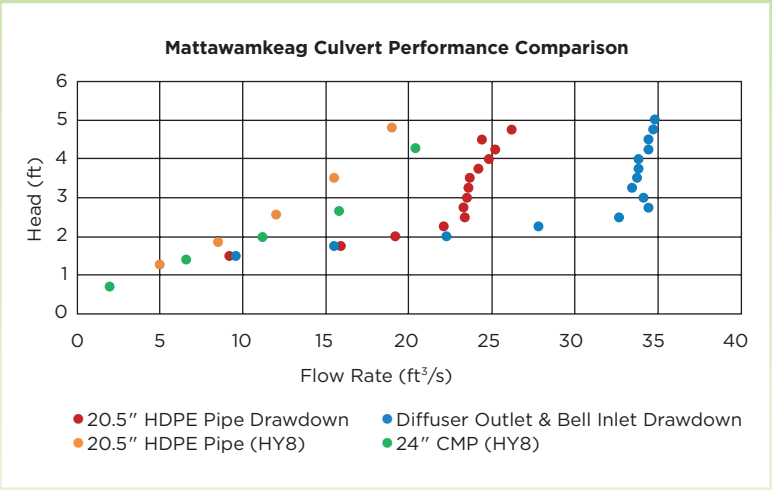

FIGURE 4 Performance of the original 24-inch projecting CMP (*green*) and 20.5-inch slip lined pipe (*orange*), compared with the measured performance of the slip lined pipe before (*red*) and after (*blue*) the installation of the diffuser outlet and bell inlet.

performance curves generated by HY-8 for the original 24-inch culvert before and after slip lining. These are compared with culvert performance curves obtained from drawdown measurements taken before and after diffuser installation.

The performance curves for the drawdown tests of the slip lined pipe and diffuser system are typical of data obtained from pressure flow. For a discussion and examples of this type of performance curve, see Blaisdell (*7*).

Using HY-8 calculated values, the slip lined culvert had a notable decrease in capacity relative to the original corrugated metal pipe (CMP) culvert because of the reduction in diameter from 24 inches to 20.5 inches. In the drawdown tests, the addition of the diffuser outlet and bell inlet significantly increased the capacity of the slip lined pipe and markedly exceeded the calculated values for the original 24-inch CMP. The increase in performance achieved by adding the diffuser was comparable to that found in Yarnell's testing of diffusers.

Benefits

Many benefits are associated with an effective diffuser installation. These include the following:

- Properly installed diffusers increase the flow rate in existing or slip lined culverts.
  - — A lower inlet water level is associated with a given flow rate.
  - — The risk of the road overtopping is reduced.
  - — The risk of adjacent land flooding is reduced.
- The flared outlet reduces the outlet water velocity, which in turn reduces the amount of outlet scour and channel degradation associated with high-velocity flow.
- For deep culverts, the cost of slip lining and installing a diffuser is significantly lower than the cost of replacing the pipe.
- The installation is relatively simple and often can be accomplished by maintenance crews.
- Traffic control typically accounts for one-third of project costs. Because work is performed at the inlet and outlet of the culvert, traffic is not disrupted.
- Because work is performed inside and adjacent to an existing culvert, utilities are not likely to be affected.
- Replacement of failing or undersized culverts with oversized culverts will result in increased peak flows downstream. A diffuser installation provides a compromise between the problems created by an undersized culvert and the problem of downstream impacts from an oversized culvert.

For more information, contact Alexander Mann, Maine Department of Transportation, SHS 16, Child Street, Augusta, Maine 04333, 207-215-6328, Alexander.Mann@maine.gov.

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Dale Peabody

Maine Department of Transportation

Dale Peabody began his career at Maine Department of Transportation (DOT) in 1983 as an assistant engineer in the Bridge Design Division, conducting inspections for bridge maintenance, design, computer-assisted drafting implementation, and more. "In college, I really liked the structures and materials classes, so starting out designing bridges was ideal," he recalls, adding that bridges remain his favorite area of research.

It was when he took a new position as an assistant research and development engineer that Peabody grasped the significance and complexities of asphalt. "I quickly learned that there's more to transportation than bridges and that highway construction is more than 'dirt and tar,'" he notes. "We spend millions of dollars just in my agency on hot-mix asphalt pavements each year, and performance of this material can be highly variable and is very dependent on good practices."

A registered Professional Engineer in the State of Maine, Peabody now is Director of the Research and Innovation Office at Maine DOT. He focuses on developing, coordinating, and implementing the agency's research program, from budgets to project coordination to policy recommendation. Much of his career has focused on putting research, new technologies, and innovations into practice; his agency often partners with his alma mater, the University of Maine. "University of Maine's work on use of fiber-reinforced polymer (FRP) composites and Maine DOT's leadership in trying and adopting FRP technology is leading to a real transformational technology," he observes. "These materials have been used for years in other infrastructure sectors—like shipbuilding and space travel—but much more work is needed, including education and outreach, for it to become commonplace in our transportation infrastructure." Peabody has worked on testing and adoption of FRP in girders, beams and arches, drainage structures, piles, and more.

Another focus at Maine DOT is workforce development. Recently, Peabody has been working to increase research engagement by younger engineers and professional staff, including attending Transportation Research Board (TRB) conferences and participating on Cooperative Research Program panels. "For all of the younger professionals, especially those in public service, I recommend getting involved in different aspects of your agency and in organizations like TRB to further your professional development," Peabody adds.

Soon after his first TRB Annual Meeting, Peabody joined the Quality Assurance (QA)

"Many state DOTs are recognizing that creating a culture of innovation can be a great way to get staff engaged in new things, provide individual professional growth, and show agency commitment to improvement."

Management Committee. Colleagues he met through the group helped Maine DOT implement QA specifications. Peabody also is a member of the Innovative Highway Structures and Appurtenances Committee. His commitment to research continued with membership in the TRB Technology Transfer and Conduct of Research committees, which have since merged into the Research Innovation Implementation Committee, promoting best management practices for improving research programs and delivery into practical results.

Peabody serves as chair of the American Association of State Highway and Transportation Officials (AASHTO) Research Advisory Committee (RAC) and as vice chair of the Special Committee on Research and Innovation (R&I), which selects projects each year for the National Cooperative Highway Research Program. "RAC provides support to R&I but mostly serves as an extremely active committee of state DOT research managers who want to improve their programs by learning from each other," Peabody comments. "I consider many of the current and retired RAC members my mentors when it comes to management of a research program."

Peabody also helped create a group within RAC, the Value of Research Task Force, to collect examples of successful state DOT research projects and to promote and celebrate them through AASHTO and TRB. In the 10 years since its founding, the task force has recognized more than 1,000 research projects as having made a difference in transportation.

"Many state DOTs are recognizing that creating a culture of innovation can be a great way to get staff engaged in new things, provide individual professional growth, and show agency commitment to improvement," Peabody observes.

Formal channels for learning about and adopting new technologies and methods, such as the Federal Highway Administration's (FHWA's) Every Day Counts Initiative and Statewide Transportation Innovation Councils, are important, he adds, but "equally important are the grassroots innovations occurring without much notice, like maintenance crews devising a better way to change plow blades or a safer way to set up and take down temporary work zones."

Peabody received an FHWA Transportation Excellence Award in 2003 and an AASHTO 25 Year Public Service Award in 2010.

Angela Newland

Retired, CCI Engineering Services, Inc.

After **Angela Newland** graduated from The Ohio State University, she had no idea that her civil engineering degree—with a major in transportation—would lead her into aviation. "The first half of my career was focused on highway, bridge, and stormwater project management," she notes. "During that time, I was heavily involved in the National Society of Professional Engineers and eventually became the first female president of its Ohio branch. That involvement exposed me to professional networking, which eventually led to an engineering management role at Port Columbus International Airport." Since following that career redirection, Newland has never looked back. "I enjoyed the variety of challenging projects and work assignments that the aviation industry offered me," she adds. "I spent 16 years of my career in airport planning and engineering executive management roles."

Newland recently retired from CCI Engineering Services in Fort Myers, Florida, where she served as Senior Project Manager responsible for business development, marketing, proposal writing, and quality control. She was Project Manager for the Port of Seattle Building Information Modeling Process and Standards contract and performed the quality control review for the airside design projects at Hartsfield–Jackson Atlanta International Airport and Jacksonville Airport Authority's Cecil Field Airport in Florida. Through the course of her aviation career, Newland has managed airport facility expansion and economic development programs of more than $1 billion. She has developed and implemented several sustainability and energy efficiency initiatives. She also coauthored *Airport Cooperative Research Program (ACRP) Research Report 214: BIM Beyond Design Guidebook*. But, of all of her career accomplishments, she is most proud of having been the Broward County Aviation Department's Program Executive for the Fort Lauderdale–Hollywood International Airport's new runway, a project that ran from 2009 to 2013.

"This $791 million project involved the design and construction of an 8,000-foot runway over an existing railroad and highway on the south side of the airport," she explains. "Time was of the essence in completing the project and within the established budget. Thanks to the cooperation and dedication of hundreds of people, we reached that monumental goal."

"A challenging and rewarding career is important, but maintaining a balanced life also is important."

Throughout her career, Newland has made a practice of using solid research to achieve her objectives. "Current research into best practices in the transportation industry is critical to the effective, efficient, and economical resolution of the many issues industry stakeholders face," Newland observes. "In the aviation industry, the management and operational challenges are diverse and complex. ACRP reports help airport managers and other stakeholders tackle these challenges with fewer resources, in a timelier manner, and with greater knowledge of the best options for addressing those challenges."

Since 2007, Newland—a registered Professional Engineer—has served as chair of five ACRP project panels, including the panel on Developing an Airport Wayfinding System for the Elderly and Persons with Disabilities, the panel on Research Roadmap on Policy and Planning Issues, and, most recently, the panel on Airside Planning, Design, and Operations: Electronic Resource Delivery. She was an ACRP Ambassador from 2014 to 2015 and has been an Ambassador Emeritus and Mentor since 2016. Newland also has been an involved member of the Airports Council International Operations and Technical Affairs Steering Committee, the American Association of Airport Executives, the American Public Works Association, and the American Society of Civil Engineers. Among her many awards are the Ohio Society of Professional Engineers (OSPE) Citation Award and the OSPE Engineering Management Award.

Although Newland fully commits to her volunteer work, she believes in keeping everything in perspective. "Be selective in what jobs, organizations, and extracurricular activities you pursue," she advises. "A challenging and rewarding career is important, but maintaining a balanced life also is important. By using the Transportation Research Board's research to help you perform your job better, you will enhance your ability to achieve a balanced life and a successful career."

And, what advice does Newland offer young professionals entering her field? In two words: diversify and network! "Expose yourself to as many diverse work assignments as you can," she challenges. "It will not only give you a more well-rounded experience profile, but it will also help you identify where your professional passion lies. Networking with others in your field will allow you to find mentors and colleagues who can help guide you in your career and expose you to new career opportunities."

INFLUENCERS

Naomi Stein

Naomi Stein is Principal, EBP, Pittsburgh, Pennsylvania. She is a member of the Standing Committee on Economic Development and Land Use, former cochair of the Young Members Council Planning and Environment Group, and is involved in the Young Members Council Coordinating Committee and the development of the young member involvement strategy for the new Sustainability and Resilience Group.

How did you first hear about or become involved in TRB?

I was an undergraduate at the Massachusetts Institute of Technology, serving as a teaching assistant to Professor Joseph Sussman and simultaneously in the process of becoming more serious about pursuing a career in transportation. He was a tireless Transportation Research Board (TRB) volunteer and a personal mentor who first introduced me to TRB and encouraged my involvement.

How has TRB informed your career so far?

The TRB Annual Meeting is directly responsible for my current professional position. I was browsing a poster session at the meeting and struck up a conversation with Stephen Fitzroy, who was presenting on work by EDR Group (now EBP) on high-speed rail and economic development. High-speed rail was the focus of my master's thesis, so we had a lively conversation. After the annual meeting, I followed up with Steve via email, learned more about the company, and the rest—as they say—is history.

What was one of your most memorable Annual Meeting moments?

I'm going to cheat and give you two. First, the TRB Annual Meeting always provides memorable opportunities to reunite with friends from school, fellowships, or my project work. Those connections—over lunch, dinner, coffee, or even just in the lobby—are something I love. Second would be the first time I sat in on a committee meeting, and, later, in a Young Members Council and TRB section meeting. TRB has a way of unfolding to you over time and gradually letting you understand the organization and leadership behind the posters, presentations, papers, and research projects. I'm still learning!

Transportation Influencers is a new section in *TR News*, highlighting the journey of young professionals active in TRB. Have someone to nominate? Send an e-mail to TRNews@nas.edu.

Doing Our Part for Diversity, Equity, and Inclusion

Don't miss Part 2 of the Transportation Research Board's (TRB's) blog series on transportation equity, which specifically highlights years of TRB research on travel accessibility for people with disabilities. The subject is timely since this year is the 30th anniversary of the Americans With Disabilities Act.

TRB also has been working with the Conference on Minority Transportation Officials (COMTO) to address the 12 items that compose the TRB–COMTO Memorandum of Understanding agreement. These items include collaborating and participating in each other's conferences, contributing to each other's magazines and newsletters, and making COMTO's members aware of opportunities for participation in TRB activities.

COOPERATIVE RESEARCH PROGRAMS

Artificial Roosts Provide Important Habitat for Bats Near Highways

NCHRP Project 25-25

ANN M. HARTELL AND DALE W. SPARKS

Hartell is Senior Program Officer, Transportation Research Board, National Academies of Sciences, Engineering, and Medicine, Washington, D.C., and Sparks is Senior Project Manager, Environmental Solutions and Innovations, Inc., Cincinnati, Ohio.

Many species of North American bats face challenges to their survival from the fungal disease White-Nose Syndrome, ongoing loss of natural habitat, and other impacts. Bats fill important niches in ecological systems and benefit humans because they consume insect pests and serve as pollinators. Transportation agencies can support bat populations and overall ecosystem health by avoiding, minimizing, or offsetting impacts from transportation infrastructure. The National Cooperative Highway Research Program sponsored a study to develop detailed information on a wide range of strategies that can be used to support bat populations and help agencies comply with environmental regulations that require protection for threatened and endangered bat species.

Photo: National Park Service

A tricolored bat is examined at the Chickamauga and Chatanooga National Military Park in Georgia. In the United States, bats face a number of threats, including climate change; habitat loss; collisions with wind turbines; and White-Nose Syndrome, a deadly fungal disease that is evident in this bat.

Photo: Dan Pancamo, Flickr

Batlike in its own right, the Frost Bank Tower in Austin, Texas, is a fitting backdrop for a colony of bats emerging from the Ann W. Richards Congress Avenue Bridge.

Because bats frequently use bridges as roosts, the research investigated bridge design elements that attract bats. These include niches, crevices, and materials that offer shelter and have the thermal properties bats favor. The research also reviewed the use of artificial roosts—or bat boxes—to evaluate the effectiveness of various designs and site choices. The analysis drew from existing research and a survey of transportation professionals.

The analysis was then used to develop a practitioner-friendly resource for understanding interactions between bats and transportation infrastructure. Titled *Bridging the Gap Between Bats and Transportation Projects: A Manual of Best Management Practices for Bridges, Artificial Roosts, and Other Mitigation Approaches for North American Bats*, the guide was published in 2019. It explains the essentials of North American bat ecology, including hibernation and migratory patterns, which can help agencies plan construction or maintenance activities during times of the year when bats will not be present. A section on recognizing bat habitat—on a bridge, in a culvert, on rocky roadcuts, or underground—explains how agencies can identify locations of bat populations and be better informed about how to design effective strategies that avoid negative consequences.

The manual describes a wide range of ways that agencies can mitigate negative effects and even enhance bat habitat. Various designs and materials for artificial

(Continued on page 60)

Bats by the Numbers

- Number of bats in the Congress Avenue Bridge bat colony in Austin, Texas: 1.5 million+/–
- Approximate temperature, in degrees Fahrenheit, a roosting site can reach before it is fatal to bats: 113
- Number of bat species in the 50 states: 41[1]
- Number of bat species listed as endangered or threatened by the U.S. Fish and Wildlife Service: 12[2]
- Total mass of insects typically consumed by a little brown bat in one night: 4 to 8 grams
- Width of crevice for roosting preferred by bats: 0.5 to 1.5 inches
- Number of vampires who have turned into bats: 0

[1] According to Bat Conservation International.
[2] According to the U.S. Fish and Wildlife Service, and in the United States and territories.

PROJECTS IN PROGRESS

MASH Railing Load Requirements for Bridge Deck Overhang

The University of Nebraska–Lincoln has been awarded a $440,000, 36-month contract [National Cooperative Highway Research Program (NCHRP) Project 12-119] to 1) propose modification to the American Association of State Highway and Transportation Officials (AASHTO)'s *Load and Resistance Factor Design Bridge Design Specifications* related to loading requirements of the *AASHTO Manual for Assessing Safety Hardware* (MASH) for bridge deck overhang and to 2) develop examples to demonstrate the application of the proposed modifications.

For more information, visit https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4753.

Proposed AASHTO Guidelines for Implementation of MASH for Sign Supports, Breakaway Poles, and Work Zone Traffic Control Devices

The University of Nebraska–Lincoln has been awarded a $500,000, 33-month contract (NCHRP Project 22-43) to develop guidelines for implementation of, and to propose modification to, AASHTO MASH for sign supports, breakaway poles, and work zone traffic control devices. Also included will be examples to demonstrate the application of the proposed guidelines.

For more information, visit. https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4775.

Guidelines for Applications of RFID and Wireless Technologies in Highway Construction and Asset Management

The University of Kentucky Research Foundation has been awarded a $370,000, 30-month contract (NCHRP Project 03-140) to develop guidelines for the applications of radio-frequency identification (RFID) and wireless technologies for highway construction and infrastructure asset management and to plan and conduct a workshop to introduce the proposed guidelines to transportation agency staff and other stakeholders.

For more information, visit https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4737.

Guidelines for Selection and Application of Manning's Roughness Values in Two-Dimensional Hydraulic Models

Pennsylvania State University has been awarded a $500,000, 30-month contract (NCHRP Project 24-49) to 1) develop guidelines for selection and application of Manning's roughness values in 2-D hydraulic models for transportation-related riverine settings and to 2) propose modifications to the *AASHTO Drainage Manual*; the Federal Highway Administration's (FHWA's) Hydraulic Design Series No. 7: Hydraulic Design of Safe Bridges; and FHWA's *Every Day Counts 2-D Hydraulic Modeling Reference Manual*.

For more information, visit https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4790.

AASHTO LRFD Design, Installation, and Standard Practice of Testing for Cured In-Place Pipe (CIPP) Liners

Golder Associates, Inc., has been awarded a $370,000, 33-month contract (NCHRP Project 18-20) to develop 1) an AASHTO guide for design and installation of CIPP liners for structural rehabilitation of existing pipelines and conduits, including design examples, and 2) an AASHTO standard practice for test methods for CIPP liner technology.

For more information, visit https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4769.

(Continued from page 59)

bat roosts are described. For common types of artificial roosts, the manual presents information about the relative cost and the degree to which bats are known to use each design. This information is presented in graphic format, allowing practitioners to compare design options and select the most cost-effective design for a given context. The manual also includes detailed information about elements appropriate for new bridge designs and for retrofitting existing bridges to provide habitat for bats.

Once mitigation measures are in place, agencies need to follow through with a program to monitor whether the measures are successfully attracting bats. To do this, bat biologists collect information about the presence and behavior of bats with specially designed traps or nets, routine inspection of structures to check for evidence of bats, devices to detect ultrasonic bat calls, and even radio tags that can be used to track bats as they move.

The research provides transportation professionals with evidence-based guidelines to protect and conserve bat populations year-round.

For access to the research report, the practitioner manual, and a set of presentation slides, visit https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4098.

2021 Transportation Research Board Annual Meeting Is Going Virtual

The Transportation Research Board's (TRB's) 100th Annual Meeting (#TRBAM), originally scheduled to take place in Washington, D.C., will be conducted as a virtual event over a series of dates throughout January 2021.

In its traditional face-to-face format, TRBAM brings together more than 14,000 transportation professionals from all over the world. "If other virtual events are a good indication, we expect to surpass that total attendance for the 2021 TRBAM," said TRB Executive Director Neil J. Pedersen.

For more information, visit http://www.trb.org/AnnualMeeting/AnnualMeeting.aspx.

Seat Belt Reminders Effective

Photo: Brady Holt

Buckled up and ready to go, a crash dummy undergoes testing at the IIHS Vehicle Research Center in Ruckersville, Virginia.

Seat belt reminders are as effective as interlock systems for promoting belt use and are less able to be circumvented, according to a 2019 report from the Insurance Institute for Highway Safety.

Researchers conducted two studies to examine the best way to encourage belt use. In one study, 49 participants—considered part-time belt users—drove vehicles with either an interlock system or one of three audible belt reminders. The audible reminders chimed at a minimal rate, for 100 seconds, or indefinitely. The interlock restricted speeds to 15 mph while the driver or front seat passenger was unbelted. The interlock, 100-second alarm, and indefinite alarm all increased seat belt use by 30 percent.

To read more, visit https://www.iihs.org/iihs/sr/statusreport/article/54/3/3.

More Electric Vehicles Could Mean More Funding

Increased sales of zero-emission vehicles (ZEVs) raised concerns of a transportation funding deficit along with decreased gas tax revenues, but a recent study shows that accelerated adoption of electric vehicles could increase transportation funding.

Researchers at the Mineta Transportation Institute examined taxes and fees collected by the state of California through gas sales and road improvement fees. Projections were made using scenarios that included state population, the number of vehicles and vehicle miles traveled, fuel prices, and adoption rates for ZEVs. Although a slower adoption of ZEVs did result in lower transportation revenues because of the reduced gas tax income, accelerated adoption of these vehicles increased revenues via greater improvement fees, primarily because of the higher cost of ZEVs.

The projections did not account for the possibility of significant population decreases or of ZEV pricing, which would influence the outcome.

To read more, visit https://transfersmagazine.org/2019/08/01/do-more-evs-mean-less-transportation-funding-not-so-says-new-study/.

INTERNATIONAL

Electric Buses Cost More than Anticipated

Many cities are electrifying their bus fleets. Two reports from the World Resource Institute examines efforts by 16 cities across the world that are in the process of adopting e-buses and analyzes the major barriers the cities face.

Researchers focused on cities that were early in the planning stages and on those in pilot programs, as well as on two Chinese cities that have fully electrified their fleets. The biggest barrier that planners face, the researchers found, is looking beyond the transportation sector. Electric vehicles require significant power-grid updates and charging infrastructure, which can be a costly and land-consuming obstacle for cities. One of the Chinese fleets, for example, uses enough energy in one charge to power 1,200,000 homes.

The reports explore the challenges, unforeseen costs, and stakeholder requirements to move a fleet from pilot mode to fully electric and offers a roadmap for transit officials, utility companies, and operators through each stage.

To read more, visit https://www.citylab.com/transportation/2019/06/electric-bus-china-grid-ev-charging-infrastructure-battery/591655/?utm_source=twb.

Guide Specification for Service Life Design of Highway Bridges, 1st Edition

This American Association of State Highway and Transportation Officials (AASHTO) guide specification offers design recommendations for agencies wishing to implement service life design principles and detailing recommendations. It incorporates quantitative approaches and proven deemed-to-satisfy provisions into a single comprehensive design document for implementation on a national level.

To purchase a copy, visit the AASHTO Store online at https://store.transportation.org, and searching by the publication's item code: HBSLD-1.

Culvert and Storm Drain System Inspection Guide, 1st Edition

This guide provides inspectors with guidelines for routine condition assessment of culverts or storm drains and includes a reliable, reproducible method to rate the condition of all system components. This rating system enables qualified inspectors to assess common distress types, evaluate their severity, understand their significance, and assign a numerical condition rating.

To purchase a copy, visit the AASHTO Store online at https://store.transportation.org, and searching by the publication's item code: CSDIM-1.

Pipe Ramming, 2nd Edition

This manual presents the latest and best practices used by engineers and construction professionals for the design and construction of road and railroad crossings using pipe ramming technologies. The manual is based upon the results of case studies, workshops, project reviews, technical papers, and other information contributed by industry experts.

Edited by Glenn M. Boyce. American Society of Civil Engineers, 2020, 212 pp., $110, 978-0-7844-1560-3.

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

TRB PUBLICATIONS

Transportation Research Record 2674
Issue 3

In this volume, authors present research on such topics as optimum volume of freeway corridors, park-and-ride choice behavior in a multimodal network with overlapping routes, and roadway safety management in small municipalities.

2020; 354 pp. For more information, visit http://journals.sagepub.com/home/trr.

Transportation Research Record 2674
Issue 4

Among the topics presented in this volume are a statewide analysis of individuals' exposure to business establishments and active travel behavior, using resilience in risk-based asset management plans, and validation of bicycle level of traffic stress and perceived safety for children.

2020; 484 pp. For more information, visit http://journals.sagepub.com/home/trr.

Transportation Research Record 2674
Issue 5

A capacity-constrained network performance model for urban rail systems, frequency optimization models for reducing overcrowding discomfort, and a dynamic contract time determination system for highway projects are some of the topics explored in this volume.

2020; 684 pp. For more information, visit http://journals.sagepub.com/home/trr.

Traffic Forecasting Accuracy Assessment Research
NCHRP Research Report 934

This report focuses specifically on project-level traffic forecasts of public roads in the United

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.

States. It assembles the largest known database of traffic forecasts and reports empirical evidence on the accuracy of these forecasts and factors related to accuracy.

2020; 103 pp; TRB affiliates, $54.75; nonaffiliates, $73. Subscriber categories: highways, operations and traffic management, planning and forecasting.

Proposed AASHTO Seismic Specifications for ABC Column Connections
NCHRP Research Report 935

This volume develops AASHTO specifications for three types of precast column connections to facilitate accelerated bridge construction (ABC) implementation in moderate- and high-seismic regions.

2020; 254 pp; TRB affiliates, $76.50; nonaffiliates, $102. Subscriber category: bridges and other structures.

Guide to Ensuring Access to the Publications and Data of Federally Funded Transportation Research
NCHRP Research Report 936

The U.S. Department of Transportation (DOT) has essential requirements for researchers and research institutions requesting and receiving transportation-related federal research funds. This report assists state DOTs and other research organizations in complying with the U.S. DOT policy.

2020; 138 pp; TRB affiliates, $61.50; nonaffiliates, $82. Subscriber categories: administration and management, data and information technology, research.

Alternative Intersection Design and Selection
NCHRP Synthesis 550

Documented in this volume are the evaluation and selection processes within state DOTs for intersection projects. Roundabouts are the most widely implemented type of alternative intersection. Ninety percent of state DOTs surveyed reported having at least one working roundabout in their jurisdiction.

2020; 218 pp; TRB affiliates, $71.25; nonaffiliates, $95. Subscriber categories: design, highways, operations and traffic management.

Measuring Quality of Life in Communities Surrounding Airports
ACRP Research Report 221

This report addresses an emerging need for airports: taking a holistic look at how they affect their neighbors and how they can build stronger community relationships. Supplemental materials include a dataset, a quality of life assessment survey tool, and a sample quality of life assessment introduction PowerPoint.

2020; 124 pp; TRB affiliates, $58.50; nonaffiliates, $78. Subscriber categories: aviation, environment, planning and forecasting.

Data Sharing Guidance for Public Transit Agencies: Now and in the Future
TCRP Research Report 213

The research presented in this volume helps agencies make decisions about sharing their data, including how to evaluate benefits, costs, and risks. Many transit agencies have realized benefits from sharing their internal data sets, ranging from improved customer information to innovative research findings that help the transit agency improve performance.

To view this report online, visit www.trb.org/Main/Blurbs/180188.aspx.

Equity Analysis in Regional Transportation Planning Processes
TCRP Research Report 214, Volumes 1 and 2

This two-volume report is designed to help metropolitan planning organizations analyze and address equity effectively in long-range, regional, multimodal transportation planning and programming processes. The first volume is a guide to public engagement, and the second is a research overview.

To view this report online, visit www.trb.org/Publications/Blurbs/180936.aspx.

Attracting, Retaining, and Advancing Women in Transit
TCRP Synthesis 147

This synthesis explores the strategies that have been deployed in transit and other related industries in order to attract, retain, and advance women in a variety of roles. Critical first steps to ensure success in these areas are to remove barriers to entry and address challenges women face once employed.

To view this report online, visit www.trb.org/Publications/Blurbs/180392.aspx.

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Did You Know?

First-Ever Speeding Ticket

In 1896, Walter Arnold drove an electric-powered Benz automobile through the streets of Paddock Wood, Kent, England, at the not-so-breakneck speed of 8 miles per hour. This was, however, four times the legal speed limit—and Arnold also was breaking a traffic law that required a flag-waving escort walk alongside the vehicle at all times. He was issued a 1-shilling fine, plus costs.

Soon after, however, less restrictive laws were instated (the speed limit was changed to 14 miles per hour and an escort no longer was required). In November 1896, the Emancipation Run road race celebrated this change; now called the London to Brighton Veteran Car Run, it is the longest-running motoring event in the world.

Resources

London to Brighton Veteran Car Run. Wikipedia. https://en.wikipedia.org/wiki/London_to_Brighton_Veteran_Car_Run#1896_Emancipation_Run.

Sergeev, A. This Is the First Car to Ever Receive a Speeding Ticket. Motor1.com. May 11, 2017. https://www.motor1.com/news/145180/first-car-speed-ticket.

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 a 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 Stephen Maher at 202-334-2955 or smaher@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, Transportation Research Board, 500 Fifth Street, NW, Washington, DC 20001, 202-334-2986 or 202-334-2278, and lcamarda@nas.edu or cfranklin-barbajosa@nas.edu.
- Submit **graphic** elements—photos, illustrations, tables, and figures—to complement the text. Images must be submitted as TIFF or JPEG files and must be at least 3 in. by 5 in. with a resolution of 300 dpi. Large photos (8 in. by 11 in. at 300 dpi) are welcomed for possible use as magazine cover images. A detailed caption must be supplied for each graphic element.

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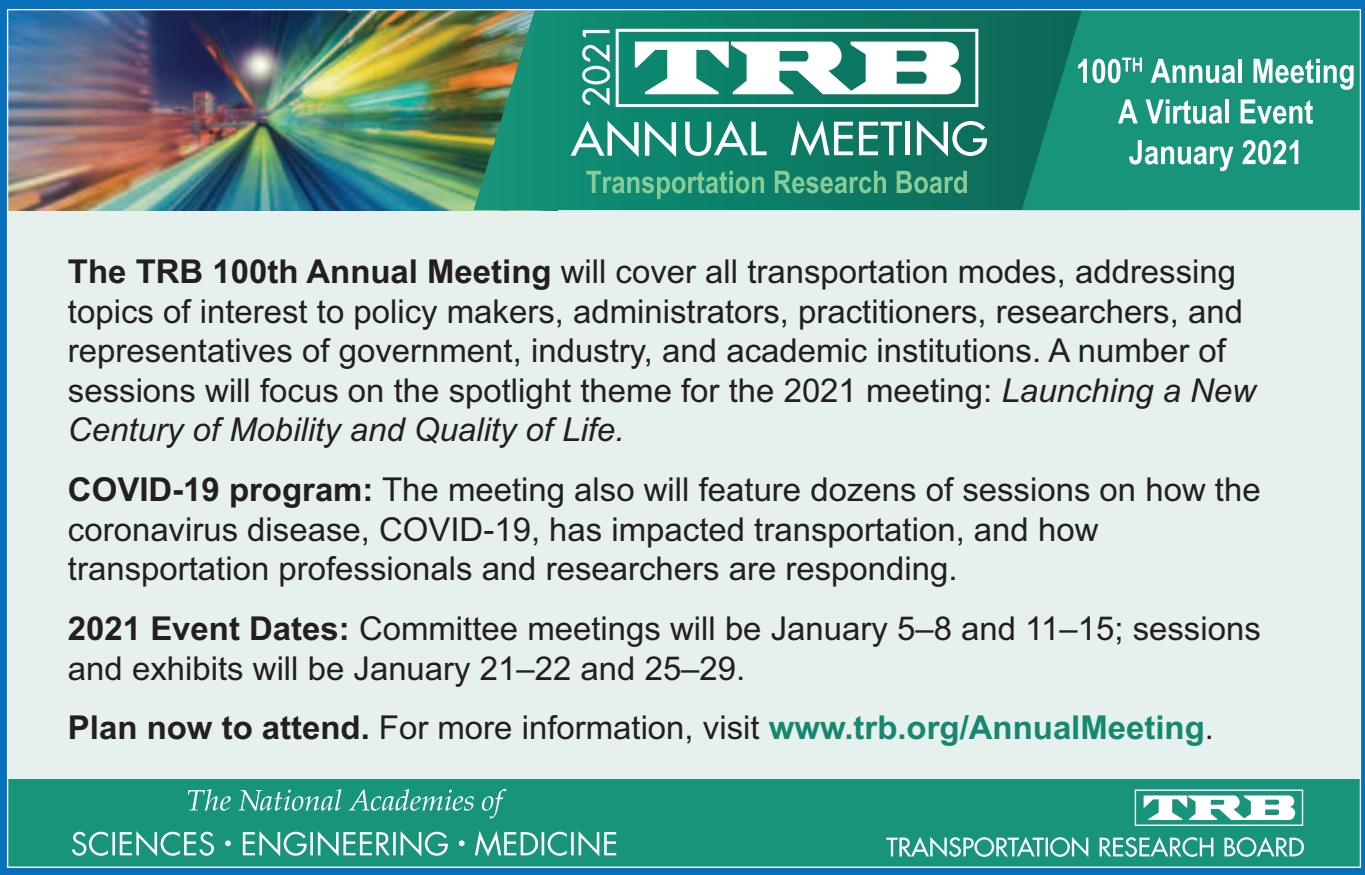

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