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SEPTEMBER–OCTOBER 2017

TR NEWS

Transportation Systems Resilience

Preparation, Recovery, and Adaptation

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TRANSPORTATION RESEARCH BOARD 2017 EXECUTIVE COMMITTEE*

TR NEWS

NUMBER 311 SEPTEMBER–OCTOBER 2017

TRANSPORTATION SYSTEMS RESILIENCE

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COVER: Texas National Guard conducts search-and-rescue operations during Hurricane Harvey in Houston, Texas. Articles in this issue examine how communities and transportation systems can prepare for, respond to, and recover from adverse events. (Photo: Zachary West, Texas Military Department)

TR NEWS

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

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ALSO IN THIS ISSUE:

COMING NEXT ISSUE

How can the Port Authority of New York and New Jersey remake, redesign, reconfigure, and reinvent one of its central, vital transportation hubs, the aging Port Authority Bus Terminal in densely developed Midtown Manhattan? A special feature in the November–December *TR News* by distinguished researcher and longtime TRB leader Martin Wachs details the lessons learned and problems solved—and unsolved—by entries in a design competition to re-envision the essential transportation facility. Another feature follows up on the innovations presented by participants in the TRB Six-Minute Pitch Competition since 2013 and finds inspiring successes. Other articles describe policy studies related to transportation by other units of the National Academies in conjunction with TRB—on commercial motor vehicle driver fatigue; the research program of the U.S. DRIVE Partnership; and transportation's role in assuring health equity for communities; plus highlights from the U.S. Surgeon General's call to action for walking and walkability.

PHOTO COURTESY MARTIN WACHS

An international design and development competition for a new Port Authority Bus Terminal in New York City offered many lessons—about policy and decision making, the bus terminal's history and future, and competitions involving transportation facilities. (*Above:*) The terminal's heavily trafficked bus ramp after dark.

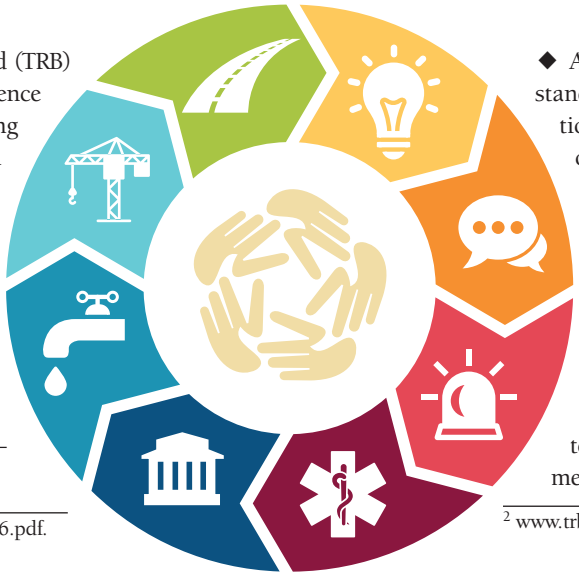
INTRODUCTION

Transportation Systems Resilience

Lessons Learned in Planning, Engineering, and Operations and Management

In 2015, the Transportation Research Board (TRB) formed the Transportation Systems Resilience Section, which comprises three standing committees that focus their activities on infrastructure protection, business continuity and disaster logistics, and emergency evacuations research. This theme issue of *TR News* is part of a yearlong, coordinated release of implementation-ready information and resources on transportation systems resilience, including a Transportation Research e-Circular as a compendium to this issue.[1]

Other transportation systems resilience–related activities include the following:



◆ At the 2018 TRB Annual Meeting, the standing committees in the Transportation Systems Resilience Section will offer three workshops: a workshop on developing a resilience research road map, a workshop tackling cybersecurity, and a tabletop exercise exploring community response coordination, as well as a special session examining the impacts of the 2017 hurricanes. All registered attendees are encouraged to add these events to their annual meeting program agendas.[2]

[1] http://onlinepubs.trb.org/onlinepubs/circulars/ec226.pdf.

[2] www.trb.org/AnnualMeeting/Program.aspx.

Photo: Zachary West, Texas Military Department

In September 2017, Hurricane Harvey inundated parts of eastern Texas with a record 51 inches of rain. Effective evacuations, infrastructure preparedness, and community connections have been keys to recovery.

Photo: New York City DOT

Extensive coordination of businesses and local, state, and federal agencies facilitates resilience from natural disasters like Superstorm Sandy.

◆ TRB is creating a Resilience and Sustainability Task Force, chaired by Vicki Arroyo, Georgetown Climate Center, to explore the intersection of resilience and sustainability programs within local and state transportation agencies.

◆ A Resilience Summit and Peer Exchange in October 2018 will bring together state DOT leaders; representatives from committees of the American Association of State Highway and Transportation Officials, TRB, and the National Institute of Standards and Technology; industry representatives from the energy, water, cybersecurity, and telecommunications sectors; and more.[3]

[3] Visit www.transportation.org or www.trb.org for more information.

"Resilience is the immune system of our nation," said U.S. Coast Guard Admiral Thad Allen. Allen commanded the response and recovery activity after the 2005 Hurricane Katrina disaster; the storm's damage was so devastating that national leaders considered abandoning the city of New Orleans, Louisiana.[4]

Cognizant of the need to examine the resilience of the transportation system, members of Transportation Systems Resilience Section committees collaborated to establish the section's mission and discussed the effect of disasters like Hurricane Katrina on communities like New Orleans. An examination of the reasons that communities fail, the causes of the devastation resulting from hurricanes and other extreme events, and the mistakes made in planning, engineering, and operations and management has been launched. A look at response and recovery efforts by section committees revealed additional discoveries.

To survive, communities depend on five lifeline functions and services: transportation; communications; energy; water and wastewater; and civic groups and associations—churches, clubs, schools, halls, and more. The articles in this issue of *TR News* and the upcoming e-Circular provide a snapshot of the research issues involved in understanding and implementing transportation systems resilience.

—Thomas Wakeman, Chair
Transportation Systems Resilience Section

[4] www.nola.com/environment/index.ssf/2015/06/national_disaster_response_sho.html and www.nap.edu/read/18411/chapter/3.

The U.S. Coast Guard rescues Hurricane Katrina survivors. The 2005 hurricane caused $100 billion in damages and the loss of more than 1,800 lives.

Photo: U.S. Coast Guard

Note: The TR News *Editorial Board thanks William Anderson, TRB Senior Program Officer for Management, Policy, and International Relations, and Jon Meyer, member of the Transportation Systems Resilience Section, for their work in assembling and developing this issue.*

Photo: Jocelyn Augustino, FEMA

Governance and Resilience

Challenges in Disaster Risk Reduction

THOMAS WAKEMAN, JOHN CONTESTABILE, GERALDINE KNATZ, AND WILLIAM B. ANDERSON

(*Photo above:*) Hurricane Katrina in 2005 resulted in a critical infrastructure collapse that has shaped the way agencies now prepare for natural disasters.

Human exposure to extreme weather events and to the global effects of man-made devastation is on the rise. From 2005 through 2015, disasters had an impact on more than 1.5 billion people, causing more than 700,000 deaths, 1.4 million injuries, and the destruction of 23 million homes (*1*).

The United Nations Development Program has attributed the increasing levels of disaster risk to poor governance combined with substantial population growth. Extreme weather phenomena—such as higher temperatures or intense precipitation, drought, or flooding—are projected to increase the numbers of people at risk. The development and application of good resilience governance can reduce the risks from disasters.

Evolution of Approaches

Emergency management, state security, community resilience, and infrastructure protection are contemporary concepts. Before the Cold War, states did not have offices of emergency management. The Federal Civil Defense Act of 1950 made each state's civil defense office primarily responsible for coordinating with its federal counterpart to share information on civil defense. By the 1980s, the role of state civil defense had expanded to address all hazards. States formed offices of emergency management to handle the increased responsibility for response and recovery.

Soon after the terrorist attacks of September

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Photo: State Archives of Florida

Millard Caldwell (*center*) was the first Administrator of the Federal Civil Defense Administration, organized by President Harry S. Truman in 1950.

11, 2001, states incorporated functions to address homeland security. The governmental reaction to Hurricane Katrina in 2005, however, revealed that the coordination of the responses to major disasters was ineffectual. The Katrina response deployed pre-emergency measures, followed by an ad hoc evacuation and security activities, but failed to meet the public needs. The applications of strategic leadership and the processes of governance not only were challenged but proved problematic, because they tended to be impulsive.

The White House and the Federal Emergency Management Agency therefore developed the Emergency Support Functions as part of the National Incident Management System. The goal was to delegate leadership roles to federal agencies and to facilitate coordination with related state agencies (2).

The U.S. Department of Transportation (DOT) was designated as a lead federal agency; state DOTs usually have the leadership role for all matters relating to transportation emergency management within the state. Transportation has far-reaching impacts on the structure and function of social and infrastructure systems. Communities typically identify transportation as a critical infrastructure sector—a lifeline—essential for bouncing back from any emergency.

Unifying Activities

How are agencies planning and coordinating so that programs and services meet communities' requirements for critical services and associated infrastructure? Regional and multijurisdictional planning and coordination are essential for increasing security and resilience.

A general framework is emerging for community resilience governance and decision making before and after disruptions. Strategies for making the best decisions to prepare for and to recover from disruptions quickly, to manage highly varied stakeholder groups, and to strengthen performance after the event are as yet conceptual.

Photo: Marty Bahamonde, FEMA

A lack of strategic coordination among federal, state, and local agencies created evacuation crises before, during, and after Hurricane Katrina.

These issues have made resilience a popular and pressing field for research. Applied research is needed to address the processes of governance and resilience by unifying government, community, and individual activities.

What Is Governance?

The word *governance* derives from the Greek *kubernáo*, to steer. When associated with public good—or the "general welfare" cited in the U.S. Constitution—the purpose and definition of governance evolves with the needs of the people.

The early framers of the U.S. federal government disagreed on the definition of general welfare. According to Alexander Hamilton, the term was an open invitation to unlimited federal governance, because almost anything the government wanted to do could be categorized as general welfare. Abraham Lincoln limited the term: "…[T]he legitimate object of government is to do for the community of people whatever they need to have done, but cannot do at all, or cannot so well do for themselves in their separate capacities" (*3*).

This view opened opportunities for federal advances in infrastructure, such as building highways, airports, and seaports. Federal investments in infrastructure for the public good have incentivized private-sector investment.

More than a century later, economists and political scientists have redefined governance somewhat, and institutions such as the United Nations, the World Bank, and business have disseminated the new meaning, which embraces the "policies, processes, and rules for decision making" (*4*).

Governance today, therefore, is not necessarily a wholly government activity. A government is a formal body invested with the authority to make decisions in a given political system, jurisdiction, or environment. In contrast, governance pertains to decision making within the context of organizational guidelines and processes.

These decisions are important both for physical infrastructure and for societal resilience. Infrastructure decisions and their implementation provide the basic physical structures and facilities—such as buildings, roads, and power generation—that organizations need for the operation of their enterprises and activities. The social fabric of community, regional, national, and international affairs is equally critical to consider in the governance of disaster response and risk reduction (*5–7*).

The governance process centers on a governing body, whether the organization is a geopolitical entity such as a nation–state, a corporation such as a business or organization established as a legal entity, or a sociopolitical entity such as a community, tribe, or family. Governance comprises the rules, norms, and actions that each governing body applies to produce, sustain, and regulate decisions.

The coordination of public-sector authorities to leverage broader public- and private-sector resources for the greater good is another form of governance. In the following discussion, the term governance refers to decision making and cooperation, whether by government or by private-sector stakeholders.

What Is Resilience?

People are the core of a community. Individuals often

Photo: Maryland GovPics, Flickr

Maryland's Emergency Management Agency coordinated critical services to aid recovery after Superstorm Sandy in 2012.

Photo: Seattle Municipal Archives

The Seattle Interstate Highway in 1963. The Interstate system and other federal investments in infrastructure have bolstered private-sector investments.

Photo: Avery Bristol, Florida Fish and Wildlife

State and local agencies joined community members to conduct search and rescue operations in Houston, Texas, after Hurricane Harvey in September 2017.

can recover to a near pre-event condition within hours or days, depending on the severity of the event and on their resourcefulness and agility. The American Psychological Association's Help Center describes resilience as "adaptation in the face of adversity" (*8*).

In other words, humans can be active after a major shock, helping one another to recover, and adapting to and coping with the surrounding chaos (*9*). Without the continuity of governance processes, however, people can experience social breakdown that will prolong the disruption and extend the period of recovery.

Disruptive events can cripple infrastructure and critical functions. In poorly governed communities, the chaos stemming from disruptive events negatively influences the decision-making environment, often stalling decisions and foiling the best intentions of the decision makers.

Similar to the term governance, resilience is undergoing a shift in its connotation. Resilience is commonly understood to mean withstanding or bouncing back from any hazard or disaster. According to the National Research Council, "Individual, community, and national resilience is the ability to prepare and plan for, absorb, respond to, recover from, and more successfully adapt to adverse events" (*10*).

Both definitions consider individuals and communities. The role of people in decision making is crucial for determining what needs to be resilient and what resilience means within the community or region.

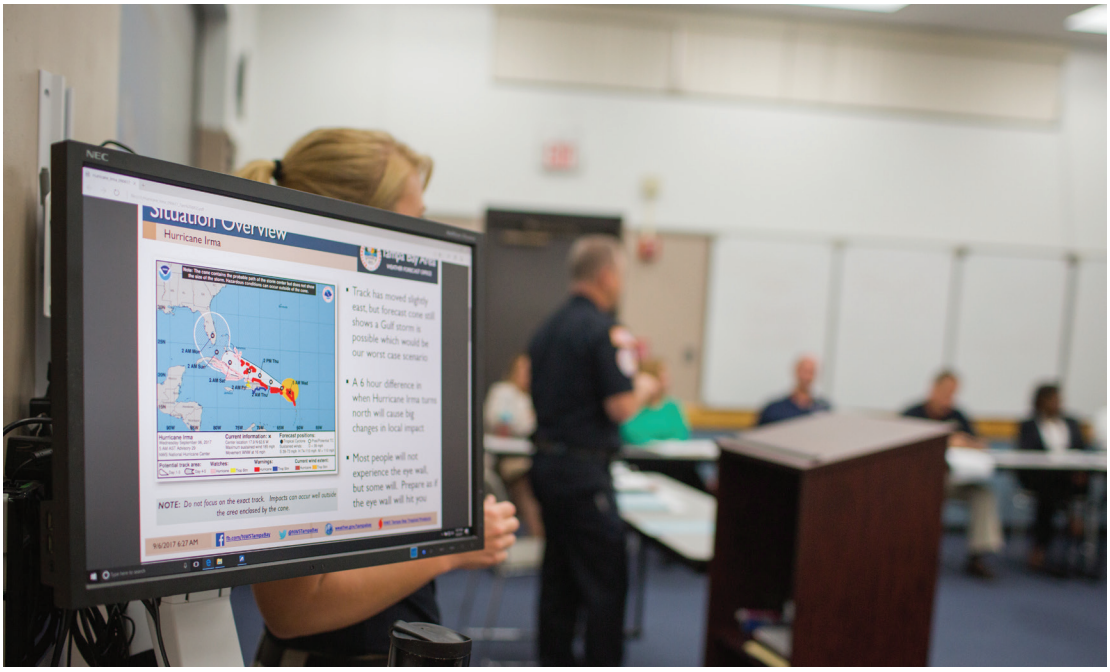
Photo: Christopher Mardore, Flickr

The Federal Emergency Management Agency partnered with local utility technicians to fix downed electrical lines in Rockport, Texas, soon after Hurricane Harvey.

Factors in Recovery

Planning for resilience occurs in government and in industry. The federal government has prepared continuity of operations (COOP) plans under National Security Presidential Directive 51, Homeland Security Presidential Directive 20, and the National Continuity Policy. These directives require an integrated, overlapping capability for continuity within the federal government. State governments also have prepared COOP or continuity of government plans for emergencies. Several studies under way are exploring governance and resilience in both the public and the private sectors, particularly for physical infrastructure resilience and recovery (*11, 12*).

Photo: CityofStPete, Flickr



The St. Petersburg Emergency Management team prepares for Hurricane Irma in September 2017. Resilience planning initiatives take place at all levels of government.

Human factors also are crucial in successful recovery. Private-sector companies that depend on supply chains, for example, have considered human factors in focusing on the best means to ensure employee stability and business continuity during disruptive events.

In general, most research has focused on physical infrastructure, and many government agencies have spent heavily to protect facilities and operations, with little regard for the associated social resilience (*13*). Better understanding is needed about how decisions are structured, made, and implemented before, during, and after disruptions, including process maps at the individual and community levels for both the public and the private sectors.

The National Institute of Standards and Technology (NIST), part of the U.S. Department of Commerce, has investigated community and social resilience (*14*). NIST has found that collaborative planning in communities can improve the management of specific disaster risks and reduce the impacts of hazards. The prioritizing of resiliency measures can improve a community's ability to manage responses to prevailing hazards, to restore vital services, and to build back after disruptive events (*12*).

Building Social Capital

In the context of disasters and emergencies, social capital helps determine a community's resilience (*15*). The Association of Neighborhoods and Housing Development, Inc., found that after Superstorm Sandy, strong social networks within many of New York City's communities enabled successful adaptation, response, and recovery (*9*). These social ties among people who knew and trusted one another emerged as a key factor in supporting restoration and recovery. Researchers in other locations also have found that social capital can hold a community together after a disruptive event (*16*).

The United Nations Development Program defines disaster risk governance as "the way in which public authorities, civil servants, media, private sector, and civil society at the community, national and regional levels cooperate…to manage and reduce disaster- and climate-related risks" (*17*). An Organisation for Economic Co-operation and Development

Direct Relief provides food and water to neighbors affected by Superstorm Sandy. Social capital—including physical and emotional support in times of disaster—is a key factor in community resilience.

Photo: Direct Relief/Flickr

TABLE 1 Disaster Characteristics

Characteristic	Lower Range	Lower Midrange	Upper Midrange	Upper Range
Temporal	Predictable or planned	Emerging	Rapid onset	Abrupt
Spatial	Local or community	Regional	National	International
Intensity	Low	High	Severe	Catastrophic

(OECD) study found that innovative risk governance can create resilience in the built environment and among stakeholders (*18*).

But what is innovative or good governance that increases resilience to disruptive events, and how should it be exercised? The OECD study identified several measures that can aid governments in boosting resilience—for example, inclusiveness, trust, cooperation, and sharing. These measures build social capital.

What then is the best way to incorporate the concept of social capital and its development into the formal governance processes that communities and other levels of government already have established?

Disaster Characteristics

Understanding the scale and character of a disaster is a first step in determining an appropriate framework for governance; a disaster's characteristics define its distinctive threats (see Table 1, above). Governance may operate within a single organization, community, multilayered agency, or nation or at an international level. The combination of disaster and governance necessitates consideration of each circumstance to develop the proper approach to governance.

A disruptive event proceeds through four phases: pre-event, disruption, recovery, and postevent (see Figure 1, below).

- The pre-event phase is relatively stable.
- The disruption itself is chaotic, with property damage and potential loss of life.
- Recovery is a period of rebuilding, but the physical environment—as well as the governance environment—is likely to be unstable and unreliable for many stakeholders.
- The postevent phase returns to normalcy, although productivity may be lower for a period.

Improved governance for resilience requires an understanding of these phases for each disaster.

Governance Characteristics

Governance frameworks can pose an obstacle to resilience. For example, governance and resilience at a seaport must function at the front line of sea level rise and global climate change. Private terminal operators may focus on preparedness for the next major storm or security event; in contrast, the port authority has broader and longer-term goals, such as adaptation to climate change.

Adaptation to climate change is not the same as preparing for the next major storm event but involves long-term strategies and long-term investments not likely to provide the terminal operator with an immediate return. The terminal operator's vision of long-term resiliency seldom extends beyond the remaining years on the lease.

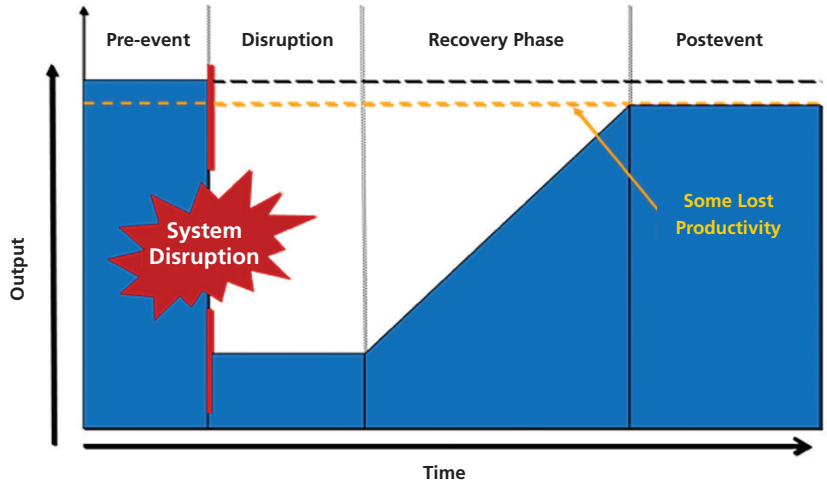


FIGURE 1 Resilience curve.

Photo: U.S. Army Corps of Engineers

To mitigate future flood risks in Ocean City, Maryland, the U.S. Army Corps of Engineers constructed a sea wall after Superstorm Sandy.

The port governance model must be integral to the effective implementation of a portwide resilience plan. Resilience planning within the seaport sector requires a thorough understanding of the motivations and goals of all the organizations involved and of the limitations of the port governance model. The ports that become the most resilient will have addressed the governance challenges directly, particularly in the context of lease agreements.

The governance and resilience environment of a coastal community and a neighboring military base, for example, must deal with the consequences of sea level rise. Community leaders may focus on mitigating the consequences of the next major storm, such as local flooding, and the military may have broader goals, such as mission assurance.

The military engineering division may address the risks by designing a sea wall to control water levels. Community leaders, however, may want to mitigate the risk of floods by installing a new drainage system to redirect flood waters away from housing—this is not the same as adapting to sea level rise with a sea wall. Nevertheless, both entities are spending resources to address the same regional disaster risk.

Typically a military base does not make decisions about mission assurance and resilience with consideration of the supporting community, nor does the community consult with the military base on community issues. If the community and military formed a regional governance body, how would risk reduction decisions be made?

The challenge in creating supportive governance frameworks is to address long-term adaptive strategies proactively to improve resilience instead of waiting until a crisis that forces decision makers to react. General models for governance to achieve resilience are still in development but should incorporate the characteristics of good or proper governance—such as disaster preparedness, resilience planning, cooperation, and consensus building at the individual and organizational levels (*19*). These characteristics enable individuals to react quickly and decisively when faced with a disaster (*9*).

Photo: Tim Pruitt, Texas National Guard

The Texas National Guard works with regional governments and local agencies to speed recovery from Hurricane Harvey. Supportive governance frameworks must address strategies proactively and coordinate community authorities and other groups like the military.

Photo: Metropolitan Transit Authority

The New York City Transit Authority moves subway cars to a new location to allow partial train service and repair tracks damaged by Superstorm Sandy.

Areas for Research

Good resilience governance addresses not only infrastructure protection and governmental responses but also the reaction and recovery of the people who are affected. Considerable evidence indicates that social capital is critical in enhancing the resilience of impacted communities, but additional research would help inform the extent to which social capital is needed.

More research also can provide insights into decision-making processes and organizational models for governments—at the regional, state, or community levels—and for private organizations to apply before, during, and after events. Research could identify desirable governance processes and guidelines for public- and private-sector collaboration to build community resilience.

As concerns increase about disaster risks and their potential impacts on world populations, research is needed to address questions and to advance answers about efficient and effective approaches to governance and resilience.

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Photo: National Renewable Energy Lab

Freight activity at the Port of Long Beach, California. Economic resiliency depends on business and supply chain continuity after disruptive events.

Supply Chain Business Continuity

A Framework for Proactive Resiliency Planning and Operations

ANNE STRAUSS-WIEDER

The author is Director of Freight Planning, North Jersey Transportation Planning Authority, Newark, New Jersey.

Resiliency planning and preparation have become increasingly crucial. Efforts can include identification of key infrastructure and personnel, emergency preparedness, formulation of working groups and operations centers, and disaster simulations.

By combining principles of resiliency and risk management in cost-effective, organized frameworks, business continuity planning offers a multifaceted approach that can augment company and agency resiliency efforts. Business continuity is defined as the "capability of the organization to continue delivery of products or services at acceptable predefined levels following a disruptive incident" (*1*). Such plans already are used by some public agencies, but primarily focused on preserving the continuity of the agency's specific operations.

Photo: Maryland GovPics, Flickr

The office of the Governor of Maryland participates in a hurricane preparedness event. Business continuity concepts can offer government agencies insights and guidance in resilience planning.

PHOTO: RAFAEL LOPEZ, JR., FLICKR

The New York City Department of Transportation (DOT) Emergency Response Center in Queens maintains infrastructure service continuity during Superstorm Sandy in 2012.

For public-sector agencies, ensuring the economic vitality of their region often is part of their mission. Within this context, business continuity principles can be applied to foster more resilient communities. When business continuity concepts are considered—particularly as they are used in supply chain evaluations—they can add to insights and guidance for government agency and community resiliency planning and operational efforts.

The term "supply chain" refers to all of the activities required to move a product from where it is produced to where it is consumed. Supply chains link companies together at three stages:

1. The supply of materials to a manufacturer,
2. The manufacturing process, and
3. The distribution of finished goods to the final customer through a network of distributors and retailers (*2*).

The business continuity principles and practices to ensure that supply chains are sustained before, during, and after disruptive events can be applied to enhance resiliency on a larger scale, by enabling regions and transportation operations to improve recovery in the short term and to reduce the longer-term impacts from such events. According to a DHL report, *Insight On: Risk & Resilience*, "82 percent of companies with effective business continuity management say that their programs have demonstrably mitigated the impact of disruptive events" (*3*, pp. 26–27).

PHOTO: WARREN ANTIOLA, FLICKR

Global supply chains were disrupted after an earthquake caused an explosion at a nuclear plant in Fukushima, Japan, in 2011.

Importance of Continuity

Business continuity is essential. Without stable services and movement of products, the financial health of individual businesses—as well as regional economic well-being—can be significantly and adversely affected.

For example, 30 percent of all companies that experience a catastrophic loss fail within the first two years after the event; another 29 percent shut down after that, according to John J. Brown, who directs risk management and supply chain and technical development for Coca-Cola. When businesses and industries fail or falter, the communities they serve can feel serious impacts that range from a lack of access to goods and services to the loss of income and jobs (*4*).

Business continuity goes beyond risk-management reviews of physical infrastructure to include assessments of suppliers, transportation mode and routing alternatives, and communication strategies.

The importance of an understanding of supply chains and of the roles and alternatives for suppliers became evident in the aftermath of the 2011 earthquake, tsunami, and nuclear disruption in Fukushima, Japan. Within days of the natural disaster, General Motors announced the temporary shutdown of a truck plant in Louisiana because the company was unable to obtain sufficient parts from its supplier in Japan (*5*).

At the time, according to a *New York Times* article, analysts had concluded that the plant closure was likely the first of widespread disruptions at North American auto plants (*5*). Because some auto manufacturers had relied on a single supplier in a single location for critical parts, entire production lines were affected.

Identifying Risks and Impacts

Business continuity programs are multifaceted—they embed resiliency and risk management into planning and operations. These assessments are continuous, rather than one-time exercises; they start with the identification of risks and impacts and then move to strategies for risk mitigation.

Risk mitigation can combine risk avoidance with responsiveness when a disruption occurs.

"Enhancing resilience really should be at the heart of any organization's purpose," says James

Photo: Rachel Clarke, Flickr

When the Fukushima nuclear explosion resulted in a nationwide energy crisis, vending machines were subjected to blackouts. Coca-Cola reengineered its vending machines in Japan to be more energy-efficient and contribute to resilience.

Crask of the International Organization for Standardization working group on risk management. "Awareness of potential vulnerabilities, adaptation to change, and the ability to turn threats into opportunities are means to ensure that a business not only survives, but thrives" (*6*).

Building a Better Vending Machine

No one can identify all of the possible risks, impacts, or outcomes; however, business continuity assessments and action plans can help create a roadmap to address issues when they occur and can even yield permanent, positive outcomes.

For example, Coca-Cola experienced an unanticipated situation after the Fukushima event. All but two of Japan's 50 nuclear power reactors were shut down by the disaster, requiring Japan to conserve a significant amount of energy.

Major energy users in the country were identified and targeted. Perhaps surprisingly, the nation's 5 million vending machines were identified as major energy users and were affected by scheduled blackouts. To maintain this major consumer channel, the companies operating the machines needed to make adjustments to the equipment to conserve power consumption (*7*).

Coca-Cola's nearly one million vending machines throughout Japan generated significant revenue for the company. Coca-Cola therefore had to reengineer the machines. The company ultimately developed vending machines that were far more energy-efficient than their predecessors as well as "specialized machines that could solicit donations for victims and be better equipped to dispense information, free drinks, and food (some of them using a hand-cranked system) during an emergency" (*7*).

Although vending machines may seem minor in the context of major disruptions, this example highlights the following:

- Disruptions can have significant and unexpected consequences, and
- Thoughtful responses can have short- and longer-term benefits that extend beyond the organization.

Risk Categories

Multiple organizations have identified risk categories or have developed detailed lists of potential risks. Such rosters can be developed and augmented over time. The top supply chain risk categories include the following (*8*, p. 5):

Photo: Cristian, Flickr

Volcanoes (*left*), hurricanes, tornadoes, earthquakes, and other natural disasters can disrupt supply chain continuity for many years.

FIGURE 1 Natural disasters, 2011 (*3*).

◆ **Natural catastrophes**, including Hurricane Katrina, the Fukushima event, the Haiti earthquake, Superstorm Sandy, flooding in Thailand, epidemics, volcanic activity, and tornadoes (see Figure 1, above). Such events can disrupt production lines, distribution facilities, suppliers, customer locations, and transportation options.

◆ **Manmade disruptions**, including labor actions, geopolitical disruptions, cargo theft or piracy, major accidents and explosions, hazardous spills, product tampering, and terrorist attacks. These events can have impacts similar to natural catastrophes.

◆ **Supplier risks** involving continuity issues with the supply of critical materials, which can directly affect production. Examples of supply risks include product availability, product quality, and the supplier's financial health, reliability, regulatory compliance, geographical location, and potential issues with second-tier suppliers.

◆ **Major information technology and cybersecurity failures** that have the potential to affect communication within the organization or externally with customers, suppliers, transportation providers, regulatory agencies, financial institutions, workers, and other core elements of production and product movement. A June 2017 cyber attack was among the largest disruptions ever to affect global shipping, with Maersk-run port terminals across the globe struggling for days to resume normal operations after the attack crippled their information technology systems (*9*).

◆ **Transportation failures** involving transportation facilities, modes, companies, or routes. Issues can include insufficient infrastructure and modal capacity; failures of modes or of infrastructure, either structural or financial; inconsistent travel times and continuous congestion; and infrastructure that cannot handle national or international standard equipment.

◆ **Quality issues** that can occur during product introduction, production, or distribution; these can lead to recalls and can damage an organization's reputation.

Understanding the Causes

The identification of potential risks is only one dimension. Understanding the factors that can cause a disruption and the potential consequences is equally important.

Some companies use a "bowtie" approach to identify and evaluate potential risks to business continuity (see Figure 2, above). One side of the bowtie focuses on identifying the causes of a disruption, and the other side assesses the consequences. This approach also encourages organizations to consider how to prevent certain disruptions and how to minimize the impacts of the disruptions.

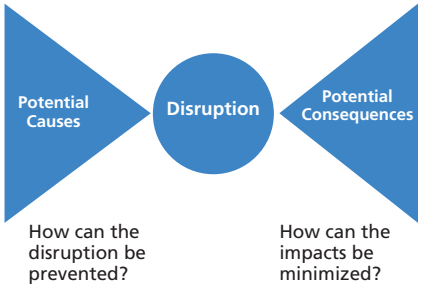

FIGURE 2 Bowtie approach to preventing disruptions and minimizing the impacts.

Organizations may also develop a "risk register" for specific products or facilities. A risk register summarizes information about identified product risks, analyzes risk severity, and evaluates possible solutions (*10*). As a living document, the risk register is revisited and updated regularly and often includes the following:

◆ A description of the disruption,
◆ The likelihood of the disruption,

Maersk-run port terminals worldwide experienced service disruptions after a 2017 cyber attack that incapacitated its technology systems.

PHOTO: MAERSK

- The potential severity,
- Possible consequences, and
- Mitigation actions and contingencies.

Building Resilience

Business continuity actively mitigates the impacts of potential disruptions. Bowtie analyses and the development of risk registers are ways to identify potential risks and methods of prevention. Unanticipated disruptions can occur, however.

The key attributes for a resilient supply chain—visibility, flexibility, collaboration, and control—offer a potential framework for public agencies (see Figure 3, right) (*11*).

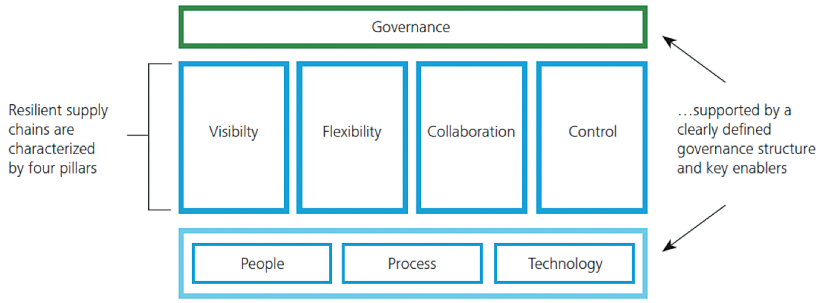

FIGURE 3 Resilient supply chain framework (*11*, p. 5).

Visibility

Visibility is the tracking and monitoring of supply chain events and patterns as they appear, enabling an organization or region to address issues proactively. Public agencies can begin by identifying how the key commodities in their areas move—including the modes of transportation used—as well as by projecting how these movements may occur in the future.

For example, the North Jersey Transportation Planning Authority (NJTPA) developed profiles of the key commodities in central and northern New Jersey and developed a freight forecasting tool based on regional economic models and multimodal freight uses. Each profile articulates the supply chain for the commodity and the location of related industries in the region. The project description notes that "understanding the freight logistics patterns within the region is critical for effective transportation planning and promoting the efficient movement of commodities in ways that support sustainability and quality of life in the region" (*12*).

Although individual companies monitor their own supply chains, public transportation and economic development agencies can track key industries and how they use freight modes, facilities, and routes. This understanding can help agencies prepare for and respond to disruptions and assist in enhancing community and economic resilience.

Flexibility

Flexibility refers to the ability to adapt to problems swiftly without significantly increasing operational costs—for example, shifting freight quickly among transportation modes, routes, facilities, and providers. Flexibility also can include the capacity to shift production among facilities within a company and to shift suppliers as needed. Supplier flexibility can address the type of disruption that General Motors and other auto manufacturers faced after Fukushima.

For regions considering the needs of critical industries and commodities, such flexibility plan-

Photo: Chris Tengi, Flickr

By monitoring commodity supply chains to track how industries move products, the New Jersey Transportation Planning Authority is working to create a better resilience framework.

Photo: Eric J. Chandler

Officers with the Marine Transportation System Recovery Unit worked in Port Au Prince, Haiti, to deliver aid and supplies after the 2010 earthquake.

ning can be equally important; for example, can companies "flex" and use alternative modes or routes if a portion of the regional transportation system goes offline? Energy companies with production facilities in remote areas can consider such locations to be more risky: "When problems do occur, limited infrastructure or logistics capacity in remote regions mean that companies often have few alternative supply options" (*3*, p. 23).

Collaboration

Collaboration is the ability to work effectively with supply chain partners to avoid disruptions and to achieve common goals. Similar collaborations have been and can be created between public- and private-sector entities, as exemplified by the U.S. Coast Guard Marine Transportation System Recovery Unit (MTSRU) and the Council on Port Performance (CPP) in New York and New Jersey.

The Coast Guard formed MTSRU in 2006 under the U.S. Maritime Transportation Security Act of 2002 and applied lessons learned from Hurricane Katrina. The unit "supports recovery efforts and ensures recovery is a critical element of planning at all levels. MTSRU members also identify communication mechanisms and informational requirements to facilitate the recovery of waterway traffic flow" (*13*). The public–private CPP was formed "to provide oversight on the implementation of programs and initiatives that will improve efficiency and service reliability in the Port of New York and New Jersey" (*14*).

When major disruptive events occur, private-sector entities that normally are competitors also may work together; for example, one railroad may allow another railroad to use its track to ensure the continued movement of critical cargo.

Common goals include helping customers and recognizing that, at another time, the situation could be reversed. After the Howard Street Tunnel fire disrupted CSX's rail freight service along the entire East Coast in 2001, the railroad was able to reroute time-sensitive trains onto track owned by Norfolk Southern:

> CSX was able to reroute six trains a day on Norfolk Southern's Hagerstown–Harrisburg–Reading corridor, including the famous Tropicana "juice train" carrying Florida orange juice to the New York–New Jersey market. . . . The railroad received help from its chief competitor, Norfolk Southern Corporation, as some CSX trains were diverted onto Norfolk Southern tracks. Other shipments were sent over alternate CSX tracks. "We cooperate with each other when we have problems like this," said Rob Gould, a spokesman for CSX. (*15*, pp. 16–18)

Photo: John H. Gray, Flickr

Norfolk Southern offered the use of its tracks to CSX's Tropicana "juice train" after a fire disrupted service. Collaboration between competitors can support recovery efforts.

Control

Robust policies, monitoring, and control mechanisms help ensure that procedures and processes are followed. Control can reduce risk exposure. For example, the Fukushima disaster disrupted auto supply chains for months because the Merck KGaA plant—the sole global source and stockpile of an essential pearl luster pigment, Xirallic—had to suspend operations (*16*).

Merck took control of the situation by opening a second production line for Xirallic in Germany and by stockpiling supplies at three globally diverse warehouse locations: Japan; Germany; and Savannah, Georgia (*17*). By taking control, Merck could retain its role as the premier supplier to automotive companies.

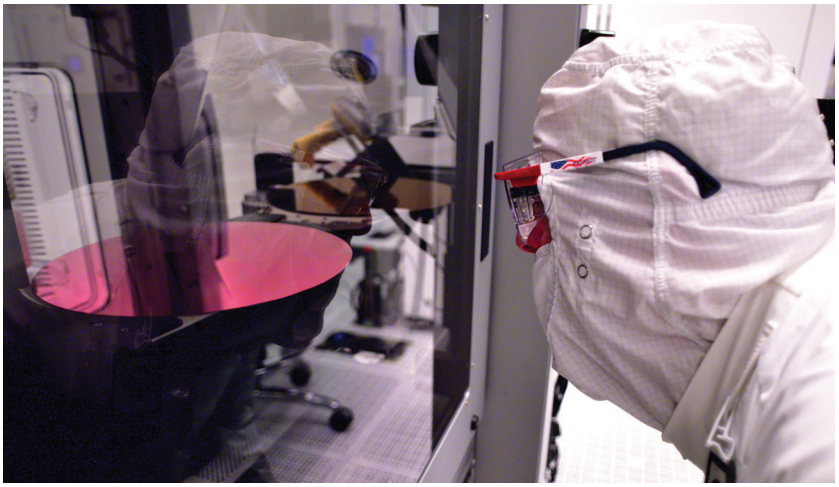

PHOTO: INTEL

Through risk management of its supply chain, Intel was able to mitigate disruption to silicon wafer production after the Fukushima nuclear disaster.

Continuity and Stability

Business continuity practices have created effective supply chains that can be sustained even through disruptive events. Moreover, continuity plans support the businesses that serve as economic engines and help communities thrive. After Fukushima, for example,

> a shortage of silicon wafers hit the global semiconductor industry. Intel, which had a sophisticated risk management approach in place before the disaster, was able to contain the disruption effectively and maintain production volumes. It reported a revenue increase of 22 percent in the months after the disaster, while competitors like Texas Instruments saw sales drop by 10 percent or more. (*3*, p. 41)

These outcomes reveal the economic benefits that are achievable for public agencies and regions. Business continuity principles, analyses, and plans—practical for private-sector operations and supply chains—provide ideas and guidance that can help areas and organizations support communities before, during, and after disruptive events, and help regions to continue to thrive.

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Hurricane Harvey's widespread flooding caused evacuation challenges, but clear communication, planning, and community action saved lives.

Photo: Florida Fish and Wildlife

Evacuation and Emergency Transportation

Techniques and Strategies for Systems Resilience

PAMELA MURRAY-TUITE, BRIAN WOLSHON, AND DEBORAH MATHERLY

Transportation is a fundamental support of society. Rail, road, water, and air networks provide the links for the movement of people and goods, delivering the food, fuel, housing materials and supplies, health care, and education essential to modern communities and economies.

Transportation systems generally operate under routine and predictable conditions, but incidents and events occasionally restrict capacity, generate sudden and wide-ranging surges in travel demand, and create unexpectedly hazardous travel. Although most commonly associated with disasters, evacuations, and other types of hazardous events, these disruptions more frequently occur as part of planned and unplanned events.

In the past, disasters and event conditions that brought unavoidable disruptions and that reduced transportation capacity were regarded as inevitable. Today, however, transportation professionals are taking a new view and are developing and applying policies, techniques, and technologies to increase the resilience and robustness of transportation networks.

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Resilience and Transportation

The Special Committee on Transportation Security and Emergency Management of the American Association of State Highway and Transportation Officials and the Resilient America Roundtable of the National Academies of Sciences, Engineering, and Medicine have defined resilience as "the ability to prepare and plan for, absorb, recover from, or more successfully adapt to actual or potential adverse events" (*1*).

Applied to transportation, resilience incorporates ways to work "smarter and more creatively" with

improved knowledge, training, and communication, adapting innovative, yet safe and effective, methods to maintain mobility and to serve the needs of travelers during nonroutine incidents and events.

Evacuations are an integral part of transportation systems resilience, widely regarded as an emergency response measure that supports protective action and decision making by authorities during catastrophic life-and-death emergencies. Nevertheless, many of the tools, techniques, and philosophies for the planning and management of evacuation traffic are applicable to incidents and events that affect the movement of people and goods—whether the events are large or small, planned or unplanned, long or short in duration, or covering large or small areas.

Techniques rely on the management of demand, the enhancement of capacity, and the improvement of communication, coordination, and resource allocation.

Evacuation and Resilience

An evacuation moves people away from a high-risk area to a safer area for the protection of life. Evacuation typically is effective in response to an advance notice of hazardous conditions. Evacuations also can occur spontaneously or under direction after a hazardous event or when dangerous conditions threaten. Post-event evacuations may occur with or without notice.

Evacuation also may be an adaptation to changing conditions, such as a coming threat or post-impact hazards. These conditions differ from the everyday and redefine normal behavior. How individuals should behave and interact in these settings is emergent and differs from established norms (*2*; *3*, p. 143).

Emergent norms of behavior have a parallel in the operation of transportation infrastructure. For large-scale evacuations and for some planned events, the roadway network can be operated in a different way from normal. One example is Evaculanes (see photos, below)—shoulders or center turn lanes that can be operated in the outbound direction to increase capacity (*4*).

Other temporary control and operational measures also can increase directional capacity away from a hazard. Each technique can be activated, terminated, and adjusted temporally and spatially in response to prevailing or anticipated conditions and can add resilience to the transportation network.

Photo: Trevor Manternach

Wildfires in summer 2017 forced residents throughout Montana to evacuate their homes.

Evacuation Behavior

Evacuation is a way to preserve life and to reduce injuries from a hazard, protecting a community's population and public health. The community plays a large role in the success of an evacuation and of the later recovery. Evacuation behavior affects a community's resilience.

Communication and Social Networks

A warning or evacuation notice is key in encouraging people to evacuate (*5*). Warnings are a social process and involve the interaction of the warning sources—such as an agency or person crafting and delivering the message (*6*, *7*)—with the message

Photo courtesy of Pamela Murray-Tuite

Texas DOT Evaculane shoulder pavement markings and signage, US-290 between Houston and Hempstead.

Photo: U.S. Navy

U.S. Navy personnel help limited-mobility patients to evacuate a hospital in the U.S. Virgin Islands after Hurricane Irma in 2017. At-risk individuals rely on social contacts and trustworthy agency sources to learn about evacuation warnings.

receivers, as well as the interaction of the receivers with each other, and of the receivers with their social networks—not necessarily via social media.

Individuals in an at-risk population may not receive the message directly from the source, but from social contacts. The source influences individuals' responses to the warnings. Individuals must trust the source and believe that the information is credible to overcome any initial disbelief that a hazard is threatening their area (*8, 9*). Trusted sources may vary across the population; nonetheless, consistent messages from multiple sources may encourage the adoption of recommended actions.

People also seek confirmation of hazard information from their social connections, such as friends, relatives, and coworkers (*9*). Once individuals believe they are at risk and that evacuation is appropriate, they can begin making related preparations and decisions, such as whether to evacuate, where to go, when to go, and how to get there.

Photo: Metropolitan Transportation Authority

The New York City Metropolitan Transportation Authority used its buses to move Bronx residents to shelters before Superstorm Sandy in 2012.

The ability to evacuate depends on several factors. People with access and functional needs may not be ready or able to self-evacuate, because of a lack of funds, appropriate accessible transportation, or accessible communication, or because of other issues.

Prearranged networks of established and diverse community-based official and unofficial service organizations, together with public and service agency transportation providers, can fill gaps of trust, communication, and transportation services to support the preparedness and response of the whole community (*10*). Transportation and transit agency websites and communications can provide information on transit and related transportation resources, as well as on general transportation conditions and options; the information should be reliable and up to date.

Personal and Community Resources

Evacuees require transportation, a place to stay, and basic necessities. Self-evacuees may use their own vehicles. People without access to personal vehicles may rely on extended family, friends, neighbors, coworkers, or other social connections for transportation. Emergency management or other agencies may request buses to help transport evacuees. All of these transportation options require energy or fuel, which in turn require financial resources.

Personal financial resources also may be required when an evacuee reaches accommodations, particularly for hotels or motels. The homes of family or friends are commonly preferred but require social resources or connections; public shelters generally are least preferred and may be close to the affected area or farther away. These accommodations generally are established in buildings such as schools and require the flexible use of community facilities.

Evacuees need water and basic life-sustaining food at the evacuation destination, and possibly en route. Some will require medicine and other items for health care. If these are not provided by a relief organization, personal financial resources are necessary. Coordination among transportation agencies and relief organizations can generate information about evacuees' origins, destinations, and resource needs to ensure effective preparation and response.

Evacuation Alternatives

For some hazards, such as tornadoes and some radiological and chemical threats, sheltering in place may be the appropriate protective action. In other cases, people may choose to remain in their homes—they may not have received appropriate information in

time, may lack personal resources, may face personal logistical challenges, or may believe that staying where they are is best. Staying behind does not necessarily mean doing nothing. "Stayers" may prepare their home—for example, by boarding windows—or may stock up on supplies, such as food and water.

Other people may shelter locally but not in their own homes—for instance, at the homes of friends or family at higher elevations or of better construction than their own home. Access to these sheltering options depends on local social connections.

Adapting the Concepts

Resilience concepts applicable to evacuation and large-scale disasters—such as transportation management techniques—can be adapted to more common, smaller-scale disruptions and vice versa. This offers the benefit of making some of these plans more routine and preparing agencies for larger-scale or more life-threatening events (*11*).

Transportation agencies have worked with law enforcement agencies to develop and implement a variety of traffic management strategies to accommodate the demand associated with evacuations. These approaches generally seek to increase system capacity or manage demand.

Techniques include a variety of methods, most of which are commonly used for controlling and managing traffic during a variety of routine planned and unplanned events. Methods to enhance capacity include control, geometric, and operational changes that favor critical movements, as well as suspending tolls during an evacuation to support faster travel. Demand management techniques seek to spread, limit, or eliminate vehicular traffic demand, temporally and spatially.

Photo: Maryland National Guard

Maryland's National Guard Armory housed more than 600 evacuees in Baltimore during Hurricane Irene in 2011.

Photo: CityofStPete, Flickr

Citizens of St. Petersburg, Florida, survey post-Irma damage. Residents who choose to shelter in place must prepare for the event or have access to safer, local accommodations.

Operational Strategies

Following are commonly used operational strategies that have been adapted for emergency evacuations.

Contraflow

Contraflow is a form of reversible traffic operation that uses one or more travel lanes for the movement of traffic in the opposing direction (*12*). Every U.S. coastal state threatened by hurricanes has a variety of plans to implement contraflow.

Contraflow can increase the directional capacity of a roadway immediately and significantly without the time or cost required to plan, design, and construct additional lanes. Contraflow segments are most common and logical on freeways—that is, on the highest-capacity roadways designed to facilitate high-speed operation. Freeways do not incorporate at-grade intersections that interrupt flow and do not permit unrestricted access into the reversed segment. Contraflow on freeways also requires fewer manpower resources than on unrestricted highways.

On selected routes during contraflow, inbound capacity may be needed for heavy equipment, such as for utility repair and emergency response.

Route Closures

The closure of road segments can manage traffic during major emergency evacuations. During radiological releases, for example, closures can limit traveler exposure to a hazard or can limit the cut-through traffic into areas not equipped to accommodate increased demand. At the regional level, closures also have been used to limit traffic flow into a downstream section that has inadequate capacity to accommodate demand from multiple incoming routes.

Emergency road closures decrease traveler exposure to hazards and reduce traffic demand on limited-capacity roads.

Photo: Oregon DOT

Photo: HJL, Flicker

No-notice evacuation strategies include timing traffic signals to facilitate the movement of vehicles away from the hazard.

Ramp Closures

Ramp closures can promote freeway traffic flow by decreasing the number of merge points that require reduced speed. Under regular, nonevacuation conditions, ramp closures have eliminated bottlenecks on mainline freeway lanes.

Although the effects can increase travel speed, ramp closures may not increase the total throughput and may lead to more delays on the arterials (*13*). Ramp closures therefore should be considered carefully.

As with route closures, ramp closures also can limit access to threatened areas. Access should be considered for responding personnel and emergency vehicles.

Turn Restrictions

Ramp closures are appropriate for freeways; for arterial roadways, turn restrictions can be applied at intersections—an evacuation strategy known as "crossing elimination." The concept is to remove all or some conflicting interruptions of the traffic stream—such as left turns and minor street crossings—to provide continuous flow in the primary outbound direction. Police control or barricades are needed to implement these restrictions.

Police were stationed at key intersections during evacuations and post-Irma recovery in Florida to manage traffic flow and alleviate congestion.

Photo: CityofStPete, Flicker

Signal Timing Modification

Traffic signals can facilitate evacuations in urban areas, particularly under no-notice conditions. Although a recent review of practice found no standards or recommended rules of operation for traffic signal control during evacuation emergencies, the primary goal is to facilitate the movement of traffic away from the hazard (*14*).

A simulation study examined the effects of varied traffic signal timings under evacuation conditions (*15*). Tests with cycle lengths of 180, 240, and 300 seconds, as well as all-yellow and all-red flashing modes, suggested that the best plan depended on what needed to be achieved.

Longer cycle lengths with longer green times for the outbound directions worked best in facilitating the movement of evacuation traffic. If volumes approached those of routine peak periods, however, typical nonemergency timing plans for the outbound peak period could be effective.

Manual Traffic Control

A common technique for addressing congestion in evacuation emergencies is to allocate police officers strategically to direct traffic at a few key, highly congested intersections. The police officers immediately observe and adapt to changing traffic patterns and can move traffic more effectively than with an actuated controller.

Recent research has suggested that manual traffic control is best suited for intersections immediately upstream of a bottleneck or for closely spaced, uncoordinated signals (*16*). Flashing yellow signals appear to work best for intersections with high, unbalanced demand and with low volumes on minor approaches.

Crossing elimination strategies, however, work most effectively when demand from nonconflicting directions is high and all other approach volumes are relatively low.

Modifying Demand

In addition to the measures described above, which focus on enhancing the capacity of travel networks during evacuations, a variety of methods can modify demand. The goal is not to prohibit or restrict evacuee departures but to influence the spatial and temporal departure of evacuees safely and shift them to other modes that reduce the total number of vehicles on

the evacuation routes. These demand management methods include transit, pretrip traveler information, incentives, and phased evacuation orders.

Traffic incident management resources, such as motorist service patrols and temporary signage, also can be used, along with traveler information and surveillance systems, such as highway advisory radio, changeable message signs, and closed-circuit television. Incident management techniques, such as emergency vehicle access into threat areas, event venues, and incident scenes, also can be useful.

During Incidents

Traffic incidents occur daily, causing delays and putting drivers at risk of secondary incidents. As in evacuations, ramp and route closures and turning restrictions can limit exposure to conditions; shoulders may be used to increase capacity near the incident; manual traffic control may be implemented; and information can be shared to manage travel demand.

During Adverse Weather

Adverse weather events have increased in frequency and intensity in the past decade. Many events, such as hurricanes, flooding, and wildfires, require evacuation. Advance warning for evacuation is usually longer for hurricanes—often multiple days of alerts are possible, with two or more days of warning once the path and intensity of the storm can be more accurately forecast.

Flooding from rain and snowmelt is usually well forecast, although additional circumstances, such as a potential dam breach, can create uncertainty. Wildfires usually occur after some warning, but the incidence and spread can be rapid.

The challenges with hurricanes, flooding, and wildfires include complacency—mostly from people who have survived previous incidents and do not acknowledge the increased risk from the current incident—and overreaction, when people not in direct danger create a "shadow evacuation" that can overwhelm roads, supplies, and shelters.

Photo: Bob B. Brown, Flickr

Changeable message signs facilitate incident management.

Authorities must be clear about who needs to evacuate. Tornadoes, hailstorms, and severe snow and ice storms are likely to require secure shelter. These events may require limited evacuation or relocation because of the potential or actual destruction of shelter—for example, in mobile home parks—or because of an extended loss of power and utilities.

Infrastructure Enhancements

Capital infrastructure improvements also can improve resilience and evacuation operations. For example, the Tampa Hillsborough Expressway Authority proposed an extension to link the Selmon Expressway directly to Gandy Bridge, one of three joining the Tampa and St. Petersburg peninsulas. Although the primary goal of the Gandy Connector was to reduce congestion on Gandy Boulevard, the surface arterial segment, the planning assessments showed that the connector would offer many resilience benefits—notably the ability to evacuate the region and to keep traffic flowing during incidents on the other bridges.

Models showed that the capacity-increasing

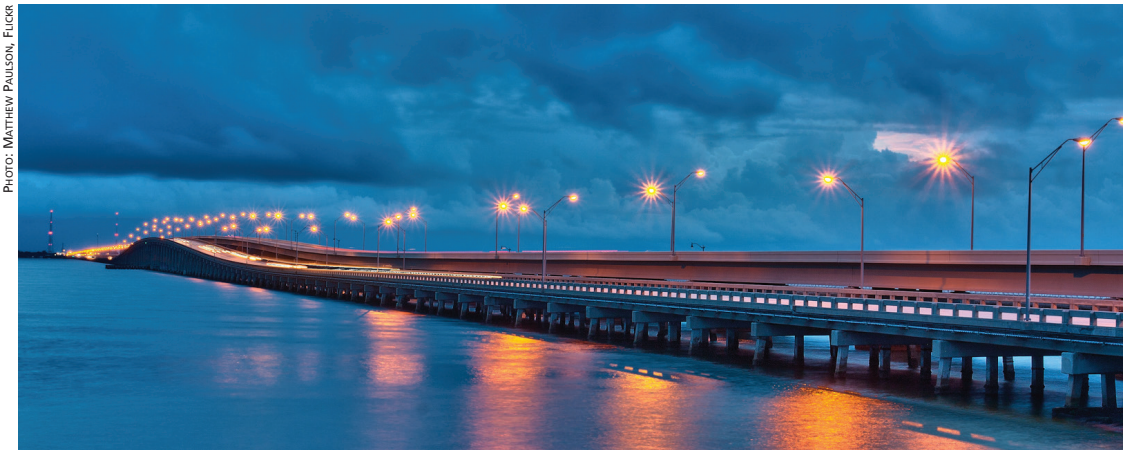

Photo: Matthew Paulson, Flickr

Along with easing daily traffic congestion, a proposed connector between the Gandy Bridge (*at left*) and the Selmon Expressway near Tampa, Florida, would improve traffic flow during emergency evacuations.

Connected vehicle technology can create smoother, faster evacuations and can provide information about routes, shelters, fuel, and other necessities.

Photo: U.S. DOT

aspects of the bridge would offset losses in functionality during emergencies and incidents by permitting a more rapid recovery. Moreover, an incident or event did not have to occur within the Gandy Bridge–Gandy Boulevard corridor; incidents occurring elsewhere would have less of an impact because the effects could be dispersed.

Future Changes

More frequent natural events and a rise in sea level, combined with increases in coastal populations, necessitate careful planning for resilience and evacuations. As shared-ride transportation modes become more popular or as the co-ownership of vehicles becomes more common, fewer households may be able to self-evacuate, leading to a greater need for multimodal and publicly assisted evacuations.

Autonomous or "self-driving" vehicles may support assisted evacuations of carless and mobility-limited populations, as well as the movement of people into and out of threatened areas unsafe for human drivers. The capacity of evacuation routes may improve with currently available autonomous vehicle technologies like automatic speed control, braking, and lane keeping, which allow vehicles to travel safely in denser, higher-speed platoons (*17*).

The U.S. Department of Transportation has worked to apply connected vehicle communication capabilities to assist evacuating travelers during emergencies. The Response, Emergency Staging and Communications, Uniform Management, and Evacuation applications, along with the Emergency Communications for Evacuation application, provide evacuees with en route information to locate shelters, fuel, food, water, cash machines, and other necessities. The technology also could provide route guidance under normal and incident conditions to alleviate congestion and communicate pickup times and location options for low-mobility and carless evacuees.

These expand the multifaceted approaches that make evacuations successful and that improve transportation and community resilience during threats.

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Social Capital and Transportation

Critical Assets in Community Resilience

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In the aftermath of Hurricane Katrina, experts sought answers to why so many residents chose not to evacuate—and how transportation can support community resilience in the future.

The world watched in late August 2005 as Hurricane Katrina approached landfall and as millions of people evacuated the U.S. Gulf Coast. By early morning on August 29, many people observing from a distance wondered why the tens of thousands of residents did not leave New Orleans, Louisiana.

Many factors influenced the dynamics of whether people stayed in or left flooded areas—finances, physical health and mobility, age and occupation, and more. Residents' social connections beyond the city of New Orleans and their access to private transportation also strongly motivated evacuation behaviors.

In the longer term, social networks and transportation also played a substantial role in recovery processes and resilience in the aftermath of Katrina. An understanding of the connections between social capital and transportation is crucial for planning and policy development for community resilience.

Social Capital

Robert Putnam popularized the notion of "social capital" in his 2000 book, *Bowling Alone*, but the term was coined more than a century ago by school reformer L. J. Hanifan. He defined social capital as the "good will, fellowship, sympathy, and social intercourse among the individuals and families who make up a social unit" (*1, 2*).

Through interactions with others, people accumulate social capital and the whole community benefits. In Putnam's words, social capital "greases the wheels that allow communities to advance smoothly."

The concept of social capital reflects trust, the convergence of shared values in a community, and

Photo: Jocelyn Augustino, FEMA

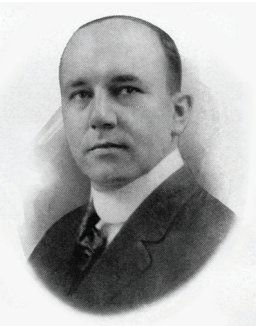

Photo: West Virginia State Archives

L. J. Hanifan, who first defined the concept of social capital.

the importance of social connections for achieving mutual goals—including building resilience.

Role in Resilience

The relatively recent inclusion of social capital as a key dimension of community resilience expands a longstanding body of literature that demonstrates the important role of social networks and social support in disaster preparedness, response, and recovery. Although "resilience" has many definitions, the term generally refers to the capacity to prevent or withstand loss and to recover from a loss.

Published in 2012, the National Research Council report *Disaster Resilience: A National Imperative* highlights the need to shift to a culture of disaster resilience in the United States (3). The report's authors argue that—along with other social factors like health and socioeconomic status—social capital influences a community's ability to recover from disaster.

Indicators of social capital include the following:

- Levels of civic engagement;
- Interpersonal, interorganizational, and institutional trust; and
- The interconnectedness and extensiveness of social networks in a given community or population.

Common quantitative measures of social capital include the number of civic, nonprofit, and religious organizations in a community, as well as levels of participation in community meetings and amount of trust within a community (4).

Photo: New York City DOT

The New York City Department of Transportation (DOT) gathers input from Brooklyn residents on redesigned bike lanes. Social capital also can be fostered through community planning activities.

Embracing the Concept

A burst of scholarly work on social capital has comprised research and publications in many disciplines and on a wide range of topics: collective action, democracy and governance, disasters, economic development, education, health, work and organizations, and more.

Some studies have shown that higher levels of social capital are associated with positive physical and mental health outcomes. Disaster researchers also have found that increased social capital is linked to faster postdisaster recovery (5).

Social capital appeals to sectors outside of academia, research, and the government. Its practical uses in community resilience planning include the development and resilience initiatives of organizations like the Rockefeller Foundation and the World Bank. These organizations have embraced the concept, recognizing the importance of social capital in the day-to-day well-being and sustainability of communities.

Community Resilience

Social capital has multiple dimensions:

- *Bonding* social capital refers to strong emotional bonds, like those found within families or close groups of friends. This type of social capital tends to encourage exclusive identities and develops among people with similar social and economic backgrounds.
- *Bridging* social capital is characterized by cross-cutting ties among individuals from diverse

Connections among neighbors—developed in daily life and at communitywide events—build social capital that increases disaster resilience.

Photo: William Avery Hudston, Flickr

Photo: Darien, Flickr

In the days after Hurricane Irene, more than 6,000 residents gathered in the Darien Library in Connecticut. Bridging social capital forges connections across geographic and political lines.

socioeconomic groups; bridging social capital nurtures connections across social, geographic, and political boundaries.

◆ A third type of social capital, referred to as *linking* social capital, connects community members and people in formal positions of authority.

Higher levels of social capital improve community resilience by enhancing a sense of belonging and by strengthening bonds among individuals and groups—bonding social capital. This potential increases when civic engagement integrates multiple, diverse sets of stakeholders—bridging social capital.

By connecting communities affected by disasters with outside assistance and resources, bridging social capital also increases resilience (*5–8*). Although these findings are consistent with the positive role of social capital in general, it is less clear how the multiple dimensions of social capital operate and interact with other factors—access to transportation and the use of various transportation modes, for example—to support community resilience.

Negative Aspects

Some negative aspects of social capital also are associated with disaster resilience. Although strong social cohesion or bonding social capital can facilitate collective action by helping disaster survivors obtain the assistance needed for quicker recovery, bonds within groups and limited bridging and linking social capital may exclude some disaster-affected populations from receiving aid.

In conflict zones, for instance, the intended recipients of aid deliveries often are unable to access supplies. Powerful in-groups then can take control of the transportation infrastructure to manipulate distribution practices, starve out pockets of opposition, or otherwise monopolize goods.

Residents of Batesville, Arkansas, donate supplies for victims of Hurricane Harvey. Resilience can be increased by connecting disaster-affected populations with outside groups.

Photo: Dave Thomas, Flickr

Photo: U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers removed debris after the 2011 flooding in North Dakota—an essential first step in community recovery.

Other Forms of Capital

A community's resilience depends not only on social capital but also on its capacity to mobilize six other types of assets, or forms of capital: natural, built, financial, human, political, and cultural capital (*9*).

Physiological and safety needs are fundamental to life. Immediately after a disaster, functioning natural and built capital are the most essential assets; for example, if air and water quality is not sufficient to sustain life, recovery is not possible.

Natural capital must be secured. Similarly, built capital—lifelines and the provision of basic services—must be repaired and reconstructed as quickly as possible. Once natural and built assets are restored and reconstructed, and after the immediate crisis has passed, other forms of capital become increasingly relevant.

As a sector of built capital, transportation systems are integral to day-to-day life and to community resilience (*4*). Physical transportation infrastructure—roads, airports, railroads, harbors and ports, and inland waterways—are essential to the maintenance of financial capital and to ensuring sustained and accessible natural, human, social, political, and cultural capital in the event of a disaster.

The transportation infrastructure in turn relies on human and financial capital to build, operate, and maintain its systems.

Channeling Assets

Fostering resilience requires a substantial amount of community capital and the ability to access, invest in, and spend that capital over months and years. The different forms of capital interact and provide a collective set of community resources, which may be invested wisely or spent.

Resources may be used to advance community growth and sustainable development and to enhance resilience and overall quality of life. On the other hand, communities—particularly disadvantaged communities—may not be in a position to nurture, harness, or benefit from the various forms of capital.

Local stakeholders, including planners, responders, and affected populations, are empowered by reliable information about available resources and about how to access and use them.

By determining the extent to which different types of capital exist in a given community—and in what forms—local stakeholders gain valuable information (*10*). With this practical knowledge in hand, efforts to create resilient communities are more likely to succeed and to produce such associated benefits as a strong economy and high levels of community satisfaction. In other words, the factors that make a community resilient to disasters also are likely to bolster its ability to resist daily internal and external threats and collectively to take advantage of opportunities.

Research Findings

Social capital is affected by the availability of various forms of private and public transportation, as well as by access to transportation. Rising automobile use and suburban development in the United States have been linked to a decline in social capital, for example. Longer commutes caused by urban sprawl have increased the amount of time that people spend alone and have decreased community involvement (*1*).

Social Effects

More recently, researchers have examined the connection between transportation systems and social exclusion, which hinders the development of social capital. Challenges related to transportation—particularly public transit—mount physical and psychological barriers to social inclusion for some users.

These challenges include peripheral residential locations and poor transit connections, the financial

Photo: Bill Geronymakis, Flickr

Suburban and exurban development often requires longer commutes and automobile-centric lifestyles, decreasing community involvement by residents.

Photo: Eric Parker, Flickr

Public transportation generates social capital and enhances community resilience by providing access to jobs, social networks, activities, and civic engagement.

costs and time demands related to public transportation, fear of crime, and concerns about prejudice and discrimination in transit settings (*11, 12*).

Other research has demonstrated that access to transportation enables face-to-face interactions that foster relationships, create social networks, and increase social inclusion (*13*).

Public Transportation

Public transportation generates social capital by increasing opportunities for social interaction, allowing community members to access social networks, and facilitating shorter commute times (*14, 15*).

Shorter commutes free up time for people to participate in social activities, including civic engagement and volunteer activities. For older adults, restricted driving—that is, less access to transportation and less travel—may lead to fewer social interactions, less civic engagement, and diminished social capital. This can decrease mental health and personal well-being (*16–18*).

Positive and negative impacts of social capital on the use of public transportation and on the likelihood of travel by other means vary by degrees. For instance, social networks influence an individual's ability to access a vehicle, to obtain a ride, or to have others make trips on their behalf (*19, 20*).

The relationships among transportation equity, transportation disadvantage, social exclusion, and social capital are extremely complex and multidirectional (*21*). Transportation disadvantages can isolate neighborhoods and rural areas, exacerbate social exclusion, inhibit linking social capital, and decrease overall resilience.

More research is needed to understand how transportation—and transportation equity in particular—shapes social capital and vice versa, as well as how these relationships affect community resilience.

Making Connections

Incorporating social capital into transportation research can help enhance resilience-building and planning efforts. Disruptions to transportation systems tend to have far-reaching negative impacts, as illustrated by the I-85 bridge collapse in Atlanta, Georgia, in April 2017.

If people are unable to move within and among communities in the wake of a disaster, they may not be able to get to work and are less likely to spend money in local establishments. External resources brought in to support response and recovery efforts are stymied. Over time, disruptions to transportation can diminish social capital by hindering interaction among people. The combination of these impacts decreases a community's resilience.

Resilience planning also can be supported by analysis of the ways in which people draw on social capital to offset challenges caused by damage to the built environment. When transportation systems are damaged or destroyed, the relationships among the individuals, families, and groups that live and work in the affected communities are increasingly important.

During Hurricane Katrina, social capital supported and hindered evacuation processes. People with strong bridging social capital were in a better position to leave New Orleans and to obtain support through their social networks for doing so. Those who were unable to evacuate offset their challenges by drawing more heavily on their collective social

Photo: Corinne Zilnicki, U.S. Coast Guard

A U.S. Coast Guard search-and-rescue operation in Houston, Texas, during Hurricane Harvey. Areas with limited transportation options face disadvantages in adverse events.

capital to access water, food, shelter, and other provisions.

Connecting extensive knowledge about the resilience of transportation systems with research on social capital seems obvious; nevertheless, these connections should not be taken for granted or realized only in the wake of a disaster. Future research on more recent events, including Hurricanes Harvey and Irma in September 2017, could continue to explore the intersection of social capital and transportation.

Providing safe, reliable, and efficient public transportation that promotes social capital is one way to enhance community resilience. Future transportation system innovations can help foster social capital and can grease the wheels of community resilience.

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Resilience Thinking and Future Research

Beyond Quick Fixes

JOHN CONTESTABILE AND LAUREL RADOW

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As the nation grapples with ways to assess the risks from potential hazards to critical infrastructure, the need for a readjustment of human behavior may become apparent. Even the best preparations for a hazard resemble a recipe for which only some ingredients are known; finding the best-case substitutes for the unknown components may require adapting or adjusting human behavior.

The numbers and types of hazardous events that have occurred are known. Despite the extent of preparations for "notice" events, new events or variations can catch public and private entities off guard. The past may be prologue but may not be as helpful as expected.

The United States is learning to make its infrastructure more resilient—but how does the nation develop the capabilities necessary to ensure that the workforce can achieve resiliency?

In the past, the nation responded or reacted, but that may not be an appropriate approach in the context of resiliency. With the likelihood of more frequent and severe weather events and the grave possibility of more terrorist attacks that change in delivery, how can the nation limit responses that are reactive, poorly focused, and ill-prepared?

The more appropriate responses may emphasize preparedness and preemption instead of reaction. If the increase in both the severity and frequency of adverse events is as great as some expect, the business-as-usual approach may lead to repeated failures.

Threat Environment

Many have assessed and described the changing threats that organizations face. Some events, such as natural hazards, may reasonably be expected and anticipated from historical data. Other events—such as terrorism or cyber attacks—are more unexpected, because the historical experience is unavailable or

The terrorist attacks on September 11, 2001, closed roadways and subways, forcing people to evacuate Manhattan on foot.

PHOTO: JACK SAWERGOLD, FLICKR

Photo: Tony Webster, Flickr

Traffic congestion on the Alaskan Way Viaduct in Seattle, Washington. Increased traffic volume poses a challenge to transportation resilience.

may not be representative of current or future threats. Although transportation systems are prepared mostly for physical threats, are transportation systems adequately prepared for all hazards?

Transportation agencies also must prepare for yet another kind of threat—the growth in travel demand. The projected growth in the numbers of vehicles on roadways, in freight movement, and in transit and air trips is pressuring transportation agencies and providers to meet the demand. Maps that show both the current and future state of the nation's transportation network make clear that continuing on the current trajectory without changes will leave the nation's transportation network less likely to be resilient.

The U.S. transportation network barely meets the criteria of a state of good repair for the everyday movement of goods and people. The occurrence of a major event—involving weather, an unintended incident, or a malevolent attack—is likely to compound the everyday problem of moving goods and people.

The Federal Highway Administration's Freight Analysis Framework maps[1] show the level of resiliency of the nation's transportation network over time, and the *Washington Post* has published maps that highlight the state of the nation's infrastructure in need of repair.[2] These sets of maps offer strong visuals of the gaps that need to be addressed to ensure that the nation's various transportation networks can function as goods movement increases in the next 20 to 40 years.

Nevertheless, the public and elected officials perhaps have never had higher expectations for U.S. transportation systems. System performance and reliability are paramount, with minimal tolerance for delays. Moreover, national policy—as promulgated in presidential directives[3] and executive orders[4] and in plans, including the National Infrastructure

The 88-year-old George Washington Bridge over the Hudson River in New York is undergoing a major renovation. Infrastructure assets must be in a state of good repair to support a resilient transportation system.

Photo: Ken Lund, Flickr

[1] http://ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/index.htm.

[2] Six Maps That Show the Anatomy of America's Vast Infrastructure. *Washington Post*, December 1, 2016. https://www.washingtonpost.com/graphics/national/maps-of-american-infrastructure/.

Protection Plan—promote partnerships, security, and resilience. The transportation sector finds itself squarely in the middle of these issues.

As described in the National Response Framework, "The ability to sustain transportation services, mitigate adverse economic impacts, meet societal needs, and move emergency relief personnel and commodities will hinge on effective transportation decisions at all levels." If a transportation agency's leaders should think that security and emergency management are not part of the agency's core functions, national policy and local constituencies indicate otherwise.

Knowns and Unknowns

Natural hazards and growth in travel demand are key drivers that are known, and the responses can be reasonably planned. The level of preparation that is sufficient can be debated, as well as the investments to meet demand, but these factors largely constitute what is known.

What is unknown is more troubling. Terrorist events, although not unexpected, are far more difficult to anticipate. When would a "no notice" event occur? What would be the means of attack—an improvised explosive device or an active shooter? Insight into this type of threat requires real-time information generally within the law enforcement community—for example, the U.S. Homeland Security office, fusion centers, or joint terrorism task forces—and the transportation community generally is not a part of these entities.

In addition, concerns are growing about cyber threats, which pose a different set of challenges. Traffic signal systems, video systems, online payment systems, websites, and toll collection systems are some of the platforms that offer potential avenues for a cyber attack.

A cyber attack on these systems also would be a no-notice event—as some have observed, the attackers already may be within the systems, but discovery takes time. Nonetheless, even the threat of a cyber attack could create a major disruption, as the operators may close the facilities to avoid the consequences—for example, in response to a threat to the ventilation system or to the fire control system in a tunnel. Preparing for cyber threats requires human resources and skill sets that a transportation agency may not have.[5]

Others have dealt with these topics in great detail; the general direction of the threat environment appears to be moving

- From known sources to those more unknown,
- From physical to cyber,
- From expected to unexpected, and
- From less to more severe.

Connectedness

In addition to the uncertainty and the nature of the threats, today's "connectedness" exacerbates any occurrence. Transportation agencies are in the

Photo: Bobby Hidy, Flickr

Cyber attacks could threaten E-Z Pass and other electronic toll collection systems on major highway arteries.

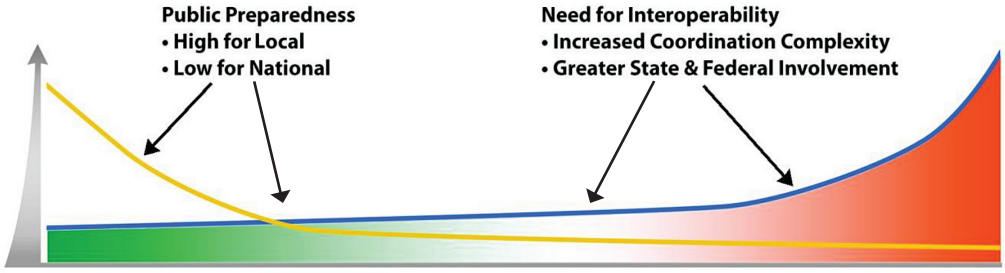
Photo: mauscreiptrep, Flickr

Millions of residents, tourists, and commuters depend on city transit networks like the Washington, D.C., Metrorail system.

[3] Presidential Directive 8, *National Preparedness*, March 30, 2011, https://www.dhs.gov/presidential-policy-directive-8-national-preparedness; Presidential Directive 21, *Critical Infrastructure Security and Resilience*, February 12, 2013, https://obamawhitehouse.archives.gov/the-press-office/2013/02/12/presidential-policy-directive-critical-infrastructure-security-and-resil.

[4] Executive Order 13636, *Improving Critical Infrastructure Cybersecurity*, February 19, 2013. https://www.gpo.gov/fdsys/pkg/FR-2013-02-19/pdf/2013-03915.pdf.

[5] See NCHRP Report 221–TCRP Report 67, *Protection of Transportation Infrastructure from Cyber Attacks: A Primer*, www.trb.org/Main/Blurbs/174382.aspx.



Classification	LOCAL	REGIONAL	STATE		NATIONAL
Examples	• Minor Traffic Incidents • Vehicle Fires • Minor Train/ Bus Accidents • Accidents W/ Injuries but no Fatalities	• Train Derailment • Major Bus/Rail Transit Accidents • Major Truck Accidents • Multi-vehicle Crashes • Hazmat Spills • Injuries & Fatalities	• Train Crashes • Airplain Crashes • Hazmat Incidents • Multi-vehicle Accidents • Tunnel Fires • Multiple Injuries & Fatalities	• Port/Airport Incidents • Large Building Fire or Explosion • Industrial Incidents • Major Tunnel/ Bridge Closure	• Terrorist Attack/WMD • Floods, Blizzards, Tornadoes • Transportation Infrastructure Collapse • Extended Power/Water Outage • Riots • Mass Casualties
Expected Event Duration	0 - 2 HOURS	2 - 24 HOURS	DAYS		WEEKS

FIGURE 1 Incident scale in relation to public preparedness, intergovernmental–multijurisdictional involvement. (WMD = weapon of mass destruction. SOURCE: Graphic courtesy of J. Contestabile, formerly with the Maryland Department of Transportation. Used with permission; previously published in *CIO Leadership for Public Safety Communications: Emerging Trends and Practices*, 2012.)

business of connecting people to jobs, freight to its destination, and much more. The high levels of connectedness are the result of advances in communication, which can link almost anyone to anything instantaneously, whether via social media, within ever tighter supply chains, across public–private partnerships, or many other connections.

This connectedness can produce cascading effects across critical infrastructure, magnifying the scale of any incident. For example, an incident that primarily affects the energy sector is likely to manifest soon after in the transportation sector, given transportation's role in connecting people and places. Moreover, an agency can only respond at its own, proportionate level to an incident of increased scale.

Figure 1 (above) shows how the increasing scale of an incident places different demands on the agencies involved. Generally, on a day-to-day basis, an agency deals with local or perhaps regional issues. But with the increases in connectedness, even relatively local incidents can become larger in scale and can pose greater challenges in the communication, coordination, and duration of the response and recovery.

Figure 1 deals largely with the kinds of physical events that transportation agencies have the most experience with and can best relate to. How does a cyber threat change the process? Connectedness through cybersystems can increase the cascading effects and the scale of an incident across transportation modes and critical infrastructure sectors.

To summarize, the threat environment is becoming less predictable and more volatile. Increased connectedness results in more incidents of larger scale in physical effect, duration, and impact. A cyber threat adds the dimensions of increased scale and cascading effects.

Members of academia and the military, along with government and industry employees, conduct a joint simulated cyber attack exercise.

PHOTO: MARVIN LYNCHARD, DEPARTMENT OF DEFENSE

Awareness and Preparedness

What is the right approach for a transportation agency, considering this environment? How does a transportation agency become more resilient despite such threats? An awareness of the larger threat environment is necessary.

The following questions can help an agency assess its level of awareness and preparedness:

◆ What mechanisms does the agency have in place to monitor the threat environment? Is the agency linked into law enforcement information

Photo: Tom Saunders, Virginia DOT

Relationships with private-sector entities, including providers of such contract services as snowplows, help transportation agencies quickly respond to emergency incidents.

about threats? Is that information structured to meet the needs of the transportation agency?

◆ What coordination mechanisms does the agency have in place for working with other agencies likely to be involved in a larger-scale incident? How strong are the relationships with agencies such as those responsible for local law enforcement, emergency management, the environment, and hazardous materials, and with the National Guard? What are the relationships with cyber entities such as the National Cyber Intelligence Center or the Cyber Information Sharing and Analysis Center? Does the agency have a contract with a cyber consulting firm? What is the agency's relationship with the state's chief information officer and chief information security officer?

◆ What is the transportation agency's relationship with private-sector entities that would be needed before and during an incident as well as those that may be directly involved in incidents—for example, hazmat carriers and shippers? What specialty services may require contracts—such as hazmat remediation, towing, plowing, and debris removal? Are these contracts in place?

◆ Does the transportation agency have the human capital with the right skill sets for this environment? Does the agency have access to cybersecurity resources? Are field personnel trained in what to look for from a security perspective? Does the agency know how to leverage social media before, during, and after an incident? Does the agency have a plan if it should lose a significant portion of its workforce during a severe event such as a pandemic? Does the agency know how to secure resources for identifying and treating posttraumatic stress disorder?

The answers to these questions will vary across transportation agencies. Similarly, the extent to which an agency will have to implement these relationships and measures will vary according to perceptions of the particular threat environment.

Figure 2 (below) suggests a hierarchy of resilience according to the compounding effects of risk-related variables. The nation's infrastructure is not in a state of good repair, and the transportation network therefore is not at its optimum and is more likely to be at risk. Weather events, human-triggered events, or climate changes can put the nation's network at even greater risk.

Body of Research

What research areas should be explored to help transportation agencies cope with these uncertainties and to improve preparedness? The Transporta-

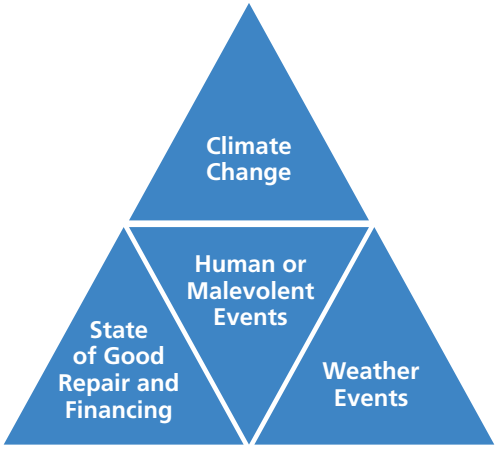


FIGURE 2 Hierarchy of resilience.
(Graphic courtesy of L. Radow)

Photo: North Charleston, Flickr

South Carolina government agencies used Facebook Live and other social media to communicate emergency information before Hurricane Irma.

tion Research Board (TRB) has accomplished much through National Cooperative Highway Research Program (NCHRP) Project 20-59, Surface Transportation Security and Resilience Research, which has funded and managed $29 million of research. Initiated after the terrorist attacks of September 11, 2001, the series includes 158 completed research projects, plus 26 in progress and 21 with contracts pending or in development.[6]

The early research focused on the immediacy of incident management and response. Several projects developed primers identifying the role of transportation in the larger emergency management cycle. Other projects explored issues involving evacuation, the freight and supply chain, and modal-specific efforts in transit and airports.

The findings and products are invaluable, but research efforts cannot rest, given the dynamic and changing threat environment. In particular, the current body of research needs to address the effects of connectedness and of cyber vulnerabilities.

[6] http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=644.

Toward Resilience

How should TRB guide research efforts in the context of resilience? How does resilience relate to adaptation, climate change, sustainability, mitigation, and asset management—all of which are areas of study within the transportation research community? By establishing a new section of standing committees focused on resilience, TRB is working to align a myriad of efforts.

Resilience can be seen as an integrative function. A 2012 policy study by the National Academies, *Disaster Resilience: A National Imperative*, defined resilience as "the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events."

Resilience is the outcome of a well-integrated set of activities emphasizing preparedness, mitigation, and recovery. This moves beyond the functions of response, which still must be executed well, but relies primarily on the public safety community. This approach allows the transportation community to examine its roles in the traditional planning, design, and operations and maintenance cycle specifically as part of the larger goal of resilience.

The National Infrastructure Advisory Council's (NIAC's) *Transportation Sector Resilience: Final Report* of 2015 presented key findings in three general topic areas: understanding systemic risks, incorporating resilience into operational practice, and investing in resilience.[7] These topics suggest essential focus areas for a transportation agency:

- Understanding risk and the related planning efforts,
- Incorporating good resilience practices into operations, and
- Seeking consensus on investments and designs that improve resilience.

[7] https://www.dhs.gov/sites/default/files/publications/niac-transportation-resilience-final-report-07-10-15-508.pdf.

Photo: Jay Inslee, Washington State DOT

Understanding the risks inherent in computerized transportation systems is a first step in planning resilience practices.

The TRB Standing Committee on Critical Transportation Infrastructure Protection has leveraged the findings of the NIAC report by developing a framework for research proposals (see Figure 3, below). The NIAC approach focuses on dependencies, which indicate connectedness, and on gaps, mitigation, public–private roles, and processes. The committee considered these factors across the areas of risk, cybersecurity, physical security, the supply chain, and the workforce and is examining research needs under this framework.

Research Topics

The NIAC report on resilience offered the TRB Critical Transportation Infrastructure Protection Committee a useful framework to develop a logical research plan. Each subcommittee chair selected a first and second area for research. Because meeting all the criteria in the first round would not be possible, the committee decided that research statements either should be foundational or should address critical gaps identified at subcommittee meetings or in other discussions.

◆ **Best practices**—What current strategies and practices promote resilience in the sector? Are the attributes mode-specific, as well as sectorwide? What understandings and differences are common in the definition and coordination of plans and actions across modes?

◆ **Goals**—What are the implicit resilience goals that align with common practices for each mode and across the sector?

◆ **Dependencies**—What considerations and cascading effects result from dependencies on other modes and other infrastructure sectors, including cybersystems and their disruptions, within a region and across the nation?

◆ **Performance gaps**—What potential gaps and seams create obstacles for the sector and the modes in achieving resilience goals?

◆ **Risk mitigation**—What unique factors within the sector influence risk mitigation? What are the practical realities of risk priorities and risk mitigation?

Photo: Chris, Flickr

When the I-35W bridge in Minnesota collapsed, Minnesota DOT completed the National Environmental Policy Act review process in two months to facilitate a quick rebuild.

Building on the Foundation

At its start in 2001, the NCHRP Project 20-59 research series focused on security and response, but after Hurricane Katrina in 2005 the emphasis changed to emergency management. As the transportation community builds on findings and products from 16 years of research, it can incorporate lessons learned from other transitions—for example, those under the National Environmental Policy Act (NEPA), which required transportation agencies to consider the environmental impacts on historical and archeological sites. NEPA necessitated a paradigm shift in planning and design; today's focus on resilience holds comparable significance.

Resiliency runs counter to short-term thinking, and the questions of behavior and human factors remain unsolved; experiences such as those under NEPA and other transformative federal policies can help the transportation community build on the foundational years of the NCHRP Project 20-59 research as the series moves to the next phase, with a broadened focus on resilience.

The question is this: What is the best way to develop a coherent resilience research program for the next 15 years, incorporating climate change, extreme weather events, cybersecurity, and physical security within the context of terrorist attacks, to produce a new set of guidance and tools for the issues that transportation agencies will need to address?

FIGURE 3 Framework for focused research on critical infrastructure protection.

Subcommittee Questions	Best Practices	Goals	Dependencies	Performance Gaps	Risk Mitigation	Public and Private Sector Roles	Process Improvements
Risk and Planning							
Cyber							
Physical Security							
Supply Chain Security							
Workforce							

Anand J. Puppala

University of Texas at Arlington

Anand J. Puppala is director of the Sustainable and Resilient Civil Infrastructure Center and professor at the University of Texas (UT) at Arlington. He explores and develops research solutions to improve the design and construction of resilient transportation infrastructure in complex hazardous environments, both natural and manmade. "The propensity of practicing engineers to design for higher resilience might counteract the sustainability agenda," Puppala observes. "A middle path balances both the sustainability and resilience aspects of a project."

A native of India, Puppala received a bachelor's degree from the Gandhi Institute of Technology and Management and a master's degree from the Indian Institute of Technology Madras. He received a PhD in geotechnical engineering and computer science from Louisiana State University and worked as a research engineer at the Louisiana Transportation Research Center in Baton Rouge before joining UT Arlington in 1996.

"The propensity of practicing engineers to design for higher resilience might counteract the sustainability agenda. A middle path balances both the sustainability and resilience aspects of a project."

Puppala's research has focused on sustainable utilization of recycled materials; stabilization of expansive soils supporting pavement infrastructure; the design of dams, levees, and embankments in challenging seismic and nonseismic environments; in situ intrusive methods for site characterization; monitoring of transportation infrastructure; and resilience and sustainability assessment studies, including life-cycle assessments.

Recently, Puppala completed a research project for the Texas Department of Transportation (DOT) to bolster the earth beneath roadways and bridges with giant, lightweight geofoam blocks and prevent settling. "Geofoam blocks cut down on sediment, can be stacked, and do not place stress on the soil, so structures are safer and more stable," Puppala notes, adding that the geofoam also does not degrade, making the blocks environmentally safe. In 2012, his research team installed the blocks near a bridge in Johnson County, Texas; since then, the team has measured less than one inch of settlement.

Another research area is stabilization of sulfate soils. Puppala recently studied a new mix of lime and fly ash to stabilize and construct two test sections of US-82, reducing soil sulfate heaving and extending highway life. A Texas DOT study on strengthening pavement shoulder subgrades with compost materials was highlighted in the Research Pays Off section of the September–October 2007 issue of *TR News*.

Puppala is leading a collaborative effort to study unmanned aerial vehicles (UAVs) for remotely monitoring Texas highways and railroads and collecting high-definition images for analysis by transportation agencies. "It is safer and less expensive to use a UAV to check pavement or bridge performance characteristics, because there is no need to close lanes or to have a person on a roadway or on active railroad tracks," he comments.

Puppala also is experimenting with recycled asphalt pavement and geocells—modular structures arranged in a honeycomb pattern, filled with aggregate, and compacted to create a drivable surface—to find effective, sustainable uses of waste materials. Sensors in the pavement will collect traffic loading data for developing specifications for future projects and will help Texas DOT's Fort Worth District determine if geocells can be used in widening roadways. Another Texas DOT–funded project under Puppala's direction is using geothermal energy to make icy bridges safer.

Teaching always has been the highlight of Puppala's career. In 2010, he received the UT system's highest teaching honor, the Regents' Outstanding Teaching Award. His teaching philosophy emphasizes engaging students in stimulating discussion and offering insights on interesting case histories, as well as a research-based pedagogy with exposure to field practice. He has supervised 26 PhD candidates and more than 50 master's students from all over the world: the United States, India, China, Iran, Ecuador, Germany, Thailand, Sudan, and more.

For the Transportation Research Board, Puppala chairs the Geotechnical Engineering Section and is a member of the Design and Construction Group. He joined the Standing Committee on Foundations of Bridges and Other Structures in 1996 and was a member of standing committees on Geotechnical Site Characterization, Geotechnical Instrumentation and Modeling, and Stabilization of Geomaterials and Recycled Materials. He also served on the planning committees for the 10th and 11th International Conferences on Low-Volume Roads in 2011 and 2015.

Puppala was chair of an American Society of Civil Engineers committee on engineering geology and site characterization, and served as president of the U.S. Universities Council on Geotechnical Education and Research from 2007 to 2009.

Shawn M. Turner

Texas A&M Transportation Institute

Senior research engineer at the Texas A&M Transportation Institute (TTI) and head of the Mobility Division in TTI's Planning and Environment Group, Shawn M. Turner has applied the principles of continuous improvement and constant learning to his 25-year transportation research career. His research interests—data and information systems for decision making and pedestrian and bicycle transportation—adapt easily to the changes enabled by new technology and methods.

"That is where research comes into play," he observes. "How can technology help with a task that was not possible even five years ago? Can new analytic methods produce more accurate and comprehensive results?"

In the late 1990s, Turner worked to integrate the Archived Data User Service (ADUS) into the National ITS Architecture.

"With growing interest in bicycling and walking comes the need for better data for planning, design, safety analysis, and performance reporting."

"At the time, public agencies were deploying lots of automated sensors to monitor traffic in real time but were discarding the sensor data that was more than 5 minutes old," Turner recalls. "ADUS created a framework to permanently save these valuable data." Since then, it has become routine to archive real-time sensor data from traffic management and operations centers and to use those data for historical analysis.

When GPS-enabled smartphones came onto the market in the mid-2000s, private companies like INRIX, HERE, and TomTom collected real-time GPS data for traveler information applications. Turner advocated strongly for the companies to archive and resell the historical travel speed data for mobility analysis. The use of private-sector GPS data for mobility analysis—understanding congestion, origin–destination patterns, and trip routing—now has become standard practice, and FHWA has incorporated the use of private-sector GPS data into the Final Rule on System Performance Measures. Turner works with public agencies to implement the new GPS data sets and to monitor approaches and with private data providers to broaden and improve their products.

"In the past 10 to 15 years, I have seen growing interest from transportation practitioners in bicycling and walking—and with this interest comes the need for better data for planning, design, safety analysis, and performance reporting," he comments. Combining a keen interest in data with a love of pedestrian and bicyclist transportation, Turner conducts research in usage monitoring, data collection and quality assurance, planning methods and tools, and safety and behavioral evaluations.

"Even though most of my career has been focused on applied, practice-ready research, I like to think that research is analogous to a balanced investment portfolio," Turner notes. "Applied research can pay a steady dividend of results to help practitioners progress and improve. Basic research is more about those few elusive breakthroughs that can propel practitioners to leaps of progress."

Turner developed systematic test protocols for evaluating the accuracy of pedestrian and bicyclist counters and supported adoption of pedestrian hybrid beacons, rectangular rapid-flashing beacons, and other innovative treatments for pedestrian crossings. Turner also developed a trail monitoring guide for the National Park Service, updated FHWA's bicycle and pedestrian transportation university course, and conducted some of the first comprehensive automatic trail counter evaluations in 2005 and 2006.

Turner joined the Transportation Research Board (TRB) Standing Committee on Urban Transportation Data and Information Systems in 1999. He is chair of the TRB Pedestrians and Cycles Section and is past chair of the Standing Committee on Pedestrians, the Archived Data User Service Subcommittee, and the Task Force on the Traffic Monitoring Conferences. As chair of the Pedestrians Committee, Turner guided efforts to identify and publicize practice-ready papers, working with the Institute of Transportation Engineers and the Association of Pedestrian and Bicycle Professionals.

"Increasingly, my measure of success is how many practitioners are using the analytic methods I have recommended or advocated," Turner observes. "That is the ultimate compliment—knowing that I have thought through the implementation challenges and that I have understood what practitioners need well enough to provide a product that is useful in day-to-day practice."

As a member of an American Society for Testing and Materials technical committee, Turner has assisted in the development of several metadata and archived data standards. He also advises federal agencies on research agendas, delivers university lectures on pedestrian and bicycle transportation, and leads bicycle safety classes. He is a licensed professional engineer in Texas and an instructor with the League of American Bicyclists.

Winners of the 2017 University Design Competition Awards Presentation gather at the Keck Center of the National Academies of Sciences, Engineering, and Medicine in Washington, D.C.

Opportunities for Young Aviation Professionals

ACRP Graduate Programs Open Research Pathways

LARRY GOLDSTEIN

The author is Senior Program Officer, Airport Cooperative Research Program, Transportation Research Board, Washington, D.C.

The work of young professionals is critical to the vibrancy and creativity of research programs. The Airport Cooperative Research Program (ACRP), a program of the Transportation Research Board (TRB), has emphasized the importance of attracting young professionals—particularly students in college and university programs—to research on airports and aviation and to opportunities for participation in ACRP and TRB activities.

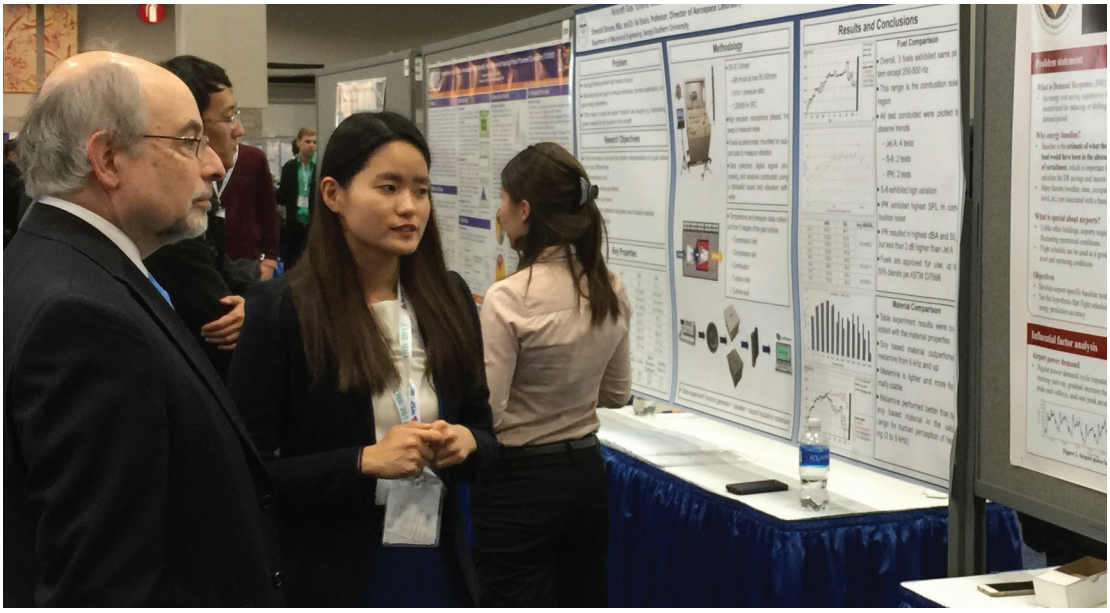
ACRP conducts two graduate-focused programs: the Graduate Research Award Program on Public-Sector Aviation Issues and the University Design Competition for Addressing Airport Needs. The Graduate Research Program was supported by the Federal Aviation Administration (FAA) and administered by TRB until 2008, and has been directed by ACRP since then. FAA operated the University Design Competition—created by the Virginia Space Grant Consortium (VSGC)—from 2007 to 2014; ACRP and VSGC now manage the program. Both programs encourage students to contribute innovative ideas and solutions to issues facing airports and the National Airspace System.

The Graduate Research Award Program and the University Design Competition are expanding their outreach to the aviation industry to offer broader exposure for student accomplishments and to share realistic solutions to complex research issues and critical, everyday airport operating and maintenance problems.

ARCHIVE PHOTO

Graduate Research Awards program recipients in 1991, soon after the program was created.

Photo: Rsdon Photograph



ACRP Graduate Research Award program recipient Minkyung Kang reviews her poster with ACRP Senior Program Officer Larry Goldstein at the 2017 TRB Annual Meeting.

Graduate Research Award

The Graduate Research Award program stimulates thought, discussion, and research by future airport managers, operators, designers, and policy makers. By encouraging applied research on airport and aviation system issues, the award program helps public-sector agencies improve the quality, reliability, safety, and security of the U.S. civil aviation system.

Each year, up to 10 highly qualified graduate students receive a $12,000 graduate research award as well as mentorship opportunities with national aviation experts. Graduate Research Award recipients also gain access to ACRP resources, deliver a research presentation at the TRB Annual Meeting in Washington, D.C.; and publish a paper in the peer-reviewed *Transportation Research Record: Journal of the Transportation Research Board*.

All applicants must be citizens or permanent residents of the United States or must have a current student visa. Each applicant also must be officially enrolled as a full-time student at an accredited North American institution of higher learning for the academic year, in a graduate course leading to a master's or doctoral degree. Guidelines for the 2018–2019 program will be available in early 2018; see box at right.

University Design Competition

The Design Competition challenges undergraduate and graduate students—individually or in teams, working with faculty advisers—to consider innovative approaches related to airport issues. The competition focuses on design solutions that address airport needs in the following areas:

- Airport operations and maintenance;
- Runway safety, incursions, and excursions;
- Airport environmental interactions; and
- Airport management and planning.

The program is a partnership of the American Association of Airport Executives, the Airport Consultants Council, the Airports Council International–North America, the National Association of State Aviation Officials, and the University Aviation Association. These groups offer expert advisers and reviewers and provide publicity for the competition.

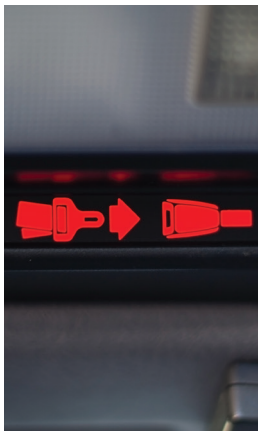
Students can win cash prizes for innovative design solutions. First-place winners also receive the opportunity to present their work at a national award ceremony and at another workshop or conference sponsored by one of the competition partners..

Exploring Research Opportunities Through ACRP

◆ More information about the ACRP Graduate Research Award program can be found at www.trb.org/ACRP/ACRP-GraduateAwardProgram.aspx.

◆ Descriptions of previous winning submissions to the University Design Competition for Addressing Airport Needs are available at www.trb.org/ACRP/ACRPDesignCompetition.aspx.

◆ Guidelines for the 2017–2018 academic year University Design Competition are available at http://vsgc.odu.edu/ACRPDesignCompetition/files/2017-2018-ACRP-Design-Guidelines-UPDATED.pdf.



Fewer riders use safety belts in the backseat of a car than in the front seat, a study found.

Seatbelt Use Lags Among Backseat Riders

Although 91 percent of adults report buckling up when driving or riding in the front seat, less than three-quarters of adults say they wear seatbelts when riding in the backseat, according to research by the Insurance Institute for Highway Safety (IIHS).

The survey, the first of its kind to focus on rear seat belt use, reports that many passengers perceive the backseat to be safer than the front and that fewer rear seat passengers are in the habit of using seatbelts—particularly among adults ages 35 to 54. Passengers of hired vehicles—taxicabs and ridesharing vehicles such as Uber or Lyft—were more likely to report not using a seatbelt than those using personal vehicles.

More than half of the people who die in passenger vehicle crashes in the United States are unbelted, according to IIHS; drivers are twice as likely to die when the passenger seated behind them is unrestrained.

The survey also shows that nearly two-thirds of part-time seatbelt users and nonusers would be more likely to buckle up if the law required them to and if there were in-car reminders.

For more information, visit www.iihs.org/iihs/news/desktopnews/adults-admit-to-not-always-using-safety-belts-in-the-back-seat-iihs-survey-finds.

Intersection Design Increases Safety

Reduced-conflict intersections (RCI) installed by the Minnesota Department of Transportation (DOT) have led to a reduction in road deaths, the agency reports. The intersections consist of a smaller road crossing a multilane highway; drivers must turn right at the intersection and must use a U-turn lane for safe entry into traffic going the other way.

Before installation of the RCIs, drivers entering the intersection from a smaller road had to navigate cross traffic, the median, and other cars making left and right turns. With two dozen points of conflict, these intersections experienced a larger number of severe right-angle crashes than other intersections. RCIs have reduced the number of possible conflicts to four.

According to Minnesota DOT research, all 12 of the state's RCIs have had a 100 percent reduction in right-angle crashes involving fatal and serious injury. At eight intersections recently studied, severe right-angle crashes decreased by 77 percent.

To learn more about RCIs and the study, visit www.dot.state.mn.us/newsrels/17/06/15rci.html.

Reduced-conflict intersections drastically reduce fatal and serious-injury crashes.

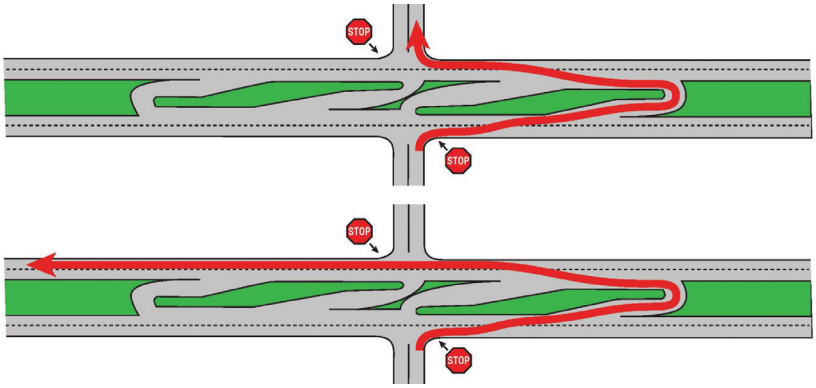


Photo: Minnesota DOT

Conditional Support for Gas Tax Increase

Most Americans support an increase in the gasoline tax, as long as the revenue is used for road and highway maintenance, according to a new survey by the Mineta Transportation Institute.

The annual national telephone survey asked more than 1,200 respondents about their support of various tax options. The survey results showed that nearly 80 percent of Americans supported gas tax increases of up to 10 cents per gallon if the funds were earmarked for specific road improvements.

Researchers also sought to understand perceptions about public transit, including federal funding. Although nearly half of respondents did not know that transit fares do not cover the full cost of transit, nearly 70 percent supported spending gas-tax revenue to pay for transit service.

To read the report, visit http://transweb.sjsu.edu/project/1728.html.

Vehicular Terrorist Attacks on the Rise

The use of vehicles as weapons in terrorist attacks is a growing trend, according to MTI researchers Brian Michael Jenkins and Bruce R. Butterworth. Since 1970, 37 vehicular attacks on surface transportation targets have resulted in a total of 247 fatalities. Eighteen of the attacks were suicide vehicle rammings (SVR), in which the primary weapons were explosives inside the vehicle, and 19 were vehicle rammings (VR), in which the primary weapons were the vehicles themselves.

According to the researchers, SVR is far more deadly. These attacks account for 90 percent of the 247 fatalities, with 12.4 average fatalities per attack; VR results in just over one fatality per attack—considerably lower than the average for all attacks on surface transportation. The number of vehicular assaults of both types is increasing overall: 14 of the 19 VR attacks since 1970 occurred between 2014 and 2017 and 10 of the 18 SVR attacks occurred between 2013 and 2015.

To read the report, visit http://transweb.sjsu.edu/PDFs/research/terrorist-vehicle-attacks-on-public-surface-transportation-targets.pdf.

CALENDAR

TRB Meetings

October

29–Nov. 2 Intelligent Transportation Systems World Congress
Montréal, Québec, Canada

November

6–9 6th International Human Factors Rail Conference*
London, United Kingdom

8–9 Forum on the Impact of Vehicle Technologies and Automation on Users*
Salt Lake City, Utah

12–15 2nd Pan-American Conference on Unsaturated Soils*
Dallas, Texas

14–15 5th Florida Automated Vehicle Summit*
Tampa, Florida

14–16 Applying Census Data for Transportation
Kansas City, Missouri

14–16 29th Road Profile Users Group Conference*
Denver, Colorado

14–17 18th International Road Federation World Road Meeting 2017*
New Delhi, India

December

7–8 National Accelerated Bridge Construction Conference*
Miami, Florida

17–20 4th Conference of Transportation Research Group of India*
Mumbai, India

January 2018

7–11 TRB 97th Annual Meeting
Washington, D.C.

30–31 2018 Planning for Shifting Trade Workshop*
Tampa, Florida

April

16–18 International Conference on Advances in Materials and Pavement Performance Prediction*
Doha, Qatar

16–19 Transport Research Arena 2018*
Vienna, Austria

May

2–4 8th Symposium on Pavement Surface Characteristics 2018*
South Brisbane, Australia

15–16 National Household Travel Survey Data for Transportation Applications Workshop
Washington, D.C.

16–18 Road Safety on Five Continents*
Jeju Island, South Korea

20–22 Tenth National Aviation System Planning Symposium
Anchorage, Alaska

27–30 4th GeoShanghai International Conference*
Shanghai, China

June

6–8 International Transportation and Economic Development Conference
Washington, D.C.

18–20 6th National Bus Rapid Transit Conference
Los Angeles, California

24–27 7th International Conference on Innovations in Travel Modeling
Atlanta, Georgia

July

9–13 9th International Conference on Bridge Maintenance, Safety, and Management*
Melbourne, Australia

14–17 12th National Conference on Transportation Asset Management
San Diego, California

17–19 12th Access Management Conference
Madison, Wisconsin

23–25 GeoChina 2018 International Conference*
Hangzhou, Zhejiang, China

August

22–24 16th National Tools of the Trade Transportation Planning Conference
Kansas City, Missouri

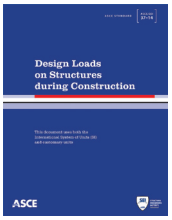
September

25–27 Workshop on Managed Lanes
Bellevue, Washington

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

*TRB is cosponsor of the meeting.

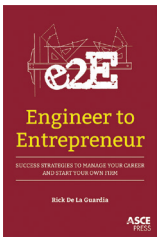
Design Loads on Structures During Construction



American Society of Civil Engineers (ASCE), 2015; 48 pp.; ASCE members, $60; nonmembers, $80; 978-0-78-441309-8.

The latest edition of this volume proposes construction loads based on probabilistic analysis, observation of construction practices, and expert opinions, considering minimum design requirements and load combinations and factors that affect structures under construction.

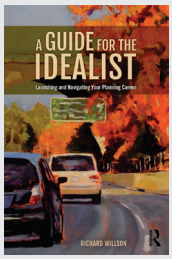
Engineer to Entrepreneur: Success Strategies to Manage Your Career and Start Your Own Firm



Rick De La Guardia. ASCE Press, 2016; 170 pp.; ASCE members, $36; nonmembers, $48; 978-0-78-441441-5.

With personal examples, suggested activities, and detailed steps, the author describes the process of entrepreneurship in engineering—from undergraduate classes to first jobs to opening and running a consulting firm.

Launching and Navigating a Planning Career



New transportation planners and engineers can find tools for shaping their professional pathways in *A Guide for the Idealist: Launching and Navigating Your Planning Career* by Richard Willson, a professor in the Department of Urban and Regional Planning at California State Polytechnic University, Pomona. The author addresses the issues that young professionals face entering the transportation field—doubt, decision making, types of work, and work settings—and offers practical guidance on making effective choices and finding meaning in a transportation career.

Willson explores the contrast between idealism and realism—that is, between the advocacy for solutions to challenging transportation problems and the acceptance of a situation as it is. For transportation professionals, this requires balancing efficiency, economy, resiliency, and environmental sustainability with budgets, local politics, and the complexity of travel behavior.

Young professionals can increase job satisfaction and success by embracing an approach that allows for multiple solutions. Willson refers to the balance of idealism and realism as "principled adaptability." The book offers practical advice for maintaining the ability to be effective in uncertain environments without compromising strong convictions about analytic techniques, design standards, efficiency, and planning values.

Routledge, 2018; 220 pp.; $54.95; 978-1-13808-587-9.

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

TRB PUBLICATIONS

Public-Sector Aviation: Graduate Research Award Papers, 2017

Transportation Research Record 2603

The 10 papers in this volume received awards in a nationwide graduate research competition on public sector aviation research. Topics covered include enhanced safety risk management, planning for ground-delay programs, weather profiles in planning, and more.

2017. Subscriber category: aviation. For more information, visit http://trrjournalonline.trb.org/toc/trr/2017/2603/+.

Socioeconomics, Sustainability, Health, and Human Factors

Transportation Research Record 2605

The papers in this volume explore the travel and living quality in different socioeconomic areas, methodologies for evaluating equity in transportation systems, the social aspects of ridesharing, and other topics.

2017. Subscriber categories: society, economics, policy. For more information, visit http://trrjournalonline.trb.org/toc/trr/2017/2605/+.

TRB PUBLICATIONS *(continued)*

Railroads, Volume 1
Transportation Research Record 2607

Railroad infrastructure topics—ballast permeability, rail-end bolt hole and fillet stress on rail joints, the effects of high-speed passenger trains, integration of light rail on floating bridges, and more—are explored in this volume.

2017. Subscriber category: railroads. For more information, visit http://trrjournalonline.trb.org/toc/trr/2017/2607/+.

Freight Systems, Volumes 1–2
Transportation Research Records 2609–2610

Logistics, probabilistic modeling, economic impacts, and capacity analysis for national and international freight transportation are among the topics presented in these two volumes.

2017. Subscriber categories: freight transportation, terminals and facilities, motor carriers. For more information, visit http://trrjournalonline.trb.org/toc/trr/2017/2609/+ and http://trrjournalonline.trb.org/toc/trr/2017/2610/+.

Marine Transportation and International Trade
Transportation Research Record 2611

Authors present research on the impacts of free trade agreement on marine transportation gateways, waterway tow operations, cost modeling of containerized exports, effects of ship emissions, and more.

2017. Subscriber categories: marine transportation, freight transportation, safety and human factors. For more information, visit http://trrjournalonline.trb.org/toc/trr/2017/2611/+.

Maintenance and Preservation
Transportation Research Record 2612

The papers in this volume address such topics as the maintenance and preservation of roads and bridges, use of materials, unmanned aircraft, and importance rankings.

2017. Subscriber categories: maintenance and preservation, pavements, bridges and other structures. For more information, visit http://trrjournalonline.trb.org/toc/trr/2017/2612/+.

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Maintenance Services, Transportation Weather, and Winter Maintenance
Transportation Research Record 2613

Maintenance and winter weather issues such as ice melting, snow fence installation, project prioritization, and bundling projects are covered in this volume.

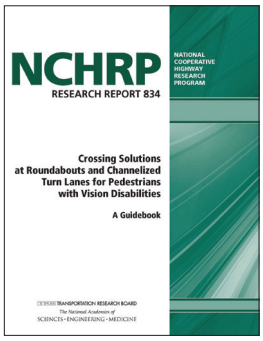
2017. Subscriber category: maintenance and preservation. For more information, visit http://trrjournalonline.trb.org/toc/trr/2017/2613/+.

Research and Education
Transportation Research Record 2614

These papers explore information related to trends in transportation research, transportation education, and student proposals.

2017. Subscriber categories: research, administration and management, education and training. For more information, visit http://trrjournalonline.trb.org/toc/trr/2017/2613/+.

Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities: A Guidebook
NCHRP Report 834



Guidance is presented on crossing solutions for pedestrians with vision disabilities. The research is particularly applicable to roundabout and channelized turn lanes at signalized intersections.

2016; 119 pp.; TRB affiliates, $50.25; nonaffiliates, $67. Subscriber categories: design, highways, operations and traffic management, pedestrians and bicyclists, safety and human factors, society.

Guidelines for Implementing Managed Lanes
NCHRP Report 835

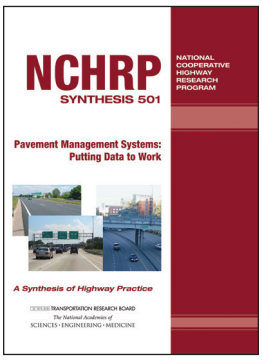
The guidelines in this volume address designing, implementing, operating, and maintaining managed lanes. Included are ways to define objectives, outline the decision-making process, and address safety concerns in design and operation.

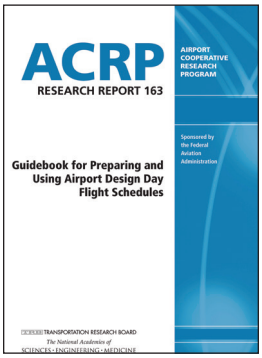
2016; 164 pp.; TRB affiliates, $56.25; nonaffiliates, $75. Subscriber categories: highways, operations and traffic management, policy.

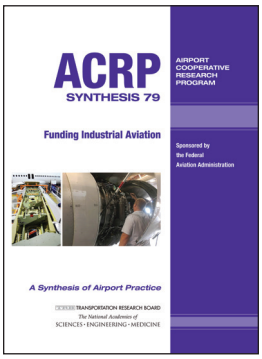
Guidelines for Emergency Ventilation Smoke Control in Roadway Tunnels
NCHRP Report 836

Considered in this report are factors related to ventilation in roadway tunnels—such as tunnel

TRB PUBLICATIONS *(continued)*







altitude, physical dimensions, type of traffic flow, and fan utilization and placement—that can affect human evacuation and emergency responder safety.

2017; 80 pp.; TRB affiliates, $48; nonaffiliates, $64. Subscriber categories: bridges and other structures, security and emergencies.

Pavement Management Systems: Putting Data to Work
NCHRP Synthesis 501

Current pavement management practices are documented, with a focus on pavement management analysis for resource allocation, determining treatment cost-effectiveness, program development, and communication with stakeholders.

2017; 85 pp.; TRB affiliates, $48; nonaffiliates, $64. Subscriber categories: data and information technology, highways, maintenance and preservation, pavements.

Practices for Establishing Contract Completion Dates for Highway Projects
NCHRP Synthesis 502

This synthesis examines methodologies and procedures used by state transportation agencies to estimate contract time for various highway project delivery methods.

2017; 63 pp.; TRB affiliates, $42.75; nonaffiliates, $57. Subscriber categories: construction, highways, law, maintenance and preservation.

Leveraging Technology for Transportation Agency Workforce Development and Training
NCHRP Synthesis 503

The report explores the planning and resources required to implement and maintain a training and development program and assists agencies that are considering ways to use information and communication technology to implement, improve, or expand programs.

2017; 104 pp.; TRB affiliates, $50.25; nonaffiliates, $67. Subscriber categories: data and information technology, education and training, highways.

Strategic Program Delivery Methods
NCHRP Synthesis 504

The strategic implementation of a variety of delivery methods for transportation programs—and their time and cost savings in comparison with individual projects—is explored in this volume.

2017; 102 pp.; TRB affiliates, $48; nonaffiliates, $64. Subscriber categories: administration and management, construction, highways.

Guidebook for Preparing and Using Airport Design Day Flight Schedules
ACRP Report 163

This guidebook for airport leaders, staff, and consultants provides an understanding of design day flight schedules, their uses, and their preparation.

2016; 158 pp.; TRB affiliates, $56.25; nonaffiliates, $75. Subscriber categories: aviation, design, planning and forecasting.

Exhaust Emissions from In-Use General Aviation Aircraft
ACRP Report 164

Authors present research on the use of airport emissions data to improve understanding and estimates of general aircraft emissions.

2016; 122 pp.; TRB affiliates, $50.25; nonaffiliates, $67. Subscriber categories: aviation, environment.

Tracking Alternative Jet Fuel
ACRP Report 165

This volume provides guidance on tracking alternative jet fuels for technical, regulatory, and commercial uses. Also presented are a greenhouse gas calculator and an alternative fuels inventory tracking spreadsheet to evaluate the advantages and disadvantages of tracking mechanisms.

2016; 66 pp.; TRB affiliates, $43.50; nonaffiliates, $58. Subscriber categories: aviation, energy, environment.

Interpreting the Results of Airport Water Monitoring
ACRP Report 166

Comprehensive guidance is presented for understanding, diagnosing, and interpreting airport water quality. The report includes tools to assist in diagnosing root causes that may require mitigation.

2017; 198 pp.; TRB affiliates, $63.75; nonaffiliates, $85. Subscriber categories: aviation, environment.

Funding Industrial Aviation
ACRP Synthesis 79

Aircraft maintenance, repair, and overhaul; manufacturing and assembly; aviation warehousing; spaceports; and unmanned aerial systems platform development are a few of the topics covered in this volume.

2017; 50 pp.; TRB affiliates, $39.75; nonaffiliates, $53. Subscriber categories: aviation, finance, policy.

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

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

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

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

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

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

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

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

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

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