AMERICAN ASSOCIATION
OF STATE HIGHWAY AND
TRANSPORTATION OFFICIALS

AASHTO

UNDERSTANDING TRANSPORTATION RESILIENCE: A 2016–2018 ROADMAP

for Security, Emergency Management, and Infrastructure Protection in Transportation Resilience

Public Safety

Emergency Management

Infrastructure Protection

Climate Change

Community Resilience

System Resilience

Asset Management

Transportation Security

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Personal Resilience

Risk Management

Design Engineering

January 2017

Acknowledgments

Foreword

January 2017

The transportation community is engaged in a conversation focused on a new challenge facing the nation's transportation systems. The challenge is preparing for severe weather events and responding to system vulnerabilities and emergencies while ensuring the resilience of the system. Resilience is working to plan, prepare, and respond in order to return to normal as quickly as possible after an emergency.

Prior to 1995, the term "resilience" was little known in the transportation community. However, the discussion of transportation system resilience gained urgency and impetus following the events of September 11th. Congress, the Department of Homeland Security, other federal agencies, various state agencies, and the National Academies began addressing and resolving a variety of topics around transportation security as the nation developed its response to the threat of terrorism.

Critical infrastructure, risk management, establishing protection approaches, and dealing with extreme weather events emerge at the heart of our challenge as the four foundational concepts critical to shaping a more resilient approach.

From the DOTs' perspective, there are three distinct viewpoints: planning (severe weather events/sustainability), engineering (infrastructure protection), and operations (traffic management/emergency management/security).

This new report developed under the guidance of the Special Committee on Transportation Security and Emergency Management (SCOTSEM) provides an overview and direction in pursuing resilience, establishing a direction for the next three years:

> *Deploying Transportation Resilience Practices in State DOTs (2017–2018)*
> *Resilience Research Roadmap (Pre- and Post-Summit versions) (2016–2018)*
> *Transportation Resilience White Papers (2016)*
> *CEO Primer on Transportation Resilience (2016)*
> *CEO Engagement Forums (2017–2018)*

We recommend this information to you and your staff as a strong starting point to help organize your next steps.

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SCOTSEM Chair

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Preface

In late 2014 AASHTO's Special Committee on Transportation Security and Emergency Management (SCOTSEM), adopted a fourth generation strategic plan. A core element of the plan is to focus on advancing the state of the practice and preparing the community for new trends affecting their business and profession.

SCOTSEM Mission Statement

Serve state DOTs, other AASHTO committees, and partner organizations by developing, promoting, and supporting the coordinated implementation of all-hazards infrastructure protection, emergency response, and related system operations/resilience programs.

SCOTSEM 2014–2018 Strategic Goals

1. Advocate for the role of all-hazards infrastructure protection and emergency management in a resilient transportation system.

2. Assist in shaping and implementing national policy, legislation, funding, and regulatory development affecting transportation infrastructure protection and emergency management issues.

3. Investigate, develop, and report on recent advances in infrastructure protection, security, and emergency management issues in urban and statewide environments, including consideration of their social and economic impacts.

4. Advance the state-of-the-practice and awareness of transportation infrastructure protection and emergency management through training, technical assistance, and technology transfer activities.

5. Develop, promote, and encourage effective working relationships among state transportation officials and other stakeholders responsible for various aspects of transportation infrastructure protection, emergency management, and system operations.

6. Develop and promote a research and implementation plan for transportation infrastructure protection, security, and emergency management.

Introduction

The transportation community is engaged in a conversation focused on characterizing a new challenge facing the nation's transportation systems. In numerous venues, the nexus of preparing for the impacts of climate change while responding to the catalog of system vulnerabilities and emergencies has emerged to be characterized as the resilience[1] of the system.

Although significant public and private sector efforts have been made to improve transportation system operations over the past decade, the 2013 Transportation Research Board (TRB) report on *Critical Issues in Transportation* concluded that "[T]he performance of the transportation system is neither reliable nor resilient, yet transportation's role in economic revival and in global economic competition has never been more important." This finding was echoed by AASHTO's Standing Committee on Research (SCOR) who noted that "A major performance issue across all modes is the inadequacy of preparation for natural and human-made disasters" when

> "The transportation system is a complex network of infrastructure, vehicles, power sources, communications, and human capital. When we speak of resilience in the transportation sense, we mean the ability of the transportation system to recover and regain functionality after a major disruption or disaster." *AASHTO SCOR, 2016*

it identified resilience as the number one National Cooperative Highway Research Program (NCHRP) emphasis area for FY2017.

This finding reinforced the 2015 National Infrastructure Advisory Council report on the critical importance of transportation sector resilience. Key in their findings and recommendations were:

- The importance of understanding the systemic risks causing system disruptions
- Incorporating resilience into operational practice
- Investing in resilient infrastructure
- The importance of conducting a quadrennial review of transportation infrastructure
- Developing tools, models, and standards to mitigate risks
- Operationalizing resilience

SCOR also noted that the application of resiliency engineering in the transportation sector is still in its infancy. This finding is echoed by the U.S. DOT, the National Research Council, AASHTO's Special Committee on Transportation Security and Emergency Management (SCOTSEM), and others who have all indicated the need for more work to be done in implementing systematic resilience-based approaches in surface transportation. Although TRB cooperative research projects have produced a wealth of resilience-related studies, products, guidelines, and effective practices, there is still much that remains to be done to ensure resilience becomes a sector-wide goal co-equal with those established for safety, mobility, and efficiency.

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1   The terms "resilience" and "resiliency" are synonymous and are used interchangeably in the text.

The purpose of this report is to provide SCOTSEM and other AASHTO and TRB resilience-oriented committees and projects a discussion tool to guide their approach to sponsoring and participating in national transportation resilience-related activities. This report is also intended to assist SCOTSEM in transitioning into its proposed new identity within the recently announced AASHTO committee reorganization.

Background

Prior to 1995, the terms resilience and resiliency were unknown in the transportation community. This language was first used when researchers and policymakers studying earthquakes and earthquake policy began applying the term resilience to communities and their vital infrastructures (water, communication, electric power, transportation, etc.) as they looked for ways to mitigate the impact from earthquakes. Their work and related other activities culminated in 1998 with Presidential Decision Directive NSC-63 *Critical Infrastructure Protection*.

The discussion of transportation system resilience gained urgency and impetus following the attacks of September 11 as the Congress, the Department of Homeland Security, other Federal agencies, various state agencies, and the National Academies began addressing and resolving a variety of topics around transportation security as the nation developed its response to the threat of terrorism.

At the heart of all this activity—research, policy development, conferences, and discussions—were four foundational concepts that emerged as critical factors in shaping a more resilience-centric approach to a changing environment.

First, there is the concept of critical infrastructure, defined in Public Law 107-56, Sec. 1016(6) as:

> "…Systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters."

Second, there was the introduction of the concept of risk defined by the 2009 National Infrastructure Protection Plan (NIPP) as:

> "… The potential for an unwanted outcome resulting from an incident, event, or occurrence, as determined by its likelihood and associated consequences."

Third was the concept of protection defined by Department of Homeland Security (DHS) Guidance and Homeland Security Presidential Directive 7 (HSPD 7) as:

> "…To cover or shield from exposure, injury or destruction…to protect means reducing the vulnerability of critical infrastructure…in order to deter, mitigate or neutralize terrorist attack."

A fourth concept was stimulated by the impacts of climate change and extreme weather. In 2011 the United States was struck by multiple disasters—including 14 related to weather

> The debate over whether to promote protection or resilience as the Nation's overarching strategic vision for preventing service disruptions may appear to be a debate over semantics. However, arguing whether protection incorporates resilience or vice versa obscures real differences between these two objectives. Reducing risks by building higher fences and deploying more guards is very different than increasing resilience by building a second facility somewhere else or strategically stockpiling replacement equipment that restore service quickly.
>
> *CRS, 2012*

and climate—that caused more than $55 billion in economic damages, breaking all records since these data were first reported in 1980. Nearly 600 Americans died, and many thousands more were displaced.

The data suggest that the cost of weather-related disasters will continue to rise, both in dollar amounts and in social, cultural, and environmental losses to communities as severe weather events are predicted to increase in both frequency and severity and as sea level rise continues its inexorable increase.

Since transportation system responses to disruptions in service are very similar regardless of their cause, emergency and risk management professionals developed all-hazards protocols for incident response and emergency management activities.

Defining Resilience

As is common in new fields of endeavor or in the adaptation of one field of knowledge to another domain, developing a common language with well-understood meaning is problematic. The language of resilience is no different.

- Originally the term and its application were developed in human psychology and referred to the human trait of being able to "bounce back" or recover from illness, adversity, depression, and other life misfortunes.
- Other related ideas focus on the ability to adapt to the demands of stressful situations or to cope successfully with significant change, adversity, or difficulty.

These core notions were easily seen as analogs of desirable characteristics of governments, communities, and complex systems such as transportation. Consequently, various agencies began to define resilience in multiple similar but not completely congruent terms.

- Presidential Policy Directive PPD21 defined resilience as "The ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents."
- DHS defines resilience variously as, "The ability to resist, absorb, recover from, or successfully adapt to adversity or a change in conditions," and also, "The ability of systems, infrastructures, government, business, and citizenry to resist, absorb, recover from, or adapt to an adverse occurrence that may cause harm, destruction, or loss of national significance."
- The 2009 AASHTO–TRB Transportation Hazards & Security Summit proposed a comprehensive definition of resilience: "The ability of a system to provide and maintain an acceptable level of service or functionality in the face of major shocks or disruptions to normal operations.
  - A system of systems characterization across 'lifeline systems' including power, water, connectivity, and mobility with a focus on providing these essential services first.
  - Self-diagnosing, self-healing, and self-repairing systems that have fewer long-term service disruptions and lower life-cycle costs.
  - Systems that are sustainable, energy efficient and performance-based."
- AASHTO's SCOTSEM defines resilience as "the ability to prepare and plan for, absorb, recover from, or more successfully adapt to adverse events" (adapted from *Disaster Resilience: A National Imperative*, National Research Council, 2012).
- The National Academies of Sciences, Engineering, and Medicine's Resilient America Roundtable has also adopted the National Imperative definition of resilience as "the ability to prepare and plan for, absorb, recover from, or more successfully adapt to actual or potential adverse events."
- Federal Highway Administration (FHWA) Order 5520 defines resilience or resiliency as, "…the ability to anticipate, prepare for and adapt to changing conditions and withstand, respond to and recover rapidly from disruptions."

- The Harbor Safety Committee Conference defined resilience as "The capability to expeditiously recover and reconstitute vital services with minimum disruption."
- The non-partisan, not-for-profit Reform Institute suggested resilience was "Mitigating the cascading adverse effects of a terrorist attack or natural disaster so that the nation can quickly recover and resume normal activity after such an episode."

While a case can be made for standardizing on a single definition, the complexity of this undertaking coupled with the questionable benefits accompanying this ambition probably render such an activity moot. On the other hand, multiple applications of this ad hoc terminology may create the notion that "resilience" may be merely just the latest "buzzword" or initiative du jour. In other words, "Resilience is just (Emergency Management or System Operations or Infrastructure Protection or Transportation Security, etc.) with a new label."

The reality is that there is room and need for a "resilience" approach in all activities that are the responsibility of the transportation community.

The Faces of Transportation System Resilience

The parable (see sidebar) teaches that along with the local bias of experience, there is some truth to every position. Each cell of the "honeycomb" shown in Figure 1 represents some facet of resilience but is not, by itself, the whole. For example, while emergency management is an essential component of resilience, its conceptual framework is ill-suited for the kinds of actions necessary to mitigate or adapt to slow disruptors such as climate change. Some disruptions are known well in advance and can be planned for in great detail; others occur with no warning and require a great deal of resourcefulness to restore service. Resilience, much like safety, affects every major business function within a transportation agency, not just operations. Planning, design engineering, maintenance, and business management divisions all play significant roles.

The parable of the six blind men and the elephant is familiar in many cultures. Each man touches a different part of the elephant—the leg, the tail, the trunk, and so on—and each interprets the whole in terms of the part—as a pillar, a snake, a tree, etc. until they come to blows. The conflict is resolved only when they stop arguing, start listening, and collaborate to "see" the full elephant.
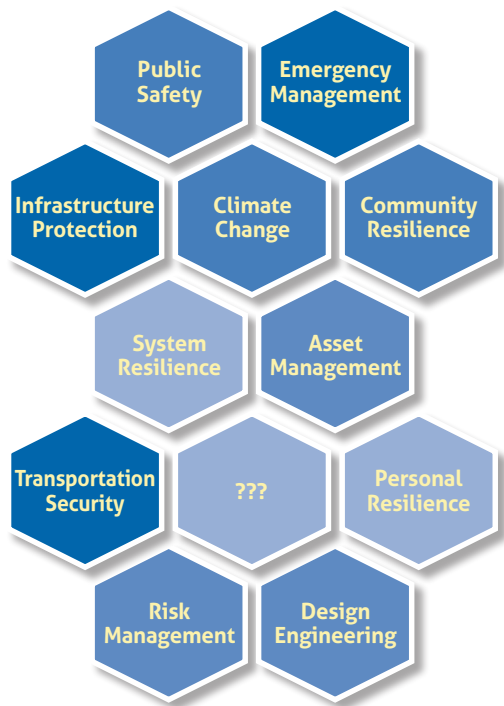
Figure 1. The Transportation Resilience Honeycomb.

The following table provides an example comparison among some of the more affected faces.

Table 1. The Faces of Resilience

Dimension	Emergency Management	Design Engineering	Climate, Community, and Societal Change
Mission	Plan, prepare, respond, recover	Resist, adapt	Plan, resist, adapt, restore
Duration	Hours–Months	Years–Decades	Decades or longer
Potential Disruptions	Planned events Incidents (incl. HAZMAT) • Weather events • Natural disasters • Terrorist incidents • Catastrophic incidents	New engineering requirements	• Extreme weather impacts • Climate change impacts • Sea-level rise • Carbon reduction initiatives • Pandemics
Impact	Local–Regional	Local	Superregional–Global
Governance (communication, coordination, resources, etc.)	Varies but public safety agencies (PSAs) generally provide incident command	Varies but state DOTs generally provide project management	• Multiple agencies at all levels of government, including international and community groups • NGOs and private sector • State DOT is not generally lead agency
Agency Role	As needed in the jurisdiction: • Support evacuation and emergency access activities • May be lead recovery agency for transportation repairs	Varies but state DOTs generally provide engineering and construction services	• Funding • Planning • Policies and standards • Mitigation projects

It is well recognized in the transportation operations and emergency response community that the framework for its activities is driven by an understanding that there is a continuum to the events for which they need to plan, prepare, respond, and recover from. The following figure illustrates that continuum.

The major take-away from this discussion is that, while state transportation departments have significant roles to play in restoring transportation services and functions, in many cases they will not be the lead agency responsible and will need to closely coordinate, collaborate, and communicate with others.

From the DOT's perspective, there are three distinct viewpoints: **planning** (climate change/sustainability), **engineering** (infrastructure protection), and **operations** (traffic management/emergency management/security); three strategic levers: **policy**, **people**, and **programs**, with two different focuses: **system** and **infrastructure component**; and two different periods of research interest: **pre-event** (risk reduction) and **post-event** (consequence reduction).
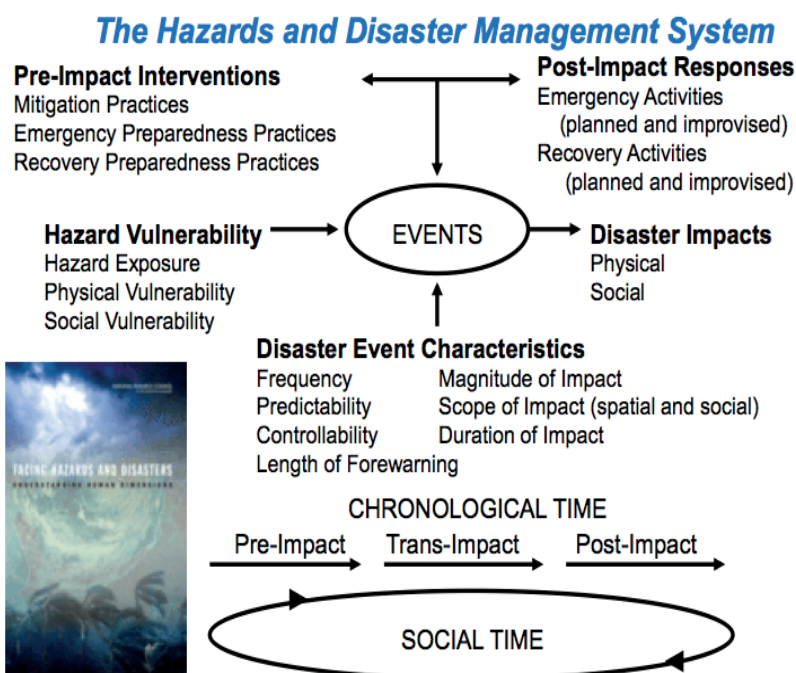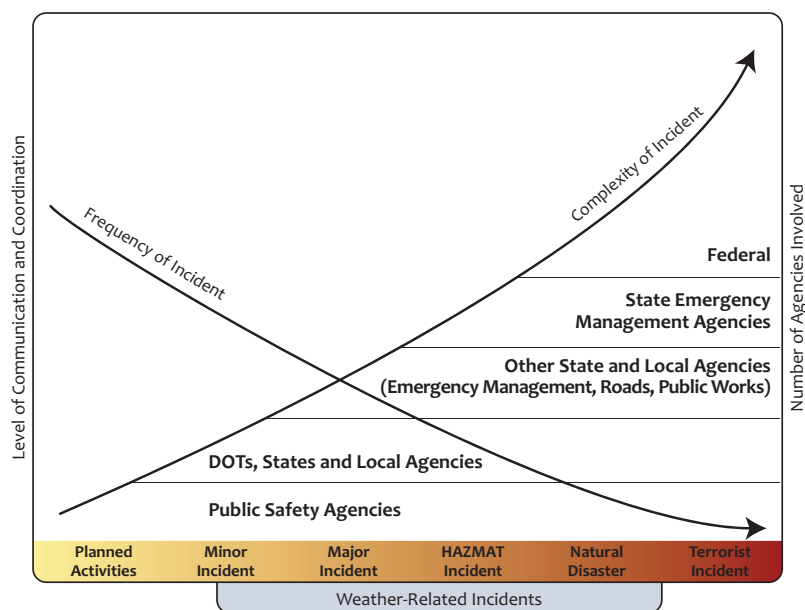
The chart shows axes: "Level of Communication and Coordination" (left vertical) and "Number of Agencies Involved" (right vertical). Two crossing curves labeled "Frequency of Incident" and "Complexity of Incident".

Agency tiers (top to bottom):
- Federal
- State Emergency Management Agencies
- Other State and Local Agencies (Emergency Management, Roads, Public Works)
- DOTs, States and Local Agencies
- Public Safety Agencies

Bottom categories (left to right):
Planned Activities | Minor Incident | Major Incident | HAZMAT Incident | Natural Disaster | Terrorist Incident

Weather-Related Incidents

The Hazards and Disaster Management System

Pre-Impact Interventions
Mitigation Practices
Emergency Preparedness Practices
Recovery Preparedness Practices

Post-Impact Responses
Emergency Activities
 (planned and improvised)
Recovery Activities
 (planned and improvised)

Hazard Vulnerability → **EVENTS** → **Disaster Impacts**

Hazard Vulnerability
Hazard Exposure
Physical Vulnerability
Social Vulnerability

Disaster Impacts
Physical
Social

Disaster Event Characteristics
Frequency   Magnitude of Impact
Predictability   Scope of Impact (spatial and social)
Controllability   Duration of Impact
Length of Forewarning

CHRONOLOGICAL TIME
Pre-Impact → Trans-Impact → Post-Impact

SOCIAL TIME

Figure 2. Resilience Continuums.

Source: Facing Hazards and Disasters (NAS, 2006), adapted from Kreps (1985), Cutter (1996), Lindell and Prater (2003)

The Roles of Security, Emergency Management, and Infrastructure Protection in Transportation Resilience
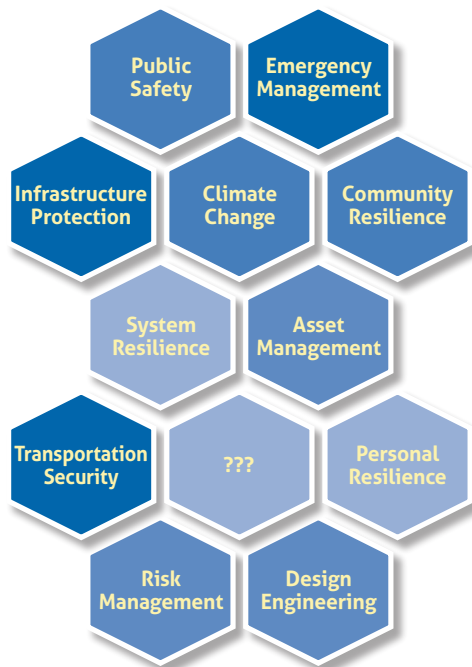
There is a commonality shared in all these faces of the transportation community. There is a new appreciation for the challenges inherent in reconciling the similarities and distinctions among four common interrelated topics:

- Critical Infrastructure
- Risk Management
- Protection
- All-Hazards Emergency Management

The development of a new strategy based on resilience includes a broad range of options to help manage risks and recover from system disruptions. In this new paradigm, resilience does not replace the four concepts, but offers instead an overarching strategy that includes risk management, protection, and preparedness as complementary strategies to prevent attacks and to identify and ward off additional threats; adaptation, recovery, and other post-disruption strategies to restore normal transportation services; and longer term strategic approaches to adapt to climate change (experienced as extreme weather and sea level rise, for example) and to wield policy tools for economic resilience.

Over the course of time there have emerged a set of eight strategies that are recognized as effective methods of improving the resilience of many areas of service delivery.

These well-understood strategies employed by the emergency management and security communities may share a common thread across all faces of resilience. The eight strategies are defined in Table 2.

Table 2. Strategies to Achieve Resilience

STRATEGY	DEFINITION
Add Redundancy	Adding redundancies to the asset or system can improve resilience by being able to reroute production or process flows through one or more parallel components or subsystems.
Backup Components	Having backup components available can improve resilience by being able to quickly replace a component or asset whose function is disrupted.
Substitution	Substitution can improve resilience by allowing a process to switch from one input or component to another, perhaps with slightly different properties, but without major impact on the final product or process.
Reduce Vulnerabilities	Products and processes can also be redesigned to reduce or eliminate their vulnerabilities to specific threats.
Improvise Approaches	Resilience may depend on the ability to improvise during a disruptive event, perhaps by re-engineering processes in real time or making do with materials and assets at hand.
Priority Access	The resilience of a critical infrastructure asset could be enhanced by giving it priority access to critical resources, thereby maintaining its services or getting services back on-line more quickly to aid in a more general community recovery.
Model Disruptions	Many discussions regarding resilience of critical infrastructure stress the importance of modeling system operations, including the system's interdependencies with other systems beyond the immediate control of operators, assessing vulnerabilities, and contingency planning.
Backup Logistics	Planning (preparedness) is particularly important if one is using back-up systems or substitution to help respond to events.

These resilience-enhancing strategies, adapted from the 2012 Congressional Research Service Report *Critical Infrastructure Resilience: The Evolution of Policy and Programs and Issues for Congress,* can be used to highlight and scope the roles, responsibilities, and interests of SCOTSEM stakeholders.

Clearly, any AASHTO sponsored, systematic approach to improving transportation systems resilience will require the involvement of many, if not most, of its standing committees, and not just the SCOTSEM or the newly proposed Committee on Infrastructure Resilience.

While much resilience-related technical material has been produced by the Cooperative Research Programs, U.S. DOT, DHS, and others, there is still a need for more information.
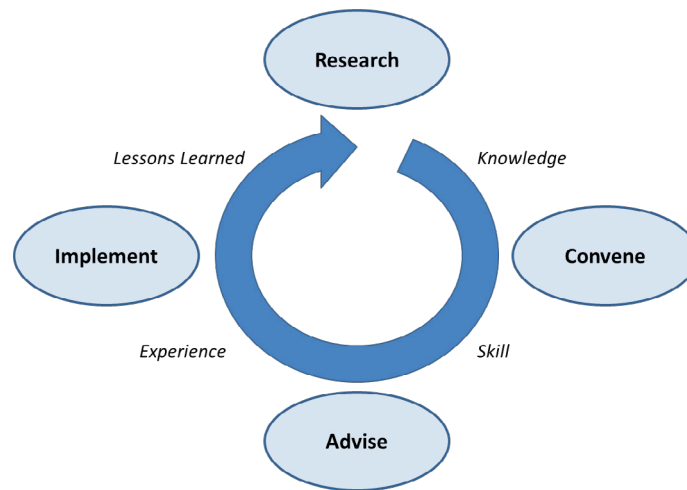

Figure 3. Resilience Research Framework.

The beginning of a solid approach begins with a positive end in mind: informing agency transportation practices to address resilience. This involves changing organizational/institutional approaches, creating new employee education and training, and reaching out to stakeholders supporting transportation agencies. NCHRP has begun the process of moving the transportation resilience conversation forward.

The following funded activities provide a forum, expert advice, and peer counsel with an implementation focus over the next several years.

NCHRP 20-59(117) Deploying Transportation Resilience Practices in State DOTs (2017–2018)

The objective of this research is to develop set of implementation support tools and services to assist transportation organizations to implement resilience-based innovations and effective practices based on the implementation recommendations contained in already completed resilience research.

The scope of these services shall encompass those activities involving (1) organizational/institutional implementation (e.g., governance, business process/data, performance measures, work plans), (2) employee learning (grounded in modern adult learning theory and centered on facilitating learning in the workplace), and (3) stakeholder outreach and engagement.

A significant component of the this project will be to organize a national summit and peer exchange on transportation resilience to be held in 2018 and co-sponsored by TRB, AASHTO (SCOTSEM, Standing Committee on the Environment (SCOE), and Resilient and Sustainable Transportation Systems (RSTS), FHWA, Federal Emergency Management Agency (FEMA), DHS, Transportation Security Administration (TSA), and other interested parties.

Resilience Research Roadmap (Pre- and Post-Summit Versions) (2016–2018)

The objective of this proposal is to develop and prepare a research roadmap for use in focusing the efforts of the transportation community in implementing a broad based program addressing a resilient transportation system. The work will inform, complement, enhance, and augment work and conclusions arising from NCHRP Project 20-59(117).

Transportation Resilience White Papers (2016–2017)

The objective of this proposal is to develop and prepare three discussion papers or reports on special topics related to transportation resilience in support of the national summit on resilience included in the scope of work in NCHRP Project 20-59(117). Final selection of the topics would be determined by the NCHRP project panel.

> "Disaster resilience is everyone's business and is a shared responsibility among citizens, the private sector, and government. Community leaders and government officials face decisions every day that may pit short-term interests against longer-term goals. Increasing resilience to disasters will require decisions and actions that are informed and forward-looking.
>
> "Although disasters will continue to occur, actions that move the nation from a reactive to a proactive approach will reduce many of the societal and economic burdens and impacts that disasters cause. Building the nation's resilience is a long-term process, one that will be socially and politically challenging, but the reward for our efforts will be a safer, healthier, more secure, and more prosperous nation."
>
> *The National Academies, 2012*

CEO Primer on Transportation Resilience (2017–2018)

This research proposes to prepare an executive level primer on transportation resilience. The focus of the primer would provide senior executives with a short and easy to follow report to define and explore the implications of the emerging focus on resilience in transportation and its potential impact on agency programs.

CEO Engagement Forums (2017–2018)

The objective of this proposal is to develop briefing material on transportation resilience and to provide a series of briefings to senior transportation executives prior to the 2018 National Summit on Transportation Resilience. These briefings would also serve to gauge interest in and garner support for resilience-related activities including the Summit, the research agenda on resilience, and for local resilience-focused initiatives.

It is clear from the preceding initiatives that resilience is more than a word but rather a concept with staying power. The goal now is to assure that transportation agencies understand and incorporate the concepts of resilience into their management framework.

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