



# RESILIENCE: A DOT IMPERATIVE

A Primer for  
Transportation Executives

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**TRANSPORTATION RESEARCH BOARD OF  
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## RESILIENCE IS THE ABILITY ...

**“to prepare and plan for, absorb, recover from, or more successfully adapt to adverse events”**

*(Disaster Resilience: A National Imperative, National Research Council, 2012).*

**“to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions ... ”**

*(FHWA Order 5520).*

**“of the transportation system to recover and regain functionality after a major disruption or disaster.”** *(AASHTO).*

**“the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow, no matter what kinds of chronic stresses and acute shocks they experience.”** *(100 Resilient Cities).*

# EXECUTIVE SUMMARY

Everything the chief executive officers of state departments of transportation and everyone else in their agencies do is based in resilience. All of the DOT's achievements, difficulties, necessities and plans— even reports on ordinary activities—have the promise of resilience in them. That promise is: We are working hard to be sure your transportation needs are met and, if they are interrupted, it won't be for long.

**“Get out there in front.  
Be bold.”**

As CEO of a transportation agency, you have the responsibility to plan, deliver, operate and maintain a safe transportation network so essential to the economic wellbeing of your state. Critical corridors of commerce need to be resilient during extreme weather events and other disruptions. Making the network resilient depends on both technical and policy factors, and there are significant roles only you can play. This CEO Primer identifies what you can do and ways you can incorporate resiliency practices into the day-to-day operation of your agency, as well as your long range planning.

Potential and real disruptions to a DOT's service, reliability and safety--from extreme weather, natural disasters, cyber incidents, system failures or combinations of these—are on the rise. Also rising are customers' expectations for system performance and reliability—and their intolerance for delay. The result is increased public and political demand for DOTs to solve disruption problems before they become critical.

Several widely used definitions of resilience share the same idea: resilience means forecasting what could happen, coping with the consequences of a disruptive event, and looking ahead to be readier than before to face future disruptions. The core ideas of resilience—anticipating, adapting, preparing, and then bouncing back from disruption even stronger—apply to every major business function in a transportation agency.

DOT CEOs across the United States contributed to this Primer and shared their approaches to becoming a transportation agency that is resilient: pro-active in maintenance and operations and ready to minimize or avoid future disruptions. A culture of resilience grows out of making resilience part of everyone's job, until it is functionally second nature, just as the idea of safety has become embedded in transportation culture. A resilient agency can deter problems and take action before a disruption becomes disastrous. A resilient transportation system improves safety, saves the state money, the public time, and the agency its respect and reputation.

## ACTIONS YOU CAN TAKE AS CEO TO MAKE YOUR AGENCY MORE RESILIENT

- Promote the importance of resilience to your agency, to your governor, to your state.
- Be actively engaged in resilience efforts.
  - » Know the most likely disruptions that could happen and what is likely to be impacted so your plans can be future-fit.
  - » Be part of the development of mitigation/adaptation approaches and the preparation of build-back strategies; ensure that cross-cutting teams (e.g., Operations and Maintenance (O&M) with Planning and Development) are involved.
  - » Make resilience part of the agency funding criteria to support planning for future events.
  - » Engage your partners in state and local governments and the private and non-profit sectors, especially in resiliency investment planning, (e.g., strengthening mutually interdependent critical infrastructure systems, such as communications, power, water and roads, bridges and tunnels).
- Model the importance of resilience in your words and actions.
  - » Support staff's spending time on resilience and encourage discussions within and across disciplines, regions and agencies.
  - » Incorporate resilience as a high-level performance factor, especially in support of cross-functional collaboration.
- Foster preparedness and resilience efforts.
  - » Integrate resilience into planning and programming, building in flexibility for changing conditions and environments.
  - » Leverage asset management life-cycle and risk assessments, to help plan preventive measures, prioritize response and coordinate recovery.
  - » Incorporate resilience into design, engineering, operations and maintenance to reduce vulnerabilities and mitigate consequences of events.
  - » View emergency management and response in a resilience context, learn from events (lessons about design, as well as operations) and highlight your successes to advocate for resources to improve resilience in the future.
- Capitalize on the resilience theme in agency communications. Broadly share the work your agency is doing to reduce future disruptions.
- See technology through a resilience lens and identify new materials and technologies that can increase resiliency.
- Address cybersecurity early and often and recognize that cyber resilience is a continuous process of monitoring and adapting to new vulnerabilities.

**“Whatever you call it, customers expect this work to be done.  
They expect us to keep things working.”**







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# INTRODUCTION

During your tenure as the CEO of a DOT, you will face many challenges, including some that will have serious impacts on your state population's mobility and safety, and possibly on your tenure. Many of these revolve around the resilience of the transportation system—how well your system can withstand disruptions from natural causes, catastrophic failures of the infrastructure or cyber events, and how quickly your agency can restore services when they are impacted. Appendix A offers some of the many current definitions of resilience that relate to transportation.

The public and political leaders expect DOTs to have plans and take actions to prevent or minimize disruptions and respond quickly when necessary.

The good news is that you are not alone. Your people have a great deal of wisdom and experience. Your organization has resilient systems and response plans. Your peers are tackling similar challenges. The information presented here has come from many DOTs' experiences to varied natural or human events. CEOs across the country in every region contributed to this Primer. Their input was gathered through one-on-one interviews and at roundtables conducted during the AASHTO 2017 regional meetings. Their quotes appear unattributed throughout. Their collective knowledge coupled with information from case studies and research is offered to assist you in meeting your challenges and making your agency more resilient.

## HALLMARKS OF A RESILIENT CEO

- **Knows** risks, hazards and time horizons
- **Plans** proactively for what if scenarios
- **Balances** risks and costs in capital decision-making
- **Maintains** an owner mentality

## HOW TO USE THIS PRIMER

This Primer provides a quick grounding in resilience benefits, the CEO's role in resilience and approaches taken in various states to increase the resilience of their transportation system. It is designed to give you concepts and tools to lead your agency toward greater resilience, given the many variables specific to your agency.

Part One of the Primer is an overview of the significant role a CEO has in resilience. The section includes key questions to help you succeed and challenges you may encounter with approaches DOTs have used to address them. Part Two provides information on how to integrate resilience into your agency. This section delves a bit deeper into the specific realms of your agency, such as Planning, Design, Engineering, Operations and Maintenance, with examples of what DOTs are doing in each. Appendices provide additional resources and references.

Wherever you are on your way towards resilience, the Primer should help you better understand and think more deeply about the opportunities and challenges. Engage with your peers on resilience to share your experiences, make use of their replicable successes and learn from their disappointments. Resilience thrives on conversation and collaboration.

# PART ONE:

## THE CEO ROLE IN RESILIENCE

Resilience—like safety and asset management—affects every major business function in a transportation agency: planning, design, engineering, operations, maintenance, finance, communications and business management. A resilient transportation agency is prepared and positioned to take action, to restore services, relocate routes or assets when appropriate, support interdependent and interconnected services, and build back better after damage. The resilience of your organization depends on both technical and policy factors, with leadership only you can provide.

### WHY YOU SHOULD CARE

When, not if, something major happens on or to your network on your watch, the governor and the public will look to you. Your commitment to resilient systems and infrastructure is your evidence of focus on readiness, with your organization being demonstrably proactive and nimble. You can show that you have made your best efforts, within available resources, to forestall impacts, as well as quickly respond to events. A resilient agency can anticipate problems and take action before a disruption becomes disastrous. This proactive approach saves the state money, the public time, and the agency its respect and reputation.

Committing to resilience means you will:

- Assess risks and vulnerabilities and make decisions despite uncertainty and limited resources.
- Develop and assess alternative strategies for adapting infrastructure and operations.
- Convince your governor, state legislature and the business community to support efforts that could provide considerable benefits, even when the impacts may not be immediate and could involve significant costs. (See Appendix B).
- Get your employees to explore how resilience tactics can help them do their jobs and improve outcomes; recognize their existing efforts to be resilient.
- Do all this in ways that endure when you eventually leave the agency.

**“A DOT is uniquely positioned to take action, look at design scenarios, and has the opportunity to develop action solutions as an infrastructure agency.”**

## WHAT YOU CAN DO

The greatest gains occur when resilience is seamlessly woven into an agency's asset management, risk management, and performance management practices. Because resilience is dependent on both technical and policy factors, there are actions you as CEO must do to build and enhance the resilience of your agency and your transportation system.

**“Part of this is implementing countermeasures versus other operational strategies. It's important to look at the full scope, not piece by piece.”**

### Promote Importance of Resilience.

**Relate resilience to the agency's mission statement.** Each transportation agency has its own mission statement, but all missions involve safety and customer service. Adding resilience to these two common characteristics gives the mission a three-legged-stool balance that should be the foundation of evaluating the agency. Be sure there are performance measures tied to resiliency in the strategic plan.

**Be prepared to explain to why we have to think about these things and how being resilient will make a difference to the agency and to the state.** You must be the advocate for resilience to the governor, the state commission and the legislature. It is important that they understand the potential risks and consequences of various types of events or threats, the potential transportation system impacts likely to occur, and what can be done to reduce losses, improve safety and minimize the impacts of events.

### Be Actively Engaged in Resilience Efforts.

**Know the most likely things that could happen and what is going to be impacted.** You need to be alert and forward-looking to new realities and threats, being creative and fostering an environment that is comfortable with uncertainty.

**Prepare for build-back strategies.** Anticipate what needs to be done and make sure that planning, design and construction, along with operations and maintenance, are part of the process. Insist that resilience be part of agency policies, such as design guidelines, and in operations and maintenance procedures. Acknowledge that in some instances, not building back may be the appropriate action.

**Make resilience part of funding criteria.** By planning ahead you can include resilience into your capital projects' plans. Looking at trends, you can identify opportunities to demonstrate the benefits of funding for resilience. Not all resilience work is driven by risk concerns—some efforts that save costs or use current approaches or advanced materials technology can provide additional resilience.

**Engage your partners in state/local governments and other organizations.** Make the resiliency discussion part of the annual plan update through your metropolitan planning agencies (MPOs). Make good use of tabletop exercises not just for emergency response, but also for resiliency investment planning. Consider the tough questions on interdependencies and cascading failures—how you would collectively deal with extended power outages and similar catastrophic failures—and what you can collectively do to strengthen infrastructure and mitigate impacts. Non-profits such as the Red Cross, faith-based organizations and other volunteer or community organizations play critical roles, particularly with social and community resilience.

## Model the Importance of Resilience in Your Words and Actions.

**Be supportive of staff's spending time on resilience.** Encourage discussions within the agency and across agencies on how they are dealing with issues and policies such as working on maintenance plans and priorities, or potential grants for programs. Authorize staff engagement in regional and national resilience conversations.

**Incorporate resilience as a high-level performance factor.** Support cross-functional collaboration by rewarding coordinated decision-making, planning and strategy development. Require that training and exercises take resilience into account. Devise strategies for measuring resilience and take an active role in promoting improvements.

## Foster Preparedness and Resilience.

**Conduct system and stress tests to assure system resiliency for system overloads and/or breakdowns.** A resilient organization can anticipate problems and take corrective action before a potential disruption becomes disastrous.

**Ensure that your agency has or develops an emergency response plan and system evacuation plans to assure resiliency of your system infrastructure.** Take advantage of crisis incidents to ensure resilience activities in lessons learned and corrective action plans

following minor and major events. Take advantage of non-emergency planned events (e.g., large concerts, large sporting events) to practice collaborating among agencies and implementing techniques and strategies to move large numbers of people efficiently.

**"It's hard to make resilience a high priority until you have experienced some of the issues that would be helped by having more resilient infrastructure."**

**Ensure that your agency understands its interconnections with other agencies and that all are working to strengthen weak links and develop work-arounds.** Consider physical and functional system interdependencies. For example, highways are often co-located with communications, power, and water and sewer utilities; failure of one could damage all. Traffic systems and rail systems rely on power and communications for safe operations. Have your team brainstorm and "table top" with a broad range of stakeholders who are willing to discuss tough questions.

**Recognize that even small changes matter.** Working toward resilience will pay off in the long run. Whatever your starting point, fostering incremental practices and procedures that build resilience and encourage preparedness will have positive impacts over time and be beneficial in the process. For example, actively maintaining a Continuity of Operations Plan (COOP) plan helps team members think about the unthinkable and the need for flexibility and continuity.

**A focus on resilience can encourage airing problems and empowering individuals to raise an alarm when necessary.** It invites adaptive thinking and improvising solutions that permit quick action in a crisis. A culture of resilience grows out of making resilience part of everyone's job, until it is functionally second nature, just as safety has become embedded in transportation culture.

## KEY QUESTIONS TO ASK

Asking questions from a resilience lens perspective helps maintain a focus on resilience: 1) Will this decision or action increase agency ability to withstand hazards (short term and long term, recurrent and rare)? 2) Will this action strengthen agency ability to quickly return to service after a disruption? 3) Will this action help the agency adapt more quickly to hazards? The following questions can assist you in developing your vision and strategies through a resilience lens.

### Resilience

- What agency issues trouble you most? How could resilience help you with these issues?
- What does resilience mean for your agency?
- Have the major events—disasters, extreme weather impacts, and human-caused catastrophes—experienced in your state or during your tenure at a state DOT impacted your view of resilience?
- How secure are your data and systems?
- Has your own point of view on resilience emerged or changed over time? If so, how?
- What level of interest in resilience do you expect from each of your audiences (e.g., the governor, legislators, business and community leaders, the general public, your employees and contractors)? How will you encourage interest if little or none exists?

### Business Processes: General

- Is resilience a focus in your strategic and long-term plans?
- How does your agency evaluate and select adaptation strategies? Do you include factors such as technical and political feasibility, safety costs and benefits, life cycle costs, efficacy, flexibility, and sustainability?
- Do you regularly review and assess agency capabilities necessary for successful implementation of resilience (e.g., improvements in business processes, systems and technologies, performance management, culture, organization and workforce, and collaboration)?
- Are the staff that will be doing the work preparing for resilient operations and recovering from disruption being asked what they will need to be successful?

### Risks and Hazards

- Has your agency implemented industry standards and best practices related to agency risks for design standards? For materials procurement and use? For asset management? For construction? For bridge management systems? For cybersecurity? For safety?
- Does the agency have a risk tolerance policy? Are there some facilities or assets too important to fail? Are there some that can be relocated if necessary?
- Where are your critical corridors of commerce / priority connections between economic sectors? How does your agency assess the wide range of risks to these corridors?
- Does your agency include geotechnical assets during corridor asset and risk assessments? Are there geologic hazards and/or extreme weather events that could interrupt critical corridors of commerce?
- Do you incorporate cyber risks into existing risk management and governance processes?
- Does your agency elevate cyber risk management discussions to the senior management?
- Do you have community and statewide plans reflecting integrated infrastructure recovery and mitigation priorities?
- What is your strategy for incorporating events and weather trends in your planning and budget-setting processes?

- What steps can be taken to identify and prioritize actions for mitigating and managing risks?
- Does your agency have regular coordination among on-the-ground staff and other departments to discuss vulnerabilities and inform investment decisions based on past performance?
- How do you maintain situational awareness of current and future hazards and threats? What additional threats should your agency consider for its operations?

## Emergency Operations and Response

- Does your agency have a system to track event- and weather-related trends and costs over time (e.g., number of emergency event triggers, labor hours for preparation, response, and recovery)? Is the system event specific or does it use categories of events? Does it comply with FHWA and FEMA requirements?
- Is your emergency training frequent and specific enough to account for changes in systems and personnel?
- Do your tabletops and exercises with emergency management, law enforcement and other stakeholders include human service agencies and individuals with functional and accessibility needs, so you're ready and resilient for the whole community?
- Have your maintenance and operations functions been prioritized to meet the anticipated emergencies?
- How do emergency operations and day-to-day operations differ?
- What efficiencies do your agency personnel have during an emergency that they don't normally have during daily operations (procurement strategies, quicker responses, etc.)? How can these efficiencies be integrated into daily operations?
- Do your emergency operations and recovery plans explicitly consider resilience? For example, do short-term recovery actions facilitate (or at least not impede) build-back-better strategies?
- Do your after-action plans include lessons learned for design and engineering as well as operations? E.g., do you deploy an engineering assessment team after major events to gather information and data on what did and did not work in terms of design, including with respect to the specific hazard?

## Communications

- Where does resilience fit into the communication agenda you have set for your tenure as CEO? Do you monitor the idea regularly to decide if it should move higher or lower on your list?
- How do you and your leadership team collaborate with internal and external sources of knowledge and insight to deliver resilience?
- What level of interest in resilience do you expect from each of your audiences (e.g., the governor, legislators, business and community leaders, the general public, your employees, and contractors)?
- What has been effective in your approach to communicating with each of your audiences? Will this approach work to encourage interest in resilience if little or none exists?

## Performance Measures

- Does your agency have a strategy for monitoring and evaluating progress toward resilience?
- Do you have an after-action reporting (AAR) system to determine what didn't go as planned?
- How do you update your plans based on the results of the AAR?
- Does your agency have any resilience performance measures? Which of your current performance measures are relevant to resilience, e.g., mobility measures, recovery measures, safety?
- What performance measures have you considered that relate to asset risks and potential damage related to events or catastrophic incidents?
- How do you know if your efforts and plans are successful?



## Asset Management and Procurement

- Has the implementation of your asset management systems discovered anything surprising that can benefit the agency?
- How can your asset management systems complement or improve risk management practices?
- Have you integrated resilience requirements in asset management, performance management, and risk management approaches in your agency? Are these functions coordinated with each other?
- How do asset management life-cycle and risk assessments consider weather and other threats? Are there ways your asset management plan can improve preventive and predictive maintenance practices?
- What are the largest maintenance issues for your agency? Which assets have the worst returns on investment? How does procurement incorporate life cycle assessments into procurement decisions?

## Interagency Interdependencies and Stakeholder Engagement

- Who are your key state and regional private and public sector counterparts for critical interdependencies, such as utility providers and suppliers: power, water and communications? Do they know you?
- How does your agency regularly engage with other key critical infrastructure stakeholders in your region (e.g., utilities, manufacturers, logistics and service providers, and public and private transportation providers from all modes)?
- What opportunities can you participate in or create to discuss and work through scenarios (e.g., tabletops) for major catastrophic events with cascading failures?
- What are the potential or likely weak links in a catastrophic event among the critical infrastructure sectors in your state and region? What impact would failures in such weak links have on the transportation system, on other critical infrastructure, and on the community as a whole?

## Funding

- Which assets have had the greatest amount of funding allocated to reconstruction for recovery from events? Have resilience and/or mitigation options been considered/ implemented for these assets?
- What are the short- and long-term financial needs associated with recovery from events? How have these needs been reflected in the investment scenarios? And in the budget?
- What types of strategies for mitigating the potential impact of events have been considered as part of the investment strategies? To what extent is priority given to mitigation and adaptation projects?
- Are funds allocated to risk monitoring/mitigation and/or programs to improve asset resiliency?
- Is funding prioritized to assure that assets along critical corridors of commerce are well-maintained?
- What existing programs, people, projects and procedures can be leveraged to enhance resilience while achieving other priorities and goals?
- Are there creative ways to bring new money and resources to the table?



## COMMON CHALLENGES

DOT leaders highlighted roadblocks to incorporating resilience into agency operations and decision-making frameworks.

### Constrained Funding

In almost every state, allocating significant personnel, monetary, and material resources to events that occur on infrequent bases (or may not ever occur) is problematic. Resilience projects are prospective costs, with no guarantee that anticipated events will occur or that assets will be completely protected. Certainly, 100 percent protection is either impossible or financially unreasonable.

State transportation leaders note that resiliency projects should have goals beyond just saving money. If savings were the sole goal, agencies could be led to only protect high-value assets, even at the expense of poor, minority, or otherwise already disadvantaged populations that live around those agency assets. Resilience planning needs to consider safety, environmental justice and impacts on the whole community, including the traditionally under-served and marginalized populations.

**“Find common causes so you can pool resources with sister agencies.”**

Federal grants can have limits on how funds are used. Funds cannot be allocated for preventive purposes unless specifically authorized. Even when funds are available, issues arise on how and where these funds are used. This limited flexibility, to comply with FEMA or FHWA restrictions or to fit agency budget buckets or categories, such as capital, maintenance or operations, can inhibit doing what is needed to increase resilience of the system.

### Approaches to Constrained Funding

- **Tell a clear story of what resilience means to your state.** Make your argument persuasive in a competitive funding environment. Explain how preparedness and investment in resilience (embodied in sound O&M practices and effective planning, design and construction) can reduce costs, save lives and keep the transportation system functioning. Be sure processes are made understandable, showing how funding is used and what expenditures accomplish.
- **Demonstrate the business case for resilience.** The National Institute of Building Sciences found that mitigation funding can save the nation \$6 in future disaster costs for every \$1 spent on hazard mitigation, based on 23 years of history. (2017 Interim Report). Life-cycle, asset management, and risk management analysis tools can help you make your financial case for the investment in greater durability and reliability.
- **Be creative to increase flexibility of funding options.** DOTs have been successful with the state “buy back” of federal funds, use of FEMA and HUD funds, issuing resilience bonds, leveraging insurance partnerships, and more. FHWA and FTA funding streams have some built-in flexibility. For example, up to 50 percent of funding from most categories of a state’s allocation of federal-aid highway funds can be transferred into the funding category with the broadest eligibility.
- **Frame investments to address common causes or reap multiple benefits so funds can be pooled.** Garnering support from other agencies, nonprofits, the business community, or other states may allow resources to be pooled among the agencies or states. Investment in resilience may become more attractive when investments are designed to reap multiple benefits, including community economic benefits.

## Performance Measures and Key Performance Indicators (KPIs)

Performance measures allow you to track the current level of system resilience at your agency and document the benefits expected from resilience investments already made and those being planned. Most importantly, they allow you to identify and track where organizational actions and investments are making a difference.

Standardized measurements for resilience of transportation systems have not been established. Common resilience metrics in the transportation sector are often related to system reliability and rapidity, the capacity to restore functionality in a timely way. They usually do not measure other aspects of resilience, such as robustness and redundancy. Quantitative approaches tend to be less flexible, more time consuming and appropriate for more narrow assessments of networks and systems. Qualitative assessments are more subject to interpretation. Perhaps the biggest challenge in measuring resilience is the difficulty of capturing measures of “doesn’t fail.” Just as it is difficult to measure the costs of inaction, it is difficult to meaningfully quantify the ability of systems and/or system elements to withstand events.

### *Approaches to Measuring Performance and KPIs*

- **Set your own performance measures for resilience.** Resilience measures ideally should be results or outcomes-based, not inputs-based. Pre-event, rather than post-event, quantifications may be more useful in developing plans and recommendations for agency policies and actions.
- **Use measures that can be translated to meaningful terms and actions.** Terms (such as Good, Fair or Poor) can be correlated to specifics to be really useful. For example, Oregon State resilience goals focus on the ability to “save lives, reduce losses, speed recovery, and rebuild better.” Corresponding measures assess the performance of existing critical facilities and systems and evaluate restoration functions at present conditions to achieve the desired performance targets. Three thresholds of resilience targets have been established—minimal, functional and operational—all defined in terms of specific levels of service and system capacity.
- **Take advantage of existing data and measures.** There are benefits to using existing data sources and operational measures compared to creating additional metrics from scratch. Because resilience is related to mobility, safety, security, and economic efficiency, measures for those areas (or similar ones) can be used. In addition to some of your asset management measures, some resilience indicators, such as travel time, total traffic delay, post-disaster maximum flow and economic loss, are similar to, if not the same as, traditional performance measures already in use for transportation project evaluation and prioritization. Current resilience metrics in use at transportation agencies include redundancy, continuity, connectivity, and travel-time reliability.
- **Adopt indirect measurement scales similar to those in use by emergency management.** Because large scale emergencies are infrequent, measures of preparedness and resilience in the emergency management sector are often made indirectly. So instead of asking, “Did we continue to function despite a hurricane this year?” emergency management organizations develop a Resilience Scorecard and rate themselves on whether they mitigated known hazards, updated response plans, conducted training and exercises, and did other things to improve response.

## No Ribbon Cutting

Many resilience projects deal with capacity-building projects that attempt to make current assets more reliable and develop systems that can prevent future problems. Unfortunately, these projects do not have the same public support as more visible projects, such as road expansions or new interchanges. DOTs have noted that there generally is not any ribbon cutting where elected officials can speak.

### *Approaches to No Ribbon Cutting*

- **Be clear about the goals these projects serve.** To gain the political and civic support you need with public or elected officials, reframe their focus by showing how your projects to increase resilience are tied to better performance of your assets, saving money, and/or providing better reliability. Performance, cost saving and reliability have indisputable value, but unless you make the connection to resilience clear, your public and policy makers may not get it.
- **Hold ribbon cutting ceremonies for resilience initiatives.** In Mississippi, the DOT generates support for investments in smaller projects, such as asset management and risk-based projects, by having ribbon-cutting ceremonies that emphasize the importance of these improvements.
- **Reward innovation in resilience.** FEMA had a project—Project Impact—to recognize and award innovation in mitigation. Having a competition and awards for the most innovative resilience projects could allow DOTs to recognize and be recognized for the work of resilience.

## Long-term vs. Short-term Perspective

Decisions that incorporate resilience are by nature forward-thinking decisions; the categorical goal is to improve the long-term performance of your agency. This may include extending the life-cycle of an asset, improving the responsiveness of your financial and labor resources, and/or preparing facilities for many types of events that could happen.

In the current socio-political climate, many short-term problems can take precedence over longer term goal-oriented actions. In discussions, DOT leaders highlighted many roadblocks to incorporating the long view toward resilience into agency operations and decision-making frameworks. In a transportation agency, these daily problems seem innumerable, and steps to avoid such problems in the future are frequently set aside by pressing challenges. The biggest challenge to resilience efforts is agency leaders' finding the time to implement long-term, risk-averse systems and facilities while dealing with the everyday O&M demands the current facilities and operations present.

### *Approaches to Balancing Long- and Short-Term Perspectives*

- **Schedule** periodic team meetings on the status of long-term initiatives.
- **Remind yourself to ask the questions.** Ensure that long-term goals are reflected, to some degree, on short-term checklists and KPIs.
- **Be persistent.** Attend meetings and ensure that long-term perspectives are included. "Keep throwing seeds—even if they land on hard ground."

# PART TWO: HOW TO INCORPORATE RESILIENCE IN YOUR AGENCY

Resiliency discussions in agencies and communities today mostly focus on mitigation approaches or adaptations/ protective measures that can be put in place to save lives and prevent property loss and disruption of daily life. Often resilience measures can be taken with marginal or no additional costs, because they fit into the agency's life cycle asset management, as well as operations and maintenance.

**Resilience is about flexibility.** Decisions made for resilience can mean trying different approaches to ordinary activities. Examples DOTs cite include creating capabilities from the bottom up; encouraging adaptive practices and procedures—especially those aimed at detecting problems before potential disruptions; and exploring innovative corrective actions such as transitional infrastructure “no regret” strategies, as well as relocating assets.

**“It’s not always about a huge investment. It’s about operating smart.”**

**Resilience is cross-cutting.** It won't flourish if assigned to just one area of an agency to develop. Resilience requires cross-departmental effort, such as operations and maintenance working with planning and design. As CEO, you can push toward engagement and commitment across all functions in your agency. You can develop across-the-board performance measures and ask each division to develop and commit to resilient programs(s) with performance measures.

**Resilience is not an independent objective—it's an objectives multiplier.** Natural and human-made events and extreme weather conditions impact safety by heightening the risk of earthquakes, bridge collapse, commercial or passenger vehicle crashes or train derailments—resilience measures lessen these risks. Forward-looking models and design standards that establish priorities for resilience don't eliminate risk, but do multiply factors of safety, reliability and cost savings, especially for projects with life spans as much as 50 to 100 years.

**Resilience applies to every-day operational decisions and to materials and maintenance.** From asphalt coatings and crack sealing to making the case for operations budgets to your state leadership, steps toward resilience do not have to be all encompassing to be effective.

## INTEGRATING RESILIENCE THROUGHOUT YOUR AGENCY

Your agency already practices resilience in some dimensions such as:

- Taking short- and long-term measures to prevent or mitigate impacts of events;
- Responding and recovering more quickly after an event;
- Applying lessons learned from previous events into current practices.

Agency resilience needs more than a response focus, which may deter investment in prevention, resilience, and long-term sustainability. In addition to emergency practice, your agency can be building resilience into everyday operations. Already you may have supportive practices in standard operating and maintenance procedures. You may already include experience from maintenance and operations into your design and construction. To be intentional, deliberate and systematic, a resilience focus can ground both long-range planning and daily practices.

While the emphasis on resilience may vary across program areas, resilience adoption is most effective when it is integrated throughout all areas of agency business. Functional business areas in transportation agencies can become silos. Figure 1 illustrates how resilience encompasses all of customer-focused transportation service, enhancing the cross-cutting practices of asset management, safety and sustainability. Appendix C highlights in tabular form what employees may expect from their CEO and what CEOs may expect from their employees across various disciplines. Appendix D provides a short list of additional useful resources geared to CEOs and senior staff.

**“We’re good at recovery. Figuring out how to prevent in the first place is the challenge.”**



**Figure 1:** Resilience adoption is most effective when it is integrated throughout all areas of the agency, providing a customer-focused service.

## INTEGRATE RESILIENCE INTO PLANNING AND PROGRAMMING

DOT planning is commonly conducted and captured in short-range operations plans, long-range transportation plans, hazard mitigation plans and emergency plans. Incorporating resilience in long-term plans acknowledges risk factors and forecasts real risks to the agency's operations and equipment over time or over the life span of a capital project.

- Resilience is a cornerstone in the long-term plan for some DOTs. Resilience doesn't mean overbuilding, but does mean building in flexibility for changing conditions, environments, and technological improvements that are current unknowns, for the lifespan of infrastructure projects.
- Scenario planning is increasingly being used by transportation planning organizations to help determine policies, strategies, or investments in light of uncontrollable or unknown future conditions. Scenario planning brings together interagency and intra-agency stakeholders needed to address an issue effectively and helps them make decisions that are robust in a variety of futures.
  - » Work with major users of transportation in your region (medical centers, manufacturers, human services) to develop prioritized strategies for response and recovery.
  - » Work with infrastructure and utility owners and operators in the energy, water and sewer, communications, and other sectors to address interdependencies and develop integrated resilience plans and strategies.
  - » Include private sector organizations that will contribute to regional recovery (e.g., big box stores, home improvement centers, logistics and distribution centers) in resilience planning.

Reach out to the press and in public long-range planning meetings to explain why resiliency is critical to the DOT's continued success. If new materials or technologies are being introduced, use the planning forums to unveil and discuss them with the public.

### ✓ Encourage wide-ranging staff engagement

- **Colorado DOT**, in the I-70 Risk and Resilience Pilot, has purposely engaged a wide range of staff—engineering, maintenance, operational, planning, and executive staff—to capture the knowledge of each of these areas and to ensure buy-in across the agency for a proactive approach.

### ✓ Take design to O&M

- **Caltrans** found that resilience has to include long-range planning and O&M working with planning and design as a team effort.

### ✓ Make sure everybody is involved

- **In Illinois DOT** at project level everybody is involved, with the driver being maintenance. Sign-off from maintenance is needed to go forward and the DOT "completes the circle" at the district level.



## LEVERAGE ASSET MANAGEMENT

Become aware of the ways you can use your asset management system (including bridge, pavement, facilities and equipment management systems) to help inform your decision-making. Proficient asset

management is the foundation of an effective approach to mitigating vulnerabilities, improving maintenance practices, and ultimately extending the life span of your assets. Asset management can also allow you to map out how assets are interconnected and gain an understanding of assets that are most critical to your agency.

**“Asset Management is starting to pay big dividends. It allows focus on what you need to do versus what you want to do.”**

- Risk-based asset management can help plan preventive measures, prioritize maintenance response, and aid in coordinating recovery efforts across your agency and with third parties. For example, you can incorporate fields to help monitor vulnerabilities (e.g., closures due to flooding) and effectiveness of adaptations over time, and you can configure the system to provide alerts when vulnerable assets are due for maintenance, repair, or replacement. You can require that asset management risk assessments explicitly include forecasts of weather events and other hazards.
- When agencies produce asset management plans that analyze future risk, it becomes easier to justify the use of the resources needed to build and maintain such assets.
- Consider resilience in the prioritization process in asset management. Projects can be scored on the basis of extreme weather, seismic, and other vulnerabilities, along with the usual considerations of age, performance, operating cost impact, ridership, customer comfort, employee welfare, safety, response to regulatory demands, and more.
- Asset management systems digitize important elements of information and action, such as operation manuals for temporary countermeasures, procedures for dealing with a large accident or emergency, or maps of which roads deteriorate fastest.

### ✓ Develop databases and keep them current

- **Vermont DOT** developed an online database after Hurricane Irene of every culvert in the state to help plan for improvements and to aid in future events. Maintaining up-to-date status and condition in the system provides information to quickly make decisions and take action.

### ✓ Overlay projections onto asset data

- **Michigan DOT** conducted an assessment using GIS to overlay climate projections onto asset information from MDOT's existing asset management database to help identify locations and infrastructure that may be at risk.

### ✓ Use systems to predict, track and assess

- **Asset management systems** with standardized site codes have been used to track and document pre-disaster conditions of DOT facilities and impacts of the event/incident. Bridge management systems have been used to predict and assess impacts of disasters on bridges.



## INCORPORATE RESILIENCE INTO DESIGN AND ENGINEERING

As infrastructure and safety agencies, DOTs are exceptionally positioned to take resilience actions and to develop actual solutions. Mitigation approaches and adaptations are available to assist in increasing the strength or the ability of your system to resist stresses and to reduce some of the vulnerabilities.

- Seek guidance to improve the design of infrastructure to increase resilience. Many resources available at DOTs identify cost-effective approaches and strategies.
- Conduct cost/benefit analyses. Understanding the trade-offs with competing priorities is critical.
- Recognize the potential co-benefits of adaptations, such as decreased operating costs or improvements in other performance measures.

**“We build and prevent scour issues upfront in bridge design.”**

**“We design facilities [to seismic standards] to provide transport to key life line facilities in a response situation.”**

### ✓ Develop asset-specific design guidance

- **PANYNJ** has developed guidance using an asset-specific approach, taking into account life expectancy of each asset and the risk of agency-specific events happening in that lifespan. PANYNJ also examines the needs for improving reliability when undertaking major repairs and reconstruction and has documented significant cost savings by doing this.

### ✓ Incorporate vulnerability in design

- **Florida DOT** signs and signals are designed with mast arms along the coastal areas instead of strain poles, to be more resilient and withstand hurricane wind loads. FDOT is strengthening areas with sea walls and elevating roads where possible to mitigate flooding. The FDOT drainage systems design is being adjusted along the coastline to allow for more efficient water flow out of flooded areas. The DOT is continuing to identify other resilience strategies.

### ✓ Learn to adapt from events

- **Maine DOT**, following Superstorm Sandy, increased its design standards for most culverts and some bridge replacements to 500-year storm events. As a result culvert blow-outs are becoming a thing of the past, annual costs for culvert cleaning and maintenance are down, and fish and wildlife habitats and passages have improved as well.

## INCORPORATE RESILIENCE INTO OPERATIONS AND MAINTENANCE

In any agency, operations and maintenance staff can be some of the most knowledgeable employees regarding the facilities you oversee. They possess hands-on critical institutional knowledge that can inform proper decision-making on virtually any topic, even those beyond their traditional roles.

**“Our state residents would rather maintain than build.”**  
**“We track conditions carefully and replace when we start doing too much maintenance.”**  
**“Lowest cost of ownership drives action.”**

- Consider preventive and predictive maintenance practices that prepare for potential natural and manmade emergencies as key to keeping operational costs in check and avoiding unforeseen events. The FHWA Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance highlights adjustments to operations and maintenance programs—ranging from minor to major changes that can help minimize the current and future risks.
- Enable best practices in the operations and maintenance of current assets to gain obvious benefits for your agency.
- Incorporate O&M input into the design of new assets—this overlooked benefit could dramatically improve the lifetime and performance of these assets. O&M staff can use their collective institutional knowledge to steer the design and engineering of assets towards a more resilient approach. Prioritizing feedback from these staff members can highlight easy-to-miss problems that should be addressed in the design of assets.
- Establish regular coordination between on-the-ground staff and other departments to discuss “hot spot” areas and inform investment decisions based on past performance.

### ✓ Incorporate flexibility in agency policies

- **Alaska DOT&PF** issued a policy directive on winter maintenance coordination that requires all regions in the agency to assist in the event of an emergency, regardless of location. **WSDOT** effectively dissolves district lines within the organization when responding to major events so that resources can be applied where they are most needed across the state.

### ✓ Purchase versatile equipment

- **Alabama DOT** purchased versatile equipment to double as snow plows. They have also established mobile stockpiles of traffic control devices equipment, factoring in likely future needs.

### ✓ Use maintenance data to identify vulnerable areas

- **Oregon DOT** uses maintenance dispatch data and weather-related data to map areas within their system most vulnerable to climate impacts. Maintenance personnel are able to identify locations susceptible to weather or other conditions that need to be monitored more closely over time.

### ✓ Configure tracking systems to create metrics

- **Configuring work order/labor tracking** systems to better track the impacts of events over time by creating work order numbers, charge codes, or similar codes tied to specific events or types of events has allowed many DOTs to create a metric or Severity Index that compare expenditures to relative severity of the event, which helps identify efficiencies and inform budgets.

## SEE EMERGENCY MANAGEMENT AND RESPONSE IN RESILIENCE CONTEXT

Response and recovery are critical aspects of resilience, because it is not possible to mitigate all risks or prevent all events from happening. Quickly responding to an incident or event and getting operations back to normal as rapidly as possible after an event minimizes disruptions and reduces impacts on the transportation system and the community.

Your agency undoubtedly has responded to weather-related events, a serious highway accident or a breakdown of critical infrastructure. Learning emergency response under fire is an all-too-common experience for CEOs of state DOTs. Some types of events are long-duration events that may slowly creep up and the consequences of these events may take time, sometimes years, to become obvious. Others, despite the best efforts of engineering and maintenance, always have potential to occur, such as accidents and structural failure.

- Know what is out there and be prepared for when events occur. Understand what types of events are likely to occur in your state and what potential impacts those events can have on your agency. By anticipating the events and the potential impacts, you can plan in advance.
- Examine the efficiencies that make your agency nimble during an emergency and explore what can be done to integrate at least some of them into daily operations.
- Recognize how the great work your staff does in emergencies can help build the argument with your public and policy makers for resilience planning and funding. Your understanding and leadership of the political implications of the event can shape guidance for the elected official (typically the governor) to whom you report.

Highlight the successes of your staff during these times, in order to advocate for greater resources needed to mitigate against and prepare your agency for any future emergency that might occur.

### ✓ Participate in multi-agency resilience groups

- **Washington State** has a multi-agency resilience cabinet with DOT participation that holds regular meetings and tabletops across the state.

### ✓ Establish coordinated processes and procedures

- **CDOT** established a flood recovery office to coordinate and oversee recovery and resilience efforts after the 2013 floods.

### ✓ Incorporate risk into recovery

- **CDOT** adopted a process for their flood emergency relief program, based on risk assessment, to justify resilience and mitigation projects at locations that suffered severe damages from the floods..

### ✓ Use continuous learning and improvement processes

- **After Hurricanes Lee and Irene in 2011 and Sandy in 2012 New York State DOT** refined its emergency responses and incorporated lessons learned into many practices from maintenance management to programming, project selection and managing assets. The maintenance management system allowed the DOT to record damages, issue work orders and capture costs for later federal emergency reimbursement.

## SEE TECHNOLOGY AND MATERIALS THROUGH A RESILIENCE LENS

Technology can play a critical role in resiliency, providing valuable information and increasing capabilities critical to resilience. Improving system infrastructure with technology your agency has in place or could obtain will require mainstreaming the possibilities into planning and programming with appropriate funding.

- Existing technologies, such as Road Weather Information System (RWIS) and Decision Support Systems (DSS), can be leveraged to track trends or examine potential scenarios for operational planning.
- Rapidly developing technologies provide digitized data acquisition and structural diagnostics through remote, in-situ, or portable monitoring/damage detection sensors and devices.
- Emergency apps can be loaded onto phones before disasters to provide tools for your personnel. Both Red Cross and FEMA offer lists of downloadable emergency apps.
- Geographic Information Systems (GIS) allow the tracking, mapping, analysis, and modeling of geospatial data that can assist and inform in asset management and emergency management. Your team most likely already includes GIS analysts, who may benefit from additional training for resiliency.
- Intelligent Transportation Systems (ITS) can help enhance resilience. ITS can be used to develop a system for forecasting the effects of weather on transportation systems, traveler information systems, and support for emergency operators. Working together, your traffic management center and your emergency response team can leverage ITS for resiliency, rerouting traffic in preparation for or during events.

Technology as a term often conjures electronic and cyber capabilities, but advances in materials technology are an important part of resilience, too. New and more durable materials, such as high performance concrete, high performance steel, smart materials for bridges, reflective paint for roads and paving materials that better address current and future conditions, are becoming available.

### ✓ Explore innovative techniques and materials

- **Virginia DOT** uses innovation to build to last longer, e.g., building corrosion-free bridges with new materials. To get buy-in for higher costs up front, DOT shows benefits, such as savings/cost avoidance down the line, consistent with agency goals

### ✓ Use materials that better address current and future conditions

- **In the City of Los Angeles**, streets covered with reflective paint were 10 to 15 degrees cooler on average than streets not covered.

### ✓ Identify means to gather better data at lower cost

- **Utah DOT** and other states have incorporated drone technology into many different functional areas to provide better information at lower cost, within a framework of training and policies to avoid abuse. Applications include topographic surveys, bridge inspections - structures and delaminations, and landslide assessment.

## CAPITALIZE ON THE RESILIENCE THEME IN AGENCY COMMUNICATIONS

Fundamentally, all communication between DOT CEOs and everyone else in their DOT's universe is about resilience. Every message about a DOT's achievements, difficulties, necessities or plans—even reports on ordinary activities—can have the baseline message of resilience in it. That baseline is: We are working hard to be sure your transportation opportunities won't be interrupted and, if they are, it won't be for long. From that baseline, a CEO can build simple, effective communication strategies and messages for internal and external audiences as a means to build agency resiliency.

**Audiences.** Resilience is important to every DOT internal and external audience, in different ways. Individuals among the public, businesses, civic and political stakeholders, as well as everyone who works for or with the DOT will have specific “how does this affect me/us?” questions that have to be answered at different times. All audiences want a CEO to be informative and, ideally, to be reassuring about safety, emergency readiness, quality and continuity of service.

As you are well aware, addressing the issue of funding and reserves is basic to building resilient infrastructure, redundancy and system security into agency assets. Honest and continued dialogue with the business community and the general public about funding challenges and prioritizations and their impact on service can provide the support you need in your discussions with the Governor and the legislature.

**Key messages.** Resilience is not so much the subject of messages on its own, but rather the essential message thread that can hold the fabric of an organization together, no matter what comes. Therefore the messages critical to your audiences are ones that reflect their needs and your DOT's capabilities to meet those needs.

The messages may take a wide variety of forms, but their content has three basics:

- **What our transportation system provides, how it functions and what we do to maintain and improve it.** People need reasonable expectations about transportation, in general, and about resilience in particular. They need to know what they can count on and what to hope for when disruption occurs.
- **How we are working to reduce disruptions and improve safety.** No doubt your agency has communications about emergency readiness, response and recovery built into overall communications and public outreach. To increase public awareness, add the fourth “r” to your messages—resilience. Share the work your agency is doing to reduce future disruptions by addressing your vulnerabilities and improving your approaches to minimize the consequences of future events.
- **Our commitment to resilience.** Once your agency has defined resilience in terms that make sense for your community, craft a message that makes clear your conviction that your DOT will be an increasingly resilient organization—and will strengthen community resilience in the process.

These three content areas ground almost any message from the tight and tidy “elevator speech,” to full keynote addresses. With remarks and examples for each, you will be ready to tell the resilience story as a meaningful part of any discussion about your agency's direction, impact and legacy.

## ADDRESS CYBERSECURITY EARLY AND OFTEN

Cyber incidents migrate from one industry to another as compromises become easier and the rewards of cybercrime become greater. The likelihood of a significant event in any industry is increasing, along with the cost of cyber incidents. Hacking is not the only cause of cyber incidents. Equipment failures, or even maintenance procedures, can cause unexpected cyber incidents. Structural network failures and human errors have the potential to occur more frequently than intentional cyberattacks.

Impacts of a cyber failure differ widely in duration and cost. For most agencies, the consequences can be significant. Along with economic and potential safety impacts, damage is done to an agency's reputation and credibility, and the resulting political repercussions can be severe.

A rich body of cybersecurity guidance and resources has developed over recent years. Transportation-specific resources are available from the TRB, AASHTO and other transportation organizations. Best practices include:

- Maintaining situational awareness of digital threats—both intentional and unintentional—is important to becoming a resilient agency.
- Fostering a cybersecurity culture—an environment in which cybersecurity best practices are a way of life—goes a long way toward preventing and mitigating cyber incidents. Awareness and training, along with established security policies and procedures, are important aspects of building a cybersecurity culture.
- Recognizing that users are crucial to cybersecurity in preparing, exercising and implementing back-up and down-time processes and systems.
- Establishing and sustaining cybersecurity requires a CEO's active—and visible—support.

Complete protection against cyber incidents is not achievable and incidents will happen. Assume that a cybersecurity incident will happen in your agency and focus on what will be needed to maintain operations while mitigating the consequences. This is cyber resilience.

In an ever-changing security landscape, cybersecurity must be a continuous process, with evaluation and monitoring as key components to identify and manage necessary changes to systems and environments. Having technology in place to provide cybersecurity is only one part of an effective approach.

**Cyber resilience is the ability to identify, prevent, detect and respond to cyber incidents and recover while minimizing service impact, customer harm, reputational damage and financial loss.**

### **Strategies that support resilience include:**

- **Plan for incidents** and have approaches to isolate attacks, contain the damage done to systems and be able to recover gracefully and as quickly as possible.
- **Establish an enterprise-wide strategic approach** to cybersecurity to yield the most long-term benefits.
- **Expand your organizational risk decision-making** and mission priorities to include cyber security, if it is not already included.
- **Advocate for cyber secure policies in your agency procurement processes** because vendors often play a major role in the implementation and maintenance of your digital systems.

# CONCLUSION

Many of the challenges you face as a CEO will revolve around the resiliency of the transportation system. How well your system can withstand events and how quickly your agency can restore services when they are impacted determines your regional economy, your state population's mobility and safety, and possibly your tenure. The public and their political representatives expect you to anticipate these events, have plans and take actions to mitigate the consequences, and be able to respond quickly when necessary.

No matter what your state's experiences have been—historically few disruptive events or many—you are responsible to manage existing infrastructure, improve the reliability and safety of the transportation network, and ensure the continuation of operations during and after emergencies.

Your end users of transportation assets and infrastructure expect you to do what's needed to make the systems they count on resilient. The greatest gains in resilience occur when it is woven throughout a transportation agency—in planning and design, asset management and risk management, operations and maintenance, and performance management.

As infrastructure agencies, transportation agencies are exceptionally positioned to take resilience actions, even when efforts to build community resilience can be complicated. Many stakeholders—federal, state and local departments and agencies, national and community organizations, and the public—are involved in regional community resilience work. Goals can differ substantially, and differing interests want to tailor outcomes to their particular needs. Your involvement as the DOT CEO is a major part of securing community commitment to investment in resilience, building important partnerships across regions, sectors, and transportation modes.

Fortunately, you are not alone. Engage with your peers to share your experiences. Make use of their replicable successes; learn from their disappointments; discuss your own challenges and ideas. Resilience thrives on conversation and collaboration.



# APPENDIX A:

## DEFINITIONS OF RESILIENCE

### DEFINING RESILIENCE

The general concept of resilience has existed for decades in transportation. In recent years, the numerous weather- related and other natural disasters, high profile incidents and system failures, have made resilience a critical focus for transportation reliability and safety.

**Resilience can be defined as** *“the ability to prepare and plan for, absorb, recover from, or more successfully adapt to adverse events.”* (Disaster Resilience: A National Imperative, National Research Council, 2012)

**The Federal Highway Administration Order 5520 has a similar definition:** *“... the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions ... ”*

Through its Special Committee on Research (SCOR), **AASHTO highlighted what this means for**

**transportation agencies:** *“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.”*

Some transportation agencies use definitions for resilience described in state law or other state plans or policies. However resilience is defined, for transportation agencies the word has some fundamental concepts in common. Most include the concept of bouncing back, the ability to recover or return to a pre- event condition or level of service after an event. Usually part of resilience is the idea of the ability to absorb shocks, to be able to lessen or mitigate the consequences of an event and/or respond quickly after the event with the restoration of services. One important concept not always included in all definitions is positive adaptability or “evolutionary resilience” that emphasizes pre-emptive action, learning from experience, preparing and “bouncing forward,” anticipating and adapting to future events.

These core ideas of resilience—anticipating, adapting, preparing and bouncing back from disruption even stronger than before—apply to every aspect of a transportation agency.

**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 ... 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 ...**

- Understanding Transportation Resilience: a 2016-2018 Roadmap (AASHTO 2016)

## DOT RESILIENCE DEFINITIONS

Some transportation agencies use definitions for resilience described in state law or other state plans or policies. Other agencies may need to define resilience in agency-specific terms, ones that best reflect your organization's responsibilities and needs. You may need to lead your agency toward its own useful definitions. For instance, while some DOTs are focused on storm surges and sea level rise, others may be concerned with heat island effects that cause rail buckling and asphalt softening.

Examples of DOT Agency definitions include:

| Department of Transportation | Definition and Source  |
|------------------------------|--|
| <b>Delaware DOT</b>          | Uses concept that outlines resiliency practices to help mitigate climate impacts and reduce emissions. (From Delaware Executive Order 41)  |
| <b>Colorado DOT</b>          | "The ability of communities to rebound, positively adapt to or thrive amidst changing conditions or challenges—including disasters and climate change—and maintain quality of life, healthy growth, durable systems, and conservation of resources for present and future generations." (Governor's Resiliency Framework, Colorado Resiliency and Recovery Office, 2015) |
| <b>New York State DOT</b>    | Resilience is the ability of a system to withstand shocks and stresses while still maintaining its essential functions ... The building blocks of resilience include having spare capacity, staying flexible, managing failures, rebounding quickly, and improving continuously, not just when disaster strikes. (NYS 2100 Commission)                                   |
| <b>Oregon DOT</b>            | Uses a definition from an ODOT seismic report, "To achieve rapid recovery, require government continuity, resilient physical infrastructure, and business continuity."   |
| <b>Arizona DOT</b>           | Developed a Resilience Program to support its mission to provide a safe, efficient, cost effective transportation system that can be compromised from the effects of heat extremes, dust storms, wildfires, flooding, landslides, rockfall incidents, and slope failures, and cope with the ever- growing cost of these threats.   |
| <b>Tennessee DOT</b>         | Uses the terms "flexible" and "proactive."<br><br>"Making decisions in a way not always done in normal situations and doing things not how they've always been done ... Another way to think about resiliency is working through and making adjustments." (Interview)  |
| <b>Utah DOT</b>              | "We prefer words such as 'adaptations.' " (Interview)  |

Source: Survey of State Highway Agencies, conducted as part of NCHRP Synthesis Topic 48-13 Resilience in Transportation Planning, Engineering, Management, Policy, and Administration, 2017, and interviews with DOT CEOs

# APPENDIX B: ECONOMIC AND COMMUNITY BENEFITS OF RESILIENCE

Transportation systems are a significant national and community asset supporting many trillions of dollars of economic activity in the private sector, as well as health, education, safety, and recreation in the public sector, as illustrated in Figure 2. Certainly all transportation assets have importance to someone, but some of your agency systems or assets may be of particular importance because of their vital economic role, absence of alternatives, heavy use, or critical function. For example, critical corridors of commerce need to be resilient during extreme weather events and other disruptions, to support recovery as well as commerce.

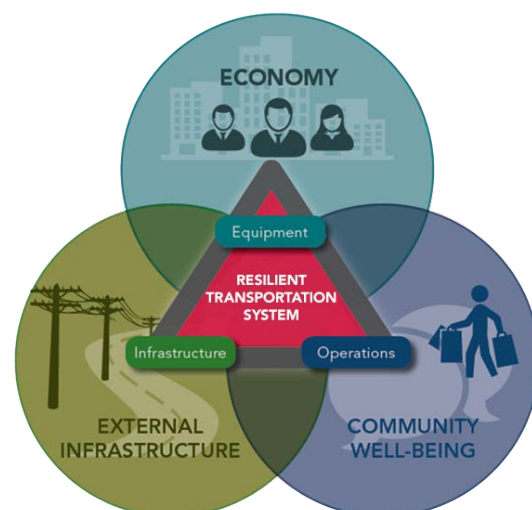
**Resilience-building is ... a lever for unlocking greater economic development and business investment, as well as improved social services and more broadly shared prosperity. This is what we call the “resilience dividend.”**

—Judith Rodin,  
Rockefeller 100 Cities Initiative

Improving your system resilience benefits the regional and national economy because of this key role in the local and regional community. Resilient communities have the ability to prevent or delay disasters, quickly return people to work, reopen businesses, and restore other essential services needed for a full and timely economic recovery. They cannot bounce back without resilient transportation systems.

Recent natural disasters have demonstrated the broad reach of events beyond local and regional impacts. For example, hurricanes such as Harvey and, more recently, Florence, not only dramatically impacted the neighborhoods and communities in the landfall and widespread rain zones, but also disrupted national supply chains. The Fukushima earthquake, tsunami, and nuclear power plant disaster destroyed communities and disrupted international supply chains for manufacturing.

Investment in resilience may become more attractive when investments are framed or designed to reap multiple benefits, including community economic benefits. For instance, the NYS2100 Commission was established by the Governor after Superstorm Sandy to make plans for Improving the Strength and Resilience of New York States’ Infrastructure. Following disasters, states recognize the wide-ranging impacts that regional events can have.



**Figure 2** illustrates how transportation supports interconnectedness of communities, economy and infrastructure.

Fixing the problems in one state and not in another impacts the economies of many states, even those not directly affected. Collaborative agency efforts in some states go beyond the disaster-related, such as in Maine where the DOT works jointly with the Maine Department of Inland Fisheries & Wildlife and the U.S. Fish and Wildlife Service to integrate ecological considerations into resilience initiatives (such as larger culverts) to protect the fishing industry so critical to the state's economy.

Certainly, efforts to build community resilience can be complicated. Goals can differ greatly among agencies; different communities need to tailor outcomes to their particular needs. To support a wide range of needs, many federal, state and local departments and agencies are involved. Because transportation systems benefit communities in so many ways, the DOT CEO's engagement can be a major part of securing a commitment to resilience by hosting constructive dialogues and building important partnerships across regions, sectors, and transportation modes.

**Resilience benefits extend beyond reducing the cost of repairs. Minimizing disruptions enhances public safety and has economic benefits.**

- National Infrastructure  
Advisory Council 2015

# APPENDIX C: MUTUAL RESILIENCE ROLES WITHIN THE AGENCY

| Major Realms                                    | What Your Employees Need and Expect from You   | What You Need and Expect from Your Employees   |
|---|--|--|
| Your Employees                                  | <ul style="list-style-type: none"> <li>• Make it a priority and talk about it often.</li> <li>• Secure resources and ensure worker safety. Ask what they need for successful implementation.</li> <li>• Communicate that resilience is everyone's job, how it makes jobs easier in the long run and makes the system better.</li> <li>• Support the cross-cutting efforts, training and time required to implement best practices that also develop resilience.</li> <li>• Encourage innovation and risk-taking to provide new and improved policies, procedures and practices.</li> </ul>                               | <ul style="list-style-type: none"> <li>• Secure commitment from supervisors and managers to "bring it up the line"—to recognize and reward actions and advice—wherever the source—that lessen impacts, lessen long-term costs, and increase resilience.</li> </ul>   |
| Operations and Maintenance and Asset Management | <ul style="list-style-type: none"> <li>• Include O&amp;M representatives in new project and reconstruction planning, design and construction.</li> <li>• Actively solicit and use information and insights—hazards, materials, procedures—to update risks and procedures.</li> <li>• Cut a ribbon on preventive maintenance projects.</li> </ul>   | <ul style="list-style-type: none"> <li>• Actively observe and report emerging threats and hazards.</li> <li>• Identify and advocate for materials and procedures that extend asset life and save money.</li> <li>• Develop and update operating protocols to reduce hazards, impacts.</li> <li>• Participate in cross-disciplinary teams, speak up.</li> </ul>                       |
| Planning, Design, Engineering, Construction     | <ul style="list-style-type: none"> <li>• Require design standard updates to reflect forward-looking risks for asset life cycles: 5 years? 20 years? 50 years? 100 years?</li> <li>• Include resilience among prioritization factors; don't "value engineer" it out.</li> <li>• Encourage "build back" strategies and "what if" options.</li> <li>• Require new project and major reconstruction planning and design teams to include operations and maintenance representatives on teams.</li> <li>• Encourage planning for scenarios outside of design range, and adaptations to meet changing environments.</li> </ul> | <ul style="list-style-type: none"> <li>• Participate in cross-disciplinary teams to identify emerging threats and anticipate and solve future problems.</li> <li>• Participate in regional workshops and planning efforts to identify regional risks and hazards and work toward mutually beneficial solutions where feasible.</li> <li>• Continue to learn and research.</li> </ul> |

| Major Realms   | What Your Employees Need and Expect from You   | What You Need and Expect from Your Employees  |
|--|--|---|
| Administration/<br>Policy, including<br>Finance,<br>Procurement,<br>Communications | <ul style="list-style-type: none"> <li>• Include resilience (preparedness/ whatever term fits best) in vision, mission. Operationalize in all divisions and employee and stakeholder communications.</li> <li>• Use “best value” contracting strategies to assure projects are designed, constructed and maintained for the long run, not short-term savings.</li> </ul> | <ul style="list-style-type: none"> <li>• Communications: research and express the value of resilience to multiple audiences.</li> <li>• Procurement: evaluate and purchase for full life-cycle value; monitor.</li> </ul>     |
| Emergency<br>Preparedness and<br>Response  | <ul style="list-style-type: none"> <li>• Be personally involved in training and exercises to assure emergency preparedness receives appropriately high priorities in organization and employee work plans.</li> <li>• Ensure that resilience is part of emergency preparedness and response.</li> </ul>  | <ul style="list-style-type: none"> <li>• Be inclusive and cross-disciplinary in training and exercises.</li> <li>• Include engineering and design teams in after-action assessments (as well as operations teams).</li> </ul> |

# APPENDIX D:

## ADDITIONAL USEFUL RESOURCES

### **Fundamental Capabilities of Effective All Hazards Infrastructure Protection, Resilience and Emergency Management for State DOTs. AASHTO, Washington D.C., 2015. (38 pages)**

An AASHTO Report that synthesizes the most recent federal/state guidance and industry research into a set of capabilities for state DOTs that address all-hazards infrastructure protection, resilience, and emergency management in support of National Preparedness Goals. The concise report was designed to be a resource for transportation agencies to support the integration of infrastructure protection and resilience into the operations and infrastructure/ capital programs of the agencies.

### **Managing Catastrophic Transportation Emergencies: A Guide for Transportation Executives. AASHTO, Washington D.C., 2015. (16 pages)**

The AASHTO Guide provides guidance to new chief executive officer about the roles and actions that they take during emergency events. It was designed in an executive format—concise and brief—with input from current and former transportation agency executive officers, as a quick way to present the decisions/steps that are needed during an emergency event and to assist in identifying the right person/agencies that need to be involved. The Guide also includes staff resources on relevant topics and issues that should be considered in preparing and responding to all-hazards emergency incidents.

### **The Innovative DOT: A Handbook of Policy and Practice. State Smart Transportation Initiative and Smart Growth America, 2014. (5-page Resilience Section, 243 pages)**

The handbook was commissioned by the U.S. DOT's Federal Highway Administration to assist state DOTs by offering strategies that can be undertaken to improve a state's transportation system. It contains a resiliency section with guidance on how to incorporate climate change adaptation into long-range transportation planning.

### **FHWA Report 5: Managing External Threats Through Risk-Based Asset Management, Risk Based Transportation Asset Management: Building Resilience into Transportation Assets. Federal Highway Administration, US Department of Transportation, Washington, D.C., March 2013. (47 pages)**

This FHWA Report, the fifth of five reports examining how risk management complements asset management, examines how physical, climatic, seismic and other external threats can be addressed in risk-based asset management programs. In managing risks to assets from external threats, this report emphasizes the Three Rs—Redundancy, Robustness and Resiliency. Asset management plays a critical role in each, particularly Robustness and Resiliency. These are defined, described and illustrated through several agency examples



**General Management Imperatives- Business Basis for the Business Agility Manifesto. Roger T. Burlton, Ronald G. Ross & John A. Zachman, Business Rule Solutions, LLC. 2017**

This document, available at <https://busagilitymanifesto.org/> is a sound foundation for CEO resilience planning.

**Incorporating Risk Management into Transportation Asset Management Plans. Federal Highway Administration, US Department of Transportation, Washington, D.C., November 2017. (21 pages)**

This FHWA document provides guidance on the risk element of the TAMP, defines risk, and provides guidance on how the risk element can be applied to meet risk-based TAMP requirements. It was developed to assist State DOTs with the development of their TAMP.

**Web-Only Document 221: Protection of Transportation Infrastructure from Cyber Attacks: A Primer. Countermeasures Assessment and Security Experts, LLC and Western Management and Consulting LLC, Transportation Research Board, Washington D.C., May 2016. (183 pages)**

An overview of cybersecurity and a compendium of effective practices that can be used to protect transportation systems from cyber events and to mitigate damage should an attack or breaches occur.

**Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance. Federal Highway Administration, US Department of Transportation, Washington, D.C., November 2015. (86 pages)**

A Federal Highway Administration report that explains how transportation management, operations, and maintenance staff can incorporate climate change into their planning and ongoing activities. The Guide includes the context and rationale for adapting and what is being done in state DOTs to adapt TSMO and maintenance programs.

**National Institute of Building Sciences (NIBS) Integrated Resilient Design Program**

**<https://www.nibs.org/page/irdp>**

The Integrated Resilient Design Program fosters innovative approaches to the design, construction and operation of buildings and infrastructures that are resilient to natural and man-made disasters. IRDP projects are sponsored by the Department of Homeland Security's Science and Technology Directorate, High Performance Integrated Design Resilience (HPIDR) program.

**National Institute of Standards and Technology (NIST) Resilience Website**

**<https://www.nist.gov/topics/resilience>**

NIST examines interdependencies in its resilience section and includes guidance such as building standards.

**100 Resilient Cities**

**<http://www.100resilientcities.org/>**

100 Resilient Cities, pioneered by The Rockefeller Foundation, helps cities around the world become more resilient to physical, social, and economic challenges. The project identifies characteristics and frameworks for resilient cities, and describes the "Resilience Dividend" that may convince additional stakeholders of the value of resilience.

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## TRANSPORTATION SYSTEM RESILIENCE: A DOT IMPERATIVE

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## IMAGE CREDITS

Cover images:

Top left: Cutler Bridge drone inspection image. Courtesy UDOT.

Center left: Fish- and wildlife-friendly resilient bridge, Abbot Village, Piscataquis County, Maine. Courtesy USDA-Natural Resources Conservation Service, photo by Ben Naumann.

Lower center right: El Monte Station. Image courtesy of Metro. ©2019 LACMTA.

Figure 1: From TCRP Web-Only Document 70: Improving the Resilience of Transit Systems Threatened by Natural Disasters, figure developed by the study team.

Figure 2: From TCRP Web-Only Document 70: Improving the Resilience of Transit Systems Threatened by Natural Disasters, figure developed by the study team, modified.

