National Infrastructure Advisory Council

Transportation Sector Resilience

Final Report and Recommendations

July 10, 2015

Jack Baylis
Working Group Co-Chair
President and Chief Executive Officer
The Baylis Group, LLC

Glenn S. Gerstell
Working Group Co-Chair
Partner
Milbank, Tweed, Hadley & McCloy LLP

Dr. Beverly Scott
Working Group Co-Chair
Chief Executive Officer
Beverly Scott Associates, LLC

Margaret E. Grayson
President
MTN Government Services

Constance Lau
President and Chief Executive Officer
Hawaiian Electric Industries, Inc. (HEI)

Jim Nicholson
President and Chief Executive Officer
PVS Chemicals, Inc.

About the NIAC

The National Infrastructure Advisory Council (NIAC) provides the President of the United States with advice on the security and resilience of the critical infrastructure sectors and their functional systems, physical assets, and cyber networks. These critical infrastructure sectors span the U.S. economy and include the chemical; commercial facilities; communications; critical manufacturing; dams; defense industrial base; emergency services; energy; financial services; food and agriculture; government facilities; healthcare and public health; information technology; nuclear reactors, materials and waste; transportation systems; and water and wastewater systems sectors. The NIAC also advises the lead Federal agencies that have critical infrastructure responsibilities. Specifically, the Council has been charged with making recommendations to:

- Enhance the partnership of the public and private sectors in securing and enhancing the security and resilience of critical infrastructure and their supporting functional systems, physical assets, and cyber networks, and provide reports on this issue to the President through the Secretary of Homeland Security, as appropriate.
- Propose and develop ways to encourage private industry to perform periodic risk assessments and implement risk-reduction programs.
- Monitor the development and operations of critical infrastructure sector coordinating councils and their information-sharing mechanisms, and provide recommendations to the President through the Secretary of Homeland Security on how these organizations can best foster improved cooperation among the sectors, the Department of Homeland Security, and other Federal Government entities.
- Report to the President through the Secretary of Homeland Security, who shall ensure appropriate coordination with the Assistant to the President for Homeland Security and Counterterrorism, the Assistant to the President for Economic Policy, and the Assistant to the President for National Security Affairs.
- Advise sector specific agencies with critical infrastructure responsibilities, to include issues pertaining to sector and government coordinating councils and their information sharing mechanisms.

Table of Contents

About the NIAC ii
Executive Summary 1
I. Study Objective and Approach 8
A. Study Charge 8
B. Study Methodology 9
C. Point of Departure: Recommendations from Prior Assessments 10
II. Current Situation: The Intersection of Resilience and Complexity in Transportation 14
A. The Nation's Transportation System: Enormous, Complex, and Diverse 16
B. Status of Federal Policy and Action 18
III. Assessment of Transportation Resilience Today 21
A. Transportation Risks 21
B. Infrastructure Investment and Funding 22
C. Policies and Practices 24
D. Leadership and Coordination 25
IV. Findings 27
V. Recommendations 31

Appendices

Appendix A: Acknowledgements 40
Appendix B: The Resilience Challenge: Key Aspects of the Problem 44
Appendix C: Infrastructure Investment in Decline 60
Appendix D: Indicators of Progress 65
Appendix E: Overview of the National Transportation System 72
Appendix F: Federal Transportation Policy and Programs 81
Appendix G: Overview of Transportation Modes and Resilience Practices 100
Appendix H: Case Study of Disruption Scenarios – Ports of Los Angeles and Long Beach 134
Appendix I: Compendium of Prior NIAC Recommendations Related to Resilience 165
Appendix J: Compendium of Prior Recommendations from Other Sources 177
Appendix K: Consolidated Interview Information Collected by the Working Group 187
Appendix L: Consolidated Information from Study Group Subject Matter Expert Discussions 204
Appendix M: References and Research Resources 213
Appendix N: Acronyms 241

Executive Summary

The Nation's transportation system is crucial to the U.S. economy and the overall quality of life for Americans from all walks of life. In today's increasingly complex and connected society, every critical infrastructure sector depends on a resilient transportation system that is safe, secure, reliable and efficient in the movement of people and goods; without it, most critical services cease to function. In recognition of this important role, the President directed the National Infrastructure Advisory Council (NIAC) to examine the resilience of the Nation's transportation sector to determine potential gaps and identify opportunities for the Federal Government to improve the sector's resilience and security.

Throughout this study, infrastructure resilience is defined as the ability to reduce the magnitude or duration of disruptive events that is accomplished by anticipating, absorbing, adapting to, or rapidly recovering from the disruption. In simplest terms, resilient systems can maintain critical functions during a disruption and require less time and fewer resources to recover functions that have degraded.

A Critical National Resource at Risk

A healthy transportation system is vital to the Nation's economy, security, and prosperity. Yet our current transportation infrastructure faces a diverse set of emerging risks for which no one Federal entity has full jurisdictional responsibility to address. Extreme weather, rising sea levels, decaying infrastructure, and cyber threats are creating new challenges for public and private owners and operators within the various modes, and among regulators and funding entities in all levels of Federal, state, and local government. Fragmentation of authority and responsibility has resulted in the lack of a national consensus—public and private—on resilience goals and outcomes. Meanwhile, critical infrastructure systems are becoming more tightly intertwined as transportation and other critical sectors integrate their cyber and physical systems to optimize operations and global supply chains. This increases productivity and efficiency but also makes systems more fragile in the event of a major catastrophe. All these factors are exacerbated by decades-long underinvestment in much of the Nation's transportation infrastructure.

> "The tragic thing is that we're letting our transportation system crumble at the exact moment we need to build it up."
>
> *Anthony Foxx, Secretary of Transportation*

The continuity of critical transportation operations is now virtually inseparable from the continuity of other lifeline infrastructures—energy, communications, and water. Greater interdependencies within regional infrastructures increase the likelihood that a localized disruption will cascade across adjacent infrastructures, transportation modes, and jurisdictions. Since this study began, there have been worker slowdowns at the Ports of Los Angeles and Long Beach, historic snowstorms that shut down Boston's transit system, an Amtrak derailment outside of Philadelphia, a freight derailment that triggered an oil spill and fire in West Virginia, and an intentionally set fire in the Chicago Air Traffic Control Center—all of which caused impacts that cascaded across modes, infrastructures, and regions for days or weeks.

These conditions create new risks that are often "hidden" at the seams between sectors and transportation modes due to a lack of awareness and understanding of new dependencies and how they complicate a rapidly changing risk landscape. As such, owners and operators are often left unprepared to plan, prepare for, and respond to major risks and disasters that can rapidly escalate to problems of national significance.

Emerging Risks Require Commitment and Coordination

America's transportation system is a very complex "system of systems," with seven distinct modes; diverse ownership across the private sector and Federal, state, local, and regional jurisdictions; and a vast array of services to move people and freight. This diversity complicates transportation planning, funding, design, and operations and presents significant challenges for integrating resilience into the built infrastructure and organizational practices. Simply put, the Federal Government alone cannot create a resilient transportation system; it will require a dedicated whole-of-nation approach involving several decades of investment and continued commitment by national leaders and the public.

> "Creating a transportation system that is more resilient will be perhaps the most significant challenge we have in the century going forward."
>
> *Peter Rogoff, Undersecretary for Policy, U.S. Department of Transportation*

Building resilience into the Nation's transportation system is an enormous task that is extremely important, challenging, and urgent. We can no longer simply repair and restore failed systems. We urgently need to increase investment in a fundamentally resilient transportation system and move beyond the "patch and repair" mentality that has dominated past approaches in many transportation systems. The Nation's continued economic strength will be determined in part by the degree to which investment—and the attendant coordination across disparate partners—incorporates resilient features.

In a sector so complex in assets, ownership, and operations, it is hardly surprising that resilience is in a nascent state of development. This simple reality highlights the enormous challenge faced by the Department of Transportation (DOT) and its partner agencies, which have worked hard to juggle the roles of funder, owner, operator, guider, and regulator of the Nation's transportation infrastructure. The Council recognizes that there are in fact many promising efforts already underway including DOT's *Beyond Traffic*, MAP-21, and the National Freight Strategic Plan.

Key Findings

The Council's key findings are presented within three major topic areas.

Finding 1: Understanding Systemic Risks

- Transportation risks are not well understood across modes, regions, and critical interdependent sectors, creating uncertainty about national-level consequences that could arise from a major system disruption.
- Owners and operators have limited visibility of risks across adjoining systems, jurisdictions, modes and critical dependent infrastructures. In particular, emerging risks related to cyber disruptions,

extreme weather, rising sea levels, aging assets, and workforce changes are not well understood across modes and regions.

Finding 2: Incorporating Resilience into Operational Practice

- Although national resilience policies are generally well established, they have not yet been integrated into comprehensive national transportation plans and strategies that coordinate decision making and risk management across modes at local, state, regional, and national levels.
- Gaps in leadership, coordination, and workforce capabilities have made it difficult for organizations to effectively incorporate resilience as an embedded function of good operating practice.
- There is no structured senior-level engagement between public and private sectors partners, and among transport modes and interdependent sectors, to address national-level transportation risks.

Finding 3: Investing in Resilient Infrastructure

- Chronic underinvestment in transportation infrastructure and the inability to monetize resilience for investment decisions have prevented resilience from being integrated into the built infrastructure.
- There is no national consensus on the need for investment in resilient transportation infrastructure due in part to a limited understanding among the public, political leaders, and industry leaders about the role and value of resilience.
- Uncertainty over the likelihood, costs, and consequences of emerging risks makes it difficult for owners and operators to invest in long-term resilience.

Recommendations

The Council makes three overarching recommendations to address these findings. In short, we need to 1) baseline current risks and establish a Federal vision for transportation resilience; 2) develop the analytic tools, models, and exercises to better understand and plan for emerging risks and interdependencies; and 3) use the results of these efforts to operationalize resilience by increasing funding and implementing effective Federal practices, procedures, and procurement processes. These recommendations strongly align with and affirm NIAC recommendations from prior studies.

Recommendation 1: Conduct a Quadrennial Review of Transportation Infrastructure

The President should direct the Secretary of Transportation and the Domestic Policy Council, working with the Secretary of Homeland Security, to **conduct a quadrennial review (QR) within 18 months that assesses systemic risks and prioritizes a path forward for the national transportation infrastructure**, similar in scope to the Quadrennial Energy Review conducted by the Department of Energy and the Domestic Policy Council. The QR should **establish a comprehensive and persuasive Federal vision and related goals for achieving resilient transportation systems**, consistent with the policies and strategic imperatives contained in PPD-21, *Presidential Policy Directive–Critical Infrastructure Security and Resilience*. The QR should **include quantitative estimates of the likelihood and magnitude of different types of risk**, drawing upon the best scientific, intelligence, and actuarial data available—enabling stakeholders to build a business case for investment and develop new design standards and best practices.

Key elements needed to implement the QR include:

- Establishing a vision and goals to manage modal, intermodal, and cross-sector risks in transportation systems of potential national significance.
- Assessing the current condition of transportation infrastructure, determining the funding requirements to bring it to a state of good repair, measuring the risks of underfunding, and identifying and quantifying transportation research and development needs.
- Operationalizing this vision through a specific strategy for guidance and funding to state, local, and regional partners; an example of such a strategy is the United Kingdom's *National Infrastructure Plan 2014*.
- Conducting an assessment of gaps in workforce capabilities, training, and tools.
- Identifying key data sets and tools, such as full lifecycle analysis, to more fully inform investment decisions.
- Articulating the business case for investment in resilient risk mitigation measures, including the cost of inaction.

Recommendation 2: Develop Tools, Models, and Standards to Mitigate Risks

To support the Quadrennial Review and its updates, the President should direct the Secretary of Transportation, in coordination with the Secretary of Homeland Security, to **fund the development of regional, national, and cross-modal transportation system models using the best available data sets to simulate transportation disruption scenarios.** These would help to further identify modal, intermodal, and cross-sector risks and evaluate mitigation options. In parallel, the White House should **urge Congress to increase funding, lead an effort to heighten awareness, and promote the development and implementation of Federal standards and mitigation measures** to address emerging physical and cyber risks in the transportation sector.

Specific steps required to implement this recommendation include:

- Fully implementing Executive Order 13636 by issuing specific cyber risk-management guidance for transportation cyber-physical systems.
- Developing a transportation-specific enterprise risk management framework that explicitly incorporates resilience aspects.
- Developing models that accurately simulate regional disruption scenarios and are validated by owners and operators to build the business case for investment in resilient infrastructure.
- Developing revised design standards and best practices that expressly incorporate resilience attributes into the planning, construction, and operation of transportation assets.

Recommendation 3: Operationalize Resilience

The President should direct the Secretary of Transportation, working with the White House and the Secretary of Homeland Security, to **"operationalize" national resilience policies** throughout all Department programs and activities by **translating them into guidance, programmatic practices and procedures, funding criteria, and procurement processes to help cultivate a "culture of resilience**." The Department should incorporate resilience, as a high-level performance factor, into all aspects of transportation systems programs, including research and development, training and exercises, and major capital projects.

Two major sub-recommendations should be undertaken to accomplish this recommendation.

- The White House and the Secretary of Transportation should work with Congress to **provide definitive resilience criteria to be incorporated into Federal funding actions, along with remedying current shortfalls in Federal infrastructure investment.** Broader use of loan programs, such as the Transportation Infrastructure Finance and Innovation Act (TIFIA) and Railroad Rehabilitation and Improvement Financing (RRIF), could enhance public transportation infrastructure and support resilience in public and private systems. Congressional support for public-private partnerships not only broadens funding for partnerships, but also enhances the relationship between the public and private sectors. The White House should explore the use of pilot programs for innovative project

financing that would enable state and local agencies to partner with private entities on joint public-private transportation projects that advance resilience.

- The Secretary of Homeland Security and the Secretary of Transportation should **facilitate the implementation of an active cross-modal Transportation Sector Coordinating Council as a senior executive body for addressing strategic cross-modal risks.** These risks could cause catastrophic infrastructure disruptions in the public and private sectors. Participants might consider adopting the model used by the Electricity Sub-Sector Coordinating Council, which now consists of CEO members who meet with their senior executive government counterparts from the Sector Specific Agency (e.g., Deputy Secretary of Energy or higher) and other senior agency executives. To address cross-sector priorities, representatives from the Transportation SCC should also be encouraged to participate in the Strategic Infrastructure Executive Council, a council of CEOs and senior executive decision-makers proposed by the NIAC in its 2015 report, *Executive Collaboration for the Nation's Strategic Infrastructure*. The agencies should also work with groups such as the National Governors Association, the National League of Cities, and the National Association of Counties to promote and strengthen transportation systems resilience.

Additional specific steps required to implement this recommendation include:

- Assessing current government and industry best practices for implementing resilience policies within organizations and establishing performance metrics in administrative and executive practices.
- Requiring state, local, and regional partners to conduct a simple "resilience impact assessment" as a prerequisite for receiving Federal funding for major capital investment projects.
- Conducting a study of public procurement practices for Federally funded transportation projects to identify best practices for ensuring resilience is included as part of the criteria in awarding grants and contracts.
- Embedding resilience and cyber readiness as a project and systems requirement in Federal transportation authorizations.
- Building, testing, and validating models to accurately price insurance coverage based on the resilience practices and level of mitigation undertaken by owners and operators.
- Reviewing safety and environmental quality regulations that should be temporarily waived to facilitate recovery following disruptions, and ensuring that recovery incorporates resilience best practices.

Moving Forward: An Urgent Case for Action

Urgent action is needed now to provide the necessary public funding to rebuild our transportation infrastructure that has suffered from decades of neglect. The need is stark—frequent reports highlight the vulnerability of the Nation's aging infrastructure to major disruptions. Achieving transportation resilience will require a long-term, systematic approach that must be embedded into transportation assets, structures, and operating cultures. The Federal Government needs to act now to implement the standards, tools, planning, and investment decisions that will ensure the resilience of systems decades

into the future. Important investment decisions are currently being made in the Administration and in Congress. These represent opportunities to begin and sustain the long and difficult journey ahead of us.

We believe our findings and recommendations will help guide the fundamental decisions and actions to make the Nation's transportation system efficient, safe, *and resilient.* The Council also notes that with spending on public infrastructure in steady decline, resilience is just part of the greater challenge to build and maintain a competitive, 21st-century infrastructure. Our recommendations lay the foundation for resilience to be addressed as a fundamental part of this greater challenge.

Finally, we strongly believe that support at the highest levels of government, including the Executive Office of the President, and the private sector is needed. Unless there is a shared political will across parties and partners to sustain a policy of resilience and back it with resources, the Nation's transportation system will remain vulnerable to a spiral of increasing disruption and continuing deterioration.

I. Study Objective and Approach

In March 2014, the President directed the National Infrastructure Advisory Council (NIAC) to examine the resilience of the Nation's transportation system to determine potential gaps and identify opportunities for the Federal Government to improve transportation resilience and security. This study identified key resilience issues and performance gaps and assessed opportunities to address them, particularly with regard to how the Federal Government can support resilient systems. This report presents the Council's findings and recommendations to the President.

Over the past six years, the NIAC has conducted four studies that examined resilience and resilience-related issues. This work defined infrastructure resilience as "the ability to reduce the magnitude and/or duration of disruptive events" as determined by the "ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event." In simplest terms, resilient systems can maintain critical functions during a disruption and require less time and resources to recover non-critical functions that have degraded.

A. Study Charge

In 2010, the NIAC developed a framework for establishing resilience goals and examined resilience in the Electricity Sector (NIAC 2010). That study recommended that the government should "promote the use of the NIAC-developed framework for setting resilience goals in the CIKR sectors and for providing a common way to organize resilience strategies within Federal and state governments and CIKR sectors." Toward this end, the President charged the Council to conduct a study to examine resilience in the transportation systems sector. This recognizes the sector's importance as one of the "lifeline" sectors (along with energy, water, and communications), meaning nearly every other sector depends on it to recover vital functions and services after a major disruption.

To conduct the study, the Council formed a Working Group to apply the NIAC-recommended framework for establishing resilience goals to the transportation sector. The objectives of the study were threefold:

- Test and validate the usefulness of the framework in another lifeline sector.
- Uncover key transportation resilience issues.
- Identify potential opportunities to address the identified key transportation resilience issues.

Due to the enormous complexity of the transportation sector (seven distinct modes; a diversity of ownership across the private sector and Federal, state, and local groups; and a vast array of goods and services provided for freight and passengers), the Council notes that the application of the framework is much more complex than in the electricity study. While the general framework applies, this complexity prohibited running a comprehensive tabletop exercise, for example. In consideration of the breadth of the sector, the selected case study focused on the national freight transportation system, recognizing that there are significant areas that overlap with passenger transportation.

B. Study Methodology

To perform engagement, research, and analysis for the study, the NIAC's Working Group established a Study Group of subject matter experts. The Working Group and the Study Group further engaged a variety of leading resilience experts and individuals with deep subject matter expertise in transportation system planning and management to gain insights and perspective that largely informed the Council's findings and recommendations. The Working Group and Study Group collected information from a variety of sources:

- 11 interviews with national leaders in transportation resilience in both the public and private sectors
- 18 interviews with regional, state, and local subject matter experts in transportation systems, state and local cross-jurisdictional coordination, cross-modal integration and management, and the planning and operation of infrastructure assets
- A workshop held by webinar with freight transportation system experts on the West Coast to develop a case study of the transportation system in the Ports of Los Angeles and Long Beach
- More than 200 reports, studies, videos, news articles, testimonies, and policy directives
- Three rounds of briefings from public-sector transportation agencies on resilience activities

The Working Group established the Study Group to conduct additional supporting research and analysis at the direction of the Working Group. Study Group members had expertise in areas that include transportation systems planning and management; risk management; multi-modal transportation systems; and Federal, state, and local planning and coordination. The research and analysis of the Study Group focused on open-source sources and non-Federal discussions and culminated in the development of a case study on disruptions in the Ports of Los Angeles and Long Beach. This complemented the Working Group's engagement with Federal leadership and other senior leaders.

To guide this study, the NIAC posed the following questions:

- **Best Practices:** What current strategies and practices promote resilience in the sector? Are there mode-specific attributes as well as sector-wide ones? What are the common understandings or differences in the definition and coordination of plans and actions across modes?
- **Goals:** What are the implicit resilience goals that align with common practices for each mode and across the sector?
- **Dependencies:** What considerations and cascading effects result from dependencies on other modes and other infrastructure sectors, including cyber systems and their disruptions, within a region and across the nation?
- **Performance Gaps:** What potential gaps and seams create obstacles for the sector and modes to achieve resilience goals?
- **Risk Mitigation:** What unique factors within the sector influence risk mitigation? What are the practical realities of risk priorities and risk mitigation?

- **Public and Private Sector Roles:** What roles and responsibilities should private sector and government at all levels play, operationally and at the senior executive level?
- **Process Improvements:** What new policies and strategies may be needed to improve resilience for the sector?

The list of Working Group and Study Group members, interviewees, and other contributors is presented in Appendix A. A synthesis of information gathered from the subject matter experts interviewed by the Working Group is presented in Appendix K, and a similar compilation from the Study Group engagements (interviews and exercises) is presented in Appendix L.

C. Point of Departure: Recommendations from Prior Assessments

The public and private sectors are more widely recognizing the importance of incorporating resilience in the Nation's critical infrastructure.

The NIAC and other organizations have produced a significant amount of work assessing the general state of resilience, the associated needs for building resilient characteristics into the structure of our national systems, and how these systems operate. The work includes a wide range of recommendations on how the Federal Government can help lead and support the national effort across stakeholders, including the private sector; state, local, and regional jurisdictions; the public; not-for-profit organizations; and Federal officials and programs.

Prior NIAC Studies

In addition to defining infrastructure resilience, the NIAC examined sector-specific resilience practices and developed distinct recommendations in three prior studies:

- ***Critical Infrastructure Resilience*** **(October 2009)** examined "steps government and industry should take to best integrate resilience and protection into a comprehensive risk-management strategy." The report recommended that the government should establish a collaborative dialogue with owners and operators in each sector to develop a commonly agreed upon set of outcome-focused goals for each sector.
- ***A Framework for Establishing Critical Infrastructure Resilience Goals*** **(October 2010)** built on the 2009 study, and through case studies of the electricity and nuclear sectors, developed a process framework for setting, testing, and improving resilience goals. The study recommended that this framework be promoted for setting and testing resilience goals in all sectors.
- ***Strengthening Regional Resilience*** **(October 2013)** examined the characteristics of critical infrastructure resilience in mitigating regional disruptions. The report found that resilience in the lifeline sectors—energy, communication, water, and transportation—is particularly critical; these sectors underpin the essential functions of government and business alike.

In addition, the two most recent NIAC studies provide a series of recommendations that the NIAC finds align very closely with the current study findings, and which the Council strongly re-affirms. For example:

- ***Executive Collaboration for the Nation's Strategic Infrastructure* (April 2015)** recommended that the President should direct the Secretary of Homeland Security to work with the Sector Specific Agency heads for the Electricity Subsector, Water, Transportation, Communications and Financial Services to establish a Strategic Infrastructure Executive Council under CIPAC, composed of CEO or Senior Executive Decision makers from the sectors and their counterpart agencies, to identify national priorities and develop joint or coordinated action plans and agreements to implement them.
- ***Critical Infrastructure Security Resilience National Research and Development Plan* (November 2014)** recommended the identification and application of best practices, including:
    - Identify and establish the elements for business and public justification for investments from lessons learned
    - Identify innovative, cost-efficient and accelerated approaches to develop a skilled workforce
    - Establish resilience metrics

A detailed listing of relevant NIAC recommendations is presented in Appendix I.

Recent Transportation Studies

In the course of developing its recommendations, the Study Group reviewed a wide range of open-source material, as shown in Appendix J. The NIAC found 11 reports especially useful in its examination of resilience in the sector:

- **National Freight Advisory Council (NFAC)** — *Recommendations for the U.S. Department of Transportation's National Freight Strategic Plan*, April 2014
- **New York State 2100 Commission** — *Recommendations to Improve the Strength and Resilience of the Empire State's Infrastructure*, 2013
- **American Society of Civil Engineers (ASCE)** — *2013 Report Card for America's Infrastructure*
- **National Research Council (NRC)** — *Disaster Resilience: A National Imperative*, 2012
- **World Economic Forum (WEF)** — *Building Resilience in Supply Chains*, 2013
- **Transportation Research Board (TRB)** — *A Guide to Emergency Response Planning at State Transportation Agencies*, 2010
- **Volpe** — *Beyond Bouncing Back: A Roundtable on Critical Transportation Resilience*, 2013
- **DHS** — *Roadmap to Secure Control Systems in the Transportation Sector*, 2012
- **Center for National Policy (Stephen Flynn and Sean Burke)** — *Critical Transportation Infrastructure and Societal Resilience*, 2012
- **Gulf Coast Research Center for Evacuation and Transportation Resiliency** — *Resilient Transportation Systems in a Post-Katrina Environment*, 2010
- **NIST** — *Developing Guidelines and Standards for Disaster Resilience of the Built Environment*, 2013

The Council strongly endorses many findings, conclusions, and recommendations from these and other sources, including the following:

- Leadership at the Federal, state, and local levels of government, and by businesses, is needed to communicate the importance of the Nation's infrastructure, craft innovative solutions that reflect the diverse needs of the nation, and make the investments the system needs (American Society of Civil Engineers, 2013).
- Resiliency requires a change in focus from near-perfect efficiency to planned redundancy, flexibility, fault tolerance, and resourcefulness (DOT/Volpe, 2013).
- Federal agencies should incorporate national resilience as an organizing principle to inform and guide the mission and actions of the Federal Government at all levels (National Research Council, 2012).
- While progress toward transportation resiliency within specific modes has been achieved, the national transportation network as a whole lacks communication and coordination across modes. (Louisiana State University, 2010).
- Metrics are needed to support risk management decisions and evaluate the impact of damage on the resilience of transportation systems and the community (National Institute of Standards and Technology, 2013).
- When resilience is the overarching strategic imperative, it leads to a different assessment of risk and highlights a wider range of solutions for dealing with that risk (Flynn/Burke, 2012).
- Security and resilience factors need to be considered and built into transportation infrastructure design and investment decisions (NFAC, April 2014).
- A dedicated fund should be created for multi-modal freight projects. First and last mile segments of regional and national significance must be included in a comprehensive freight funding program to assure freight movement is seamless across jurisdictions, modes, ports and intermodal connectors (NFAC, April 2014).

Of particular timeliness and scope is the work of the National Freight Advisory Committee (NFAC). The objective of this committee is to provide information, advice, and recommendations to the U.S. Secretary of Transportation on matters relating to freight transportation in the United States and the implementation of the freight provisions of the Moving Ahead for Progress in the 21st Century Act (MAP-21), Pub. L. No. 112-141. This specifically includes recommending action to DOT in the development of the *National Freight Strategic Plan*.

NFAC Recommendations to DOT for the National Freight Strategic Plan

In its June 2014 report, *Recommendations for the U.S. Department of Transportation's National Freight Strategic Plan*, the National Freight Advisory Board presented recommendations for the DOT plan. The board assessed statutory, regulatory, technological, institutional, financial, and other barriers to improved freight transportation performance. It also identified opportunities to remove these obstacles, best practices for improving the performance of the freight network, and best practices to mitigate community impacts. Of the board's 90 recommendations, a significant number are relevant to the NIAC Study Group's assessment of transportation resilience, particularly with respect to inter-modal considerations. They include:

- Security and resilience factors need to be considered and built into transportation infrastructure design and investment decisions.
- A dedicated fund should be created for multi-modal freight projects. First and last mile segments of regional and national significance must be included in a comprehensive freight funding program to assure freight movement is seamless across jurisdictions, modes, ports and intermodal connectors.
- Multimodal/intermodal emphasis should be included in Project Delivery Policy Declaration.
- Cross-modal security programs, policies, and regulations should be harmonized, including areas such as credentialing, to ensure consistency in the system and the seamless, unimpeded movement of freight between modes.
- U.S. DOT should invest in a robust, multi-modal Federal research program that covers the range of research from basic (long range, high risk) to research development (short range) to deployment or implementation.
- Intermodal freight activity should be encouraged through streamlined investment.

As the National Freight Strategic Plan is intended to guide Federal planning and investment in the Nation's transportation system, consideration of these and other resilience-related measures will prepare the system to effectively operate in steady state and disrupted conditions.

II. Current Situation: The Intersection of Resilience and Complexity in Transportation

A healthy transportation infrastructure is fundamental to the Nation's economy and prosperity. Today's national transportation system strives to achieve efficiency, safety, and flexibility, which assure the maintenance of desired services during normal operations and steady-state conditions. Increasingly frequent and severe disruptions to these steady-state capabilities, however, have shown that the Nation is vulnerable. Infusing the Nation's transportation system with resilience—that is, the ability to reduce the severity of impacts on service and allow rapid recovery—will be needed to reduce the impact of disruption on the public and economy, and more importantly, to allow the transportation system to be a foundation for economic growth.

The integration of resilience into the transportation system cannot simply function as a response to a system failure. It is a long-term, systematic approach that must be embedded in transportation systems and operating culture. The need is clear—there are seemingly daily reports concerning the vulnerability of the Nation's aging infrastructure to major disruptions such as extreme weather, terrorist attacks, and cyber incidents. Since this study began, we witnessed disruptions in every key transportation mode—all of which caused impacts that cascaded across modes, infrastructures, and regions for days or weeks. Figure 1 summarizes these disruptions. Moreover, this vulnerability reflects long-standing underinvestment in the Nation's public infrastructure. Given the complexity and long life spans of critical sector assets, the resilience of systems decades in the future will be determined by the planning and investment decisions made in the near term. Appendix C presents an overview of the pattern of investment in national infrastructure.

While investing for the future can be an unpopular proposal due to the lack of visible short-term benefits, the long term benefits almost always outweigh the initial cost. For example, featured in the 2013 NIAC report, *Strengthening Regional Resilience*, the Red River Floodway, or "Duff's Ditch," was once a deeply unpopular idea championed by Canadian politician Dufferin "Duff" Roblin in the 1950s. Though it faced severe criticism when it was proposed, it has since prevented more than $30 billion in flood damage in Manitoba and has been used 20 times since its inception. In contrast, a 1997 flood cost the U.S. more than $1.5 billion in damages to Grand Forks, North Dakota, which is located less than 150 miles away from the Red River Floodway and is not adequately protected.

The Council strongly believes that decisive action is needed to make the Nation's transportation system efficient, safe, and resilient. Support at the highest levels of government and the private sector is needed for these to take root. Unless there is a shared political will—across parties and partners—to sustain a policy of resilience and back it with resources, the Nation's transportation system will remain vulnerable to a cycle of increasing disruptions and continuing deterioration.

Figure 1. Select Transportation Disruptions in Every Mode Since the Study Began

Selected Transportation Disruptions

March 2014 – May 2015

WEST COAST PORT SHUTDOWN

Date: July 2014 - February 2015 • Mode: Maritime • Cause: Labor Strikes
Labor strikes caused slowdowns at West Coast ports. This resulted in ships sitting at anchor, food expiring, and shifts in shipment mode and location. Businesses lost millions of dollars and had to reroute goods. Adding ports to the Railway Labor Act would ensure ports stay open due to their impact on interstate commerce.

CHICAGO AIR TRAFFIC CONTROL CENTER FIRE

Date: September 26, 2014 • Mode: Aviation • Cause: Insider Threat
An FAA contractor set a fire in the telecommunications room of the Aurora Air Route Traffic Control Center (ARTCC), which caused communication issues that cancelled 66% of all flights at O'Hare and Midway that day. Severe delays continued for two weeks. Using a satellite-based navigation system would have allowed another ARTCC to take over air traffic control.

BOSTON STORM TRANSIT SHUT DOWN

Date: February 2015 • Mode: Mass Transit • Cause: Snowstorm
Record snowfall hampered Boston's public transportation system, causing issues such as power losses, breakdowns, and fires. The system experienced complete closures and weeks of delays, which affected the state's economy. A lack of funding and aging infrastructure affected the system's performance.

WEST VIRGINIA FREIGHT DERAILMENT

Date: February 16, 2015 • Mode: Freight Rail • Cause: Unknown
During a snowstorm, cars from a freighter carrying crude oil jumped their tracks and caught fire, leaking oil into the Kanawha River. As many as 2,400 residents were displaced from their homes, and a water plant shutdown affected around 2,000 customers. In May, the U.S. Department of Transportation issued new rules for rail cars carrying crude oil to take place by 2020.

WYOMING HIGHWAY PILEUP

Date: April 21, 2015 • Mode: Highway and Motor Carrier • Cause: Blizzard
A heavy blizzard along I-80 in Wyoming caused three major accidents between passenger and commercial vehicles, which left two dead and dozens injured. Responders closed I-80 for several days. Expanding variable speed sections and adding a third lane may have reduced accidents.

PHILADELPHIA AMTRAK DERAILMENT

Date: May 12, 2015 • Mode: Passenger Rail • Cause: Unknown
An Amtrak train leaving Philadelphia derailed while entering a curve. While there is no official cause for the derailment, which killed at least seven people and injured over 200 others, the train was travelling over twice the speed limit when it entered the curve. Amtrak had to suspend or modify service and could face millions of dollars in legal claims. Positive Train Control would have automatically slowed or stopped the train.

SANTA BARBARA PIPELINE BURST

Date: May 14, 2015 • Mode: Pipeline • Cause: Unknown
A burst pipeline released up to 105,000 gallons of oil along a stretch of beach, spilling up to 21,000 gallons into the ocean. The oil killed and threatens wildlife, and hurt the area's billion-dollar tourist economy. The oil company may not have detected or reported the spill as quickly as possible, and the pipeline did not have an automatic shutoff valve that would have reduced the amount of oil released.

A. The Nation's Transportation System: Enormous, Complex, and Diverse

The Nation's transportation system is an extraordinarily complex network of interconnected systems of airways, roads, tracks, terminals, and conveyances. The sector includes seven modes—aviation, freight rail, highway, maritime, mass transit and passenger rail, pipelines, and postal and shipping—each of which comprises an extensive system that is highly interconnected with the other modes.[1]

Facts and Figures

The *Transportation Statistics Annual Report 2013*, compiled by the DOT Bureau of Transportation Statistics (BTS), provides an excellent overview of the size, complexity, and economic importance of the U.S. transportation system:[2]

- The transportation system has 4.1 million miles of **highways**, 140,000 miles of **railroads**, more than 12,000 miles of commercially active inland and inter-coastal **waterways**, 2 million miles of **pipelines**, more than 5,000 public use **airports**, more than 8,000 commercial **waterway and lock facilities**, 180 **maritime ports**, and 4,900 **transit stations**.
- The estimated value of **U.S. transportation assets was $7.7 trillion in 2012.** By value, **one-half of the assets** (highways and streets, airports, waterways, and transit facilities) were owned by the public sector. **Private companies owned about 31 percent of transportation assets** (railroads, pipelines, trucks, planes, and ships), and consumer-owned motor vehicles accounted for the remaining 17.7 percent of asset ownership.
- People, businesses, and governments have about **254 million motor vehicles**, which has risen about 2.5 percent since 2005.
- Transportation accounts for $1 trillion in purchases and investments, $119 billion of public expenditures on operations and maintenance, 12 million jobs in transportation-related industries, and more than 70 percent of the total petroleum consumption in the United States. In 2012, **transportation accounted for nearly 9 percent of total U.S. gross domestic product of $13.3 trillion**.
- The **U.S. freight system moved about 19.7 billion tons of goods valued at $17.4 trillion in 2012**. That equates to 53.9 million tons of goods worth $47.5 billion each day, or 62.6 tons of freight per year, for every man, woman, and child in the United States.
- Exports and imports accounted for about 11 percent of the weight and 20 percent of the value of freight transported throughout the United States in 2012.

---

[1] DHS, *TS-SSP 2010*, 1.

[2] DOT, Bureau of Transportation Statistics (BTS), *Transportation Statistics Annual Report 2013*. Congress requires the Bureau of Transportation Statistics to compile transportation statistics under Section 52011: *Moving Ahead for Progress in the 21st Century Act* (Public Law No. 112-141). For a 2014 update in some categories, see DOT, BTS, *Multimodal Transportation Indicators* (October 2014).

Seven separate-but-interconnected transportation modes constitute the Transportation Systems Sector: aviation, freight rail, highway and motor carrier, maritime, mass transit and passenger rail, pipeline, and postal and shipping. The major assets of the individual modes, as well as their ownership structure, operations, and cross-modal and cross-sector interconnections, are described in Appendix E. A review of transportation modes and corresponding practices that may contribute to resilience is presented in Appendix G.

Boosting the National Economy

Incorporating resilience into the national transportation system will not only reduce government expenditures for repeated construction and maintenance, but will also ensure and promote a strong national economy. As President Eisenhower once said, "A modern, efficient highway system is essential to meet the needs of our growing population, our expanding economy, and our national security." In the same manner today, resilient characteristics can underpin the 21st-century transportation systems needed to compete in highly fluid and competitive international markets. In addition, the Nation's military relies on a healthy and reliable national transportation infrastructure to accomplish its missions. A 2014 report on transportation infrastructure investment from the National Economic Council and the President's Council of Economic Advisers stated, "The economic benefits of smart infrastructure investment are long-term competitiveness, productivity, innovation, lower prices, and higher incomes, while infrastructure investment also creates many thousands of American jobs in the near-term.[3]" This view is supported by a wide range of voices, including:

- "Transportation is a critical engine of the Nation's economy. Investments in our transportation network over the country's history have been instrumental in developing our Nation into the world's largest economy and most mobile society." (U.S. Department of Transportation. *Budget Highlights: Fiscal Year 2016*.)
- "Sound transportation investments lower the costs of moving people and goods. This increases economic productivity, which roughly can be measured as the output of goods and services per dollar of private and public investment. And improved productivity leads to a higher standard of living… well-chosen transportation investments can advance both long-term productivity growth and short-term job creation." (Martin Wachs, "Transportation, Jobs, and Economic Growth," *Access*, Fall 2014.)
- "Because of its intensive use of infrastructures, the transport sector is an important component of the economy and a common tool used for development. This is even more so in a global economy where economic opportunities are increasingly related to the mobility of people, goods and information. A relation between the quantity and quality of transport infrastructure and the level of economic development is apparent. High density transport infrastructure and highly connected networks are commonly associated with high levels of development. When transport systems are

[3] National Economic Council and Council of Economic Advisers. "An Economic Analysis of Transportation Infrastructure Investment." 2014.

efficient, they provide economic and social opportunities and benefits that result in positive multipliers effects such as better accessibility to markets, employment and additional investments. When transport systems are deficient in terms of capacity or reliability, they can have an economic cost such as reduced or missed opportunities and lower quality of life." Jean-Paul Rodrigue et al. "The Economic Importance of Transportation," (Hofstra University, *The Geography of Transport Systems*, 2013.)

The Council considers economic strength and security as a predominant driver for infusing the Nation's transportation system with resilience, which can only be fully realized when the ability to prepare for, respond to, recover from, and mitigate the impacts of increasingly severe and prevalent disruptions is achieved.

B. Status of Federal Policy and Action

Over the past several years, Federal policy, planning, and program development has shown promising strides in incorporating resilience. However, resilience has not yet been broadly supported through action. Until this occurs—including specific funding, guidance, and programs for resilient measures—success in achieving resilience will remain elusive.

Resilience in Federal Law and Policy

Critical infrastructure resilience has become an important goal in Federal law and policy over the past few years. The *National Security Strategy* of May 2010 recognized "the fundamental connection between our national security, our national competitiveness, resilience, and moral example." In general, however, while recent policy actions such as the ones listed below have stressed the importance of resilience, this emphasis has not yet been broadly translated into the funding, guidance, and other programmatic actions required for success.

Federal law and policy related to resilience may be found in key documents including:

- The 2012 Moving Ahead for Progress in the 21st Century Act (MAP-21)
- The 2013 Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act) *as Amended*
- Presidential Policy Directive (PPD) 8: *National Preparedness*
- Presidential Policy Directive (PPD) 21: *Critical Infrastructure Security and Resilience*
- Executive Order (EO) 13636: *Improving Critical Infrastructure Cybersecurity*
- Executive Order: *Promoting Private Sector Cybersecurity Information Sharing*

All of these touch on one or more aspects of resilience as defined by the NIAC in its 2010 *A Framework for Establishing Critical Infrastructure Resilience Goals*: "Robustness includes the measures that are put in place prior to an event; resourcefulness includes the measures taken as a crisis unfolds; rapid recovery includes the measures taken immediately after an event to bring things back to normal; and adaptability includes the post-incident measures and lessons learned that are absorbed throughout the system."

Signed into law by President Obama in July 2012, MAP-21 (Public Law 112-141) was the first long-term highway authorization enacted since 2005. MAP-21 creates a streamlined, performance-based, multimodal program to address the many challenges facing the U.S. surface transportation system. These challenges include improving safety, maintaining infrastructure condition, reducing traffic congestion, and improving efficiency of the system and freight movement. Among other provisions, the law requires the DOT to develop a *National Freight Strategic Plan*, originally due in June 2015, but now delayed until October 2015.

MAP-21 and the *National Strategic Freight Plan*

MAP-21 requires DOT to develop, within three years of enactment of MAP-21, a national freight strategic plan in consultation with states and other stakeholders, and to update the plan every five years. The plan must:

- Assess the condition and performance of the national freight network
- Identify highway bottlenecks that cause significant freight congestion
- Forecast freight volumes
- Identify major trade gateways and national freight corridors
- Assess barriers to improved freight transportation performance
- Identify routes providing access to energy areas
- Identify best practices for improving the performance of the national freight network and mitigating the impacts of freight movement on communities
- Provide a process for addressing multistate projects and strategies to improve freight intermodal connectivity

As resilience is a key component of the law's intent, the strategic plan will be opportunity – and perhaps a litmus test – for DOT's focus on transportation resilience.

Federal Agencies with Major Transportation Roles

The Sector Specific Agencies (SSAs) for the sector reside in DHS and DOT; among other duties they lead the collaborative effort to develop the Sector Specific Plan (SSP), which details the application of NIPP concepts to the unique characteristics and conditions of the transportation sector.

U.S. Department of Transportation

The Security Policy and Plans Division, located within the Office of Intelligence, Security, and Emergency Response in the DOT, serves as the designated SSA, and is part of the Office of the Secretary of Transportation. In addition to its SSA responsibilities, the Policy and Plans Division develops DOT policy and coordinates DOT participation in interagency policy development related to intelligence, security, and all-hazards preparedness. The Division coordinates DOT-wide interaction with the National Security Council and its interagency policy committees. The Division also serves as the Secretary's public health advisor, and is the focal point for both Departmental and interagency response and recovery planning.[4]

[4] DOT, "Security Policy and Plans Division."

In addition to the SSA, multiple components within DOT are responsible for ensuring a fast, safe, efficient, accessible, and convenient transportation system.[5] Of particular note is the John A. Volpe National Transportation Systems Center (Volpe) which assists Federal, state, and local governments, as well as industry and academia, in areas including human factors research; system design, implementation, and assessment; global tracking and situational awareness of transportation assets and cargo; and strategic investment. Other components are described in Appendix F, Overview of Federal Transportation Policy and Programs.

U.S. Department of Homeland Security

Within DHS, the Transportation Security Administration (TSA) and the United States Coast Guard (USCG) share SSA responsibilities for ensuring the sector's security and for ensuring freedom of movement for people and commerce. The Federal Emergency Management Agency (FEMA) has key transportation roles during national disasters.

Transportation Security Administration

TSA has a lead role for security of the aviation and surface transportation modes and supports the USCG as the lead for maritime security. As part of its mission, TSA is responsible for assessing intelligence, issuing and enforcing security directives, ensuring the adequacy of security measures at transportation facilities, and ensuring effective and timely distribution of intelligence to sector partners. TSA collaborates with DOT to manage protection and resilience programs for all hazards. The total TSA budget request for fiscal year (FY) 2014 was about $7.4 billion. For FY 2015, the request was about $7.3 billion.

United States Coast Guard

The USCG is a multi-mission maritime service and one of the Nation's five Armed Forces. Its mission is to protect the public, the environment, and U.S. economic interests in the Nation's ports, on navigable waterways inland, along the coast, on the high seas, and in any maritime region, as required to support national security. In the event of a maritime incident, the USCG will often act as a first responder. The USCG has the primary responsibility for the security of the maritime domain, including coordinating mitigation measures to expedite the recovery of maritime infrastructure and transportation systems and supporting incident response with the U.S. Department of Defense (DoD). The total USCG budget request for FY 2014 was about $9.8 billion. For FY 2015, the request was also about $9.8 billion.

In addition to the SSA organizations, DHS has several other components with roles related to resilience in transportation systems. These include FEMA, the Science and Technology Directorate, and the national Cybersecurity and Communications Integration Center. Federal agencies and components are further described in Appendix F.

[5] Descriptions of these DOT administrations, TSA, and USCG roles are taken from DHS, *TS-SSP 2010*, 93 and 18.

III. Assessment of Transportation Resilience Today

The Council conducted dozens of interviews with diverse transportation and resilience experts. Throughout these interviews we noted four recurring themes:

A. Transportation Risks
B. Infrastructure Investment and Funding
C. Policies and Practices
D. Leadership and Coordination

Our observations and conclusions in each area are summarized below, with more detailed information provided in Appendix B.

A. Transportation Risks

The scale, scope, and diversity of the Nation's transportation system create the need for effective risk management to successfully confront a broad range of challenges. Four primary factors contribute to the complex risk environment faced by the Nation's transportation systems.

Limited Understanding and Visibility of Risks across Interdependent Infrastructures

- Transportation assets are highly interconnected across modes and other critical sectors—such as energy, communications, and water—creating hidden risks within regions that operators cannot easily anticipate. Understanding how different modes and sectors interconnect is challenging because operators and stakeholders rarely possess the system-wide visibility needed for managing risk throughout the transportation system.

Cross-Sector Interdependencies Create Hidden Risks

In the aftermath of Superstorm Sandy, unforeseen and severe shortages of liquid fuels in New Jersey exposed the government's limited understanding of the intricacies of the supply chain. The shortage cascaded to other lifeline sectors and delayed restoration: without a steady source of gasoline and diesel for utility vehicles, repair crews were slowed in their ability to repair downed power lines that were needed to pump fuels at local service stations.

- Owners and operators often lack the tools that draw on real-world experience to model "what if" scenarios and simulate how cascading disruptions play out within a particular region. Even with such tools, however, there is limited understanding of the complex decisions made at the local, state, regional, and national levels as an event unfolds.

Limited Redundancy and Critical Points of Failure

- Optimizing transportation systems often reduces redundancy and creates potential choke points within regions. These become single points of failure due to the number of transportation services that would be incapacitated in a disruption.
- "Substitutability," in which alternative services are used to accomplish the same outcome, can help improve resilience by providing functional continuity while damaged assets are restored. For example, the use of "bus bridges" in New York during Superstorm Sandy provided a substitute for disabled subways.

Lack of Intermodal and Cross-Sector Resilience Coordination for Regional Systems

- Regional coordination is imperative to ensure local actions do not delay recovery on a regional scale. For example, schools are often used as shelters for displaced people following natural disasters, but a crucial part of the larger regional recovery includes getting kids back to school as quickly as possible.
- Effective, resilient, and rapid recovery requires strong coordination among highly disparate groups prior to a disruption. Yet many of the regional stakeholders needed for this—first responders, emergency personnel, engineers, system planners, and capital investors—may not have traditionally partnered in the past.

> "During large-scale disruptions, localized actions that may be rational can end up causing globalized disruption because of the inability to see the forest for the trees. Each actor independently does what makes sense for it to do, but without visibility about what other actors are doing. They end up with all kinds of cascades that are working against the overall recovery."
>
> *Dr. Stephen Flynn, Professor of Political Science, Founding Co-Director of the George J. Kostas Research Institute for Homeland Security, Northeastern University*

Poor Ability to Address Rapidly Changing Risks

- The Nation is facing emerging risks that are creating a "new normal." This requires a more aggressive approach to risk management rather than one based on extrapolating risks from past experience. Among these risks are:
  - Aging Infrastructure
  - Rising Sea Levels and Extreme Weather
  - Cyber Threats
  - Workforce Deficiencies

> "Today's 100-year flood could be 2050's annual flood and 2100's high tide."
>
> *Vivien Li, President, The Boston Harbor Association*

B. Infrastructure Investment and Funding

Our transportation infrastructure has been chronically underfunded. For example, experts estimate $13 billion more per year is needed to maintain highway and transit systems and to reduce the risk posed by aging infrastructure. However current funding mechanisms for transportation systems is often biased *against* investment in resilience.

Inability to Monetize Resilience Benefits Biases Investment Decisions

- The inability to quantify the value of resilience investments causes transportation agencies to select least-cost solutions that lack resilience features. Resilience benefits extend beyond reducing the cost of repairs. Minimizing disruptions enhances public safety and has economic benefits.
- Owners and operators lack the data, tools, and guidance to accurately measure the lifecycle risks of assets and to assign the appropriate value to resilience improvements. For example, system planners are being asked to examine the risks transportation infrastructure will face decades into the future, while the effects of climate change are uncertain.

Reluctance to Invest Today for Future Returns

- As a nation, we have consistently lacked the political and social will to make capital investments in infrastructure that may not pay off for decades, particularly when they are designed to mitigate risks that may never materialize. Experts frequently cite an average four-fold return on capital infrastructure improvements made before anticipated disasters, yet our infrastructure continues to fall into disrepair. One expert called the reluctance to invest "the disease of the public sector."
- States and regions are now working to design coordinated long-term investments with multiple benefits across the risk spectrum that generate far greater than a 1:4 return. The challenge is that decision makers in many cities, states, and regions are not well versed in long-term risk planning.

> "We need to break away from the old planning and funding mechanisms that promote short-sighted decision making. We need to break away from a cost-benefit process that justifies projects solely based on what happened in the past and ignores real data that points to a very different future. Taxpayers shouldn't be footing the bill for the resurrection of transportation assets and infrastructure that are not in line with the new normal. We should encourage, not discourage, investments that are planned and designed to sustain this new normal, even when it costs more money in the short run."
>
> *Peter Rogoff, Undersecretary for Policy, US Department of Transportation*

Incorporating Resilience into Lifecycle Planning and Design

- It is far more cost-effective to bake resilience into system designs than to retrofit transportation systems to meet evolving risks. Transportation assets are planned with 50-year-plus lifecycles; today's capital investments greatly influence the resilience of the transportation sector for decades to come. Resilience should as important to design decisions as construction and maintenance costs.
- Routinely integrating resilience into project planning will take a cultural shift, but will prove more cost-effective over time. For example, transforming our built environment to be handicapped accessible once seemed a herculean task, but is now simply another design principle. Developing resilient design standards and practices will require coordination by engineers, planners, operators, and emergency responders.
- When replacing assets and building new system protections, transportation agencies and companies lack the data to determine what designs will be sufficient for the next 50 years of risks. This makes it

difficult for them to determine effective actions to address the potential effects of climate change and sea level rise.

Insurance May Create the Right Incentives for Resilient Infrastructure Investment

- Combining policy and regulatory tools with other market drivers, such as disaster insurance plans, can create the right incentives to change investment behavior. This can be accomplished by integrating resilience measures into the requirements for Federal and state grants, capital investments, and disaster relief funding.

> "That's our real challenge: How can policy and regulatory tools generate market-driven tools that ultimately bring about sustained change behavior?"
>
> *Dr. Stephen Flynn, Professor of Political Science, Founding Co-Director of the George J. Kostas Research Institute for Homeland Security, Northeastern University*

- Following Superstorm Sandy, the Metropolitan Transportation Authority (MTA) in New York found it difficult to re-insure its assets at a price the agency could afford. To confront this challenge, the MTA purchased a "catastrophe bond," an insurance product built around a parametric trigger or storm surge at a specific level. For instance, if the storm surge reaches eight feet at Battery Park in Manhattan, the insurance bond pays out immediately. This type of insurance policy encourages a number of benefits: owners and operators focus on assessing and mitigating real risk, as opposed to political or other kinds of risk; insurers almost always compel the use of mitigation measures to receive a reasonable price; and insurers are able to make resources available quickly following a disaster to expedite recovery.

Appendix C provides general information on the current state of infrastructure investment.

C. Policies and Practices

Transportation policy and practices need to evolve from a model that focuses on disaster relief to one that emphasizes agile operations and resilient design and repair. While national policies for infrastructure resilience such as PPD-8 and PPD-21 have established a policy framework, resilience must be integrated into operational practices that turn concepts into concrete action.

Transportation System Resilience Requires an Operational Sea Change and National Vision

- Achieving resilience requires coordination and innovation across modes and sectors on *all* infrastructure management aspects: regulation, planning, engineering, design, operations,

maintenance, and emergency response. Federal and state agencies lack the organizational structure, resilience knowledge, and capacity to put current policy into action. Current Federal policies also do not create a unified national vision for transportation system resilience.

> "Right now, our national policy is disaster relief centric. We have a policy of responding and repairing specific disasters. When we do this, we spend our time repairing at great cost because it is under exigent circumstances. The end result is that we are repairing what is often 19th century infrastructure or early 20th century infrastructure and leaving them weaker than it was before."
>
> *William Golden, Executive Director, National Institute for Coastal and Harbor Infrastructure, Boston, MA*

Integrating Resilience Concepts into Asset Management

- Transportation system resilience requires not only having the right assets in place, but managing those assets using resilience concepts.
- MAP-21 already requires state DOTs and transit agencies to have a performance-based asset management system, providing an excellent platform to integrate resilience concepts and practices developed with Federal leadership.

Disaster Recovery Policy Creates Disincentives to Invest in Resilience

- The level of Federal assistance provided to disaster-affected regions under the Stafford Act is not only unsustainable—given the rising cost and frequency of major events—but creates unintended disincentives to mitigate infrastructure risks.
- Emergency relief funds should only support recovery from disasters above and beyond expected risks. For this to happen, transportation agencies—as a matter of due course—should be assessing their asset risk, assigning a value to that risk, and making insurance or infrastructure investments to reasonably mitigate it.

> "There are actually disincentives for resilience investment. Everybody is expecting that in a large disruptive event the Federal Government will come in and make them whole. Why should infrastructure owners invest their limited resources—already stretched too thin to support daily maintenance and operations—to invest in a "what if" that, if the "what if" does happen, will ultimately lead to generous checks being written out of Washington? This moral hazard is creating a real barrier to investing in mitigation."
>
> *Dr. Stephen Flynn, Professor of Political Science, Founding Co-Director of the George J. Kostas Research Institute for Homeland Security, Northeastern University*

D. Leadership and Coordination

Planning and investment decisions are ultimately made by leaders in both the public and private sectors. Engaging leaders in coordinating resilience efforts is an essential component that is often overlooked.

Decisive Leadership Must Leverage Public and Private Expertise

- The most comprehensive infrastructure investments our country has seen throughout history have arisen because a prominent leader championed the cause. Political will is needed to generate action.
- Effective collaboration on shared risks requires committed leadership that fuses resources from many sources. Regional consortia excel at bringing together public and private leaders to solve tangible infrastructure problems. When tapped, non-profits, think tanks, and academic institutions focused on transportation can support expertise-based solutions for policymakers.

Private Sector Leadership Engagement is Critical for Timely Action

- CEO-level engagement plays a major role in securing a commitment to resilience by fostering constructive dialogue and building partnerships across regions, sectors, and modes. The 2015 NIAC report Executive Collaboration for the Nation's Strategic Infrastructure found that CEOs play key roles in "advancing outcomes and unifying action across their institutions and their sectors."
- From a practical perspective, most CEOs are already championing resilience as a critical part of business continuity. Corporate leaders have a strong sense of stewardship; they care deeply about the business conditions they leave behind.

International Collaboration is Essential

- Transportation networks are built around geographic regions, and therefore many networks extend beyond our borders. Canada and Mexico serve as two of our Nation's biggest trading partners. Effective collaboration can reduce international supply chain disruptions and create coordinated policies that ensure transportation continuity and the public safety.

IV. Findings

As the NIAC initiated this study, seven topics emerged that framed the research and provided general context for the council's findings and recommendations. The Council summarizes these seven topics as follows:

- **Current Practices**: While there are numerous activities that support resilient actions in the sector, presently there is little coordination or sharing across modes for those aspects that do exist. Indeed, even the "language of resilience" differs substantially, with little commonality in how it is incorporated into practice.
- **Goals**: There is no broad, commonly accepted framework for resilience goals. However, while not explicitly defined, some resilient characteristics are in fact embedded in other targets, though generally not as primary aspects.
- **Dependencies**: There are widespread, major dependencies—within modes, across modes, and with other lifeline sectors. While these dependencies are typically well known, they are too often poorly understood or without defined paths for mitigation. Cross-modal and cross-sector dependencies are of particular concern.
- **Performance Gaps:** There are significant gaps in all areas of risk management, including identification, understanding, and prevention/mitigation of risks. Given that there are already known and long-standing shortfalls in addressing risks from aging infrastructure, emerging threats such as cyber intrusions exacerbate these gaps and their significance.
- **Risk Mitigation:** The extraordinarily complex and highly interconnected nature of the sector make risk mitigation an extremely broad and difficult challenge. While there are common constructs and approaches that can be broadly applied, individual modes have substantially different patterns of assets, ownership, and operation that complicate potential solutions.
- **Public and Private Sector Roles:** Ownership is divided among public jurisdictions and the private sector, which results in different patterns of operation, particularly with investment and risk management. The Federal Government acts primarily as the funder, regulator, and owner/operator of various systems. It must provide national leadership in funding and incentives for resilient practices, both public and private.
- **Process Improvements:** With increasing threat recognition, there is a substantial body of policy and strategic guidance. However, actual implementation of this guidance is modest, at best. The adoption of resilient characteristics and activities into operational practice is piecemeal, though there are significant examples of success stories.

The Council notes that in a sector so complex in assets, ownership, and operations, it is not surprising that resilience is in a nascent state of development. This greatly challenges DOT and its partner agencies, which must balance the roles of funder, owner, operator, guider, and regulator of the Nation's transportation infrastructure. The Council further notes there are many promising efforts already underway in DOT and elsewhere; Appendix D presents examples of this progress.

Finding 1: Understanding Systemic Risk

Transportation risks are not well understood across modes, regions, and critical interdependent sectors, creating uncertainty about national-level risks resulting from a major system disruption.

1.1 Owners and operators have a limited visibility of risks in adjoining systems, jurisdictions, modes, and critical dependent infrastructures. In particular, emerging risks related to cyber disruptions, extreme weather, rising sea levels, aging assets, and workforce changes are not well understood across modes and regions.

1.2 Current transportation data, modeling tools, and exercises are not sufficiently robust to effectively evaluate transportation system risks and their regional and national implications.

1.3 Transportation systems are generally effective in emergency response and surprisingly adaptive to disruptions. However, this often comes at the expense of investment in prevention, resilience, and long-term sustainability.

Finding 2: Incorporating Resilience into Operational Practice

Gaps in leadership, coordination, and workforce capabilities have made it difficult for organizations to effectively incorporate resilience into operating practice.

2.1 Although national resilience policies are well-established, they have not yet been integrated into comprehensive national transportation plans and strategies that coordinate decision making and risk management across modes at the local, state, regional, and national level.

> "It has become the 'soup de jour' for every agency to have a resiliency and risk mitigation focus. Frankly, what many agencies are doing is just relabeling their programmatic focus and utilizing a great deal of funds they say are committed to resiliency simply to sustain administrative costs they are trying to secure—keeping personnel that they would otherwise have lost if they really had to refocus things."
>
> *William Golden, Executive Director, National Institute for Coastal and Harbor Infrastructure, Boston, MA*

2.2 There is no structured, senior-level engagement between public and private sectors partners, transport modes, and interdependent sectors to address national-level transportation risks. This is compounded by the difficulty of identifying public sector authorities who have decision-making ability throughout the networks of state, city, and county leaders.

2.3 Responsibility for promoting and assuring resilience is split among several key Federal organizations (DOT, USCG, Transportation Security Agency, USACE), and there is currently no unified strategy or plan.

2.4 Under the auspices of CIPAC, the cross-modal transportation councils (SCC and GCC) are dormant, and there is no structure in place to focus on lifeline sector interdependencies.

2.5 Decision makers and operators lack a common understanding of what resilience is, why it is critical, and what actions improve it. As a result, resilience policies and strategies have not been

effectively translated into the procurement processes, management procedures, and operational practices of many public and private organizations. Resilience will only be effective when it becomes an intrinsic characteristic, similar to safety, and when organizations are able to inspire a "culture of resilience."

2.6 The composition and capabilities of the transportation workforce is changing, creating potential vulnerabilities. For example, much of the public transportation workforce is not trained in system resilience concepts and modern risk management practices, or may not have the capabilities to analyze and mitigate emerging risks such as cyber. At the same time, the valuable experience and operational knowledge of the sector's retiring workforce may be lost without careful transition and training.

2.7 There is limited availability and use of tools, methods, and best practices to support effective resilience practices. This is compounded by poor adherence to existing best practices, such as performance-based asset management and state-of-good-repair practices. Where performed, information sharing and best practices for risk management is challenging. This is due to the diversity and complexity of sector, and sometimes laws that regulate the sector and its institutions.

Finding 3: Investing in Resilient Infrastructure

Underinvestment in transportation infrastructure and the inability to monetize resilience for investment decisions have prevented resilience from being integrated into built infrastructure.

3.1 Chronic underinvestment in publicly owned and funded transportation infrastructure has resulted in inadequate and decaying infrastructure with uncertain risks. By contrast, investment in privately owned infrastructure, such as freight rail, has increased over the past decade.

3.2 There is no national consensus on the need for investment in resilient transportation infrastructure due in part to a limited understanding among the public, political leaders, and industry leaders about the role and value of resilience.

3.3 Federal Government legal authorities and funding streams are widely distributed across agencies, often resulting in siloed and uncoordinated transportation investments. There is also limited Federal coordination regarding transportation investments made at the local level and a lack of clear Federal guidance to help jurisdictions make informed investments that promote resilience.

3.4 Resilience is not being fully considered in capital planning for new transportation infrastructure, particularly in public projects. This is due to the difficulty of prioritizing competing considerations and finding information on the costs and benefits of resilient features.

3.5 Uncertainty over the likelihood, costs, and consequences of emerging risks, such as aging infrastructure, cyber threats, and rising sea levels, makes it difficult for owners and operators to invest in long-term resilience. This inability to monetize resilience often leads to favoring investment in emergency response at the expense of longer-term investment in resilient

infrastructure. This frequently yields least-cost solutions that marginalize resilience features in transportation projects, resulting in lower capital costs today but higher repair and societal costs in the future.

3.6 There is limited use of tools, such as full lifecycle cost analysis, benefit-cost analysis, and other best practices, to inform investment decisions in the transportation sector. This is compounded by the lack of adequate resilience metrics and cost data to support analysis and decision making.

3.7 The public and private sector rely on distinct business models, requiring different incentives to build resilience into infrastructure across the transportation sector. For example, private railroads have made significant long-term investments over the past decade to improve freight rail infrastructure, because it ensures continuity of operations during catastrophes and strengthens the bottom line. By contrast, public transit agencies respond to Federal funding and regulatory requirements, which may not require or prioritize investment in resilience.

V. Recommendations

The Transportation Systems Sector exhibits a complexity unlike any other the Council has studied. Its diverse and interconnected modes, fragmented ownership and authority, and chronic underinvestment create challenges for the sector to plan and achieve resilience. The Nation's severely aging and deteriorating transportation infrastructure has a diverse set of emerging risks that no one Federal entity has full jurisdictional responsibility to address.

Building resilience into the Nation's transportation system is both an enormous undertaking and an urgent task. It will ultimately require recognition, investment, and innovation from a multitude of public and private partners. Since the Council advises the President and Federal agencies, it focused on three recommendations that will enhance the Nation's and stakeholders' ability to take action. The re-authorization of national transportation appropriations offers an opportunity for Federal leaders to make resilience a key element of future funding, policy, and programmatic provisions. The Council's recommendations lay the foundation for implementing resilience in government investments.

In short, the sector needs to 1) baseline current risks and establish a Federal vision for transportation resilience; 2) develop the analytic tools, models, and exercises to better understand and plan for emerging risks and interdependencies; and 3) use the results of these efforts to operationalize resilience by increasing funding and implementing effective Federal practices, procedures, and procurement processes. These actions are designed to increase the *ability* and *opportunity* for all stakeholders to make decisions and investments that support resilience. Our recommendations strongly align with NIAC recommendations from prior studies.

In developing its recommendations, the NIAC ascertained five overarching themes that will determine the success or failure of achieving a resilient national transportation infrastructure:

- **Long-Term Commitment:** Achieving resilience is a long-term process, and resilience must be applied to all stages of asset life cycles, from defining requirements through operations and maintenance. This will require instilling a "culture of resilience," similar to the safety culture that has guided much of our present infrastructure systems.
- **Investment:** Resilience is much more than response to a disaster. It requires early investment—in resources and in sustained dedication to overcome obstacles—to plan and build improved, more robust systems rather than simply repairing and restoring failed systems. Without this, disaster response will become increasingly expensive and less effective. It is critical that current investments incorporate resilient features.
- **Partnership and Champions:** Sustained collaboration across government and the private sector—starting at the executive level—is crucial. Given the number of owners, operators, and users of the Nation's transportation system, a shared vision and buy-in from those in leadership positions is required for transportation resilience to be achieved and sustained.
- **A Systems Approach**: Today's transportation infrastructure, while highly interconnected, is an agglomeration of modal components. A "whole of systems" approach must tie together modes,

regions, jurisdictions, and the other lifeline sectors with a commonly accepted framework for resilience risk management.

- **The Federal Role**: The Federal Government plays a prominent role in the transportation sector. It acts as a funder, regulator, and sometimes owner and operator. The Federal commitment to resilience must put policy into action, and create successful standards and incentives that integrate grants, programs, and projects with guidance.

These themes permeated the Council's interviews and analysis, and provide context for the recommendations that follow.

Recommendation 1: Conduct a Quadrennial Review of Transportation Infrastructure

The President should direct the Secretary of Transportation and the Domestic Policy Council, working with the Secretary of Homeland Security, to **conduct a quadrennial review (QR) within 18 months that assesses systemic risks and prioritizes a path forward for the national transportation infrastructure**, similar in scope to the Quadrennial Energy Review conducted by the Department of Energy and the Domestic Policy Council. The QR should **establish a comprehensive and persuasive Federal vision and related goals for achieving resilient transportation systems**, consistent with the policies and strategic imperatives contained in PPD-21, *Presidential Policy Directive–Critical Infrastructure Security and Resilience*. The QR should **include quantitative estimates of the likelihood and magnitude of different types of risk**, drawing upon the best scientific, intelligence, and actuarial data available—enabling stakeholders to build a business case for investment and develop new design standards and best practices.

The first transportation sector Quadrennial Review should be conducted to establish a foundational vision for the resilience of the U.S. transportation system. The QR process will enable Federal agencies, as well as owners and operators in the public and private sectors, to acknowledge, address, and be accountable for key resilience needs. The QR should assess the entire range of risks that the transportation infrastructure must manage, determine the status of the sector in managing those risks, and establish a unified path forward for implementing priorities over the next four years. The Council also believes establishing a Quadrennial Review process for each of the critical sectors—in addition to the transportation sector—would be useful for identifying cross-sector risks that may otherwise remain hidden. The Transportation Quadrennial Review should take relevant recommendations from other sector reviews into account.

The Quadrennial Review should include the following:

- A vision and goals that emphasize the management of modal, intermodal, and cross-sector risks in transportation assets and systems of potential national significance.
- An assessment of the condition of the transportation infrastructure, determining the funding requirements to bring it to a state of good repair, measuring the risks of underfunding repairs

and resilience investments in the sector, and identifying and quantifying transportation research and development needs.

- A strategy for operationalizing this vision through guidance and funding to state, local, and regional partners. This would ensure the security and resilience of the U.S. transportation infrastructure is addressed in an integrated, holistic manner; accounts for key interdependencies; and makes resilience a fundamental cultural characteristic, similar to safety. For example, in developing the National Freight Strategic Plan, called for by MAP-21, the Department of Transportation should explicitly include resilience attributes and metrics, covering all modes as well as inter-modal considerations. These should encompass the recommendations from the National Freight Advisory Council, provided to the Department of Transportation in April 2014. For context, the United Kingdom's *National Infrastructure Plan 2014* exemplifies the size and scope of this type of national cross-sector strategy.
- An assessment of the current and future transportation sector workforce to determine where gaps may exist in capabilities, training, and tools needed to manage infrastructure risks. This should support Transportation Research Board funding on efforts such as the workforce initiatives in MAP-21.
- The identification of key data sets and tools, such as full lifecycle analysis, could better inform investment decisions and business case determinations.
- Articulation of the business case for investment in resilient risk mitigation measures, including the costs and consequences of doing nothing. Working with the Council of Economic Advisers, this should consider the criticality of long-term transportation planning and investment to national economic growth, including the value of full lifecycle maintenance cost estimates to sustain resilience in transportation systems.

Recommendation 2: Develop Tools, Models, and Standards to Mitigate Risks

To support the Quadrennial Review and its updates, the President should direct the Secretary of Transportation, in coordination with the Secretary of Homeland Security, to **fund the development of regional, national, and cross-modal transportation system models using the best available data sets to simulate transportation disruption scenarios.** These would help to further identify modal, intermodal, and cross-sector risks and evaluate mitigation options. In parallel, the White House should **urge Congress to increase funding, lead an effort to heighten awareness, and promote the development and implementation of Federal standards and mitigation measures** to address emerging physical and cyber risks in the transportation sector.

Federally developed standards and mitigation measures should be voluntary for the private sector if no Federal funds are required, unless strong evidence shows there are major risks to transportation infrastructure that are not being addressed by market mechanisms. Specific actions required to implement Recommendation 2 include the following:

Recommendation 2.1: The Sector-Specific Agencies for Transportation should **fully implement Executive Order 13636 by issuing specific cyber risk-management guidance for transportation cyber-physical systems** using NIST's *Framework for Improving Critical Infrastructure Cybersecurity*. This guidance should build on the industry's standards and best practices, such as the implementation guidance developed by the Department of Energy for the Energy Sector (*Energy Sector Cybersecurity Framework Implementation Guidance*).

Recommendation 2.2: The Department of Transportation should **fund the development of a transportation-specific enterprise risk management framework that explicitly incorporates resilience aspects**. The framework should build on existing processes and be tailored to each mode to provide guidance to state, local, and regional transportation authorities. This guidance would tie directly to Federal funding for transportation infrastructure to encourage longer-term investments in resilient infrastructure.

Recommendation 2.3: The Secretary of Transportation, in coordination with the Secretary of Homeland Security, should **develop transportation system models that can accurately simulate regional transportation disruption scenarios** to help identify and understand cascading disruptions across adjoining systems, supply chains, and interdependent infrastructures. Development should **incorporate the real-world decision-making of infrastructure owners and operators, through a series of regional, national and cross-modal exercises, to improve the models' accuracy and enhance system-level visibility of risks**. Private sector engagement should emphasize the business continuity benefits of building enterprise resilience, allowing participating organizations to use the models to stress-test systems and build the business case for resilience investments.

Recommendation 2.4: The Secretary of Transportation, working with the National Institute of Standards and Technology, the American Society of Civil Engineers, and the Transportation Research Board, should **revise design standards and identify best practices that incorporate resilience attributes into the planning, construction, and operation of transportation assets** to anticipate and mitigate future risks. This effort should build on the NIST *Community Resilience Planning Guide* and the *Compendium of Codes, Standards and Guidance that Support Community Resilience*.

Recommendation 3: Operationalize Resilience

The President should direct the Secretary of Transportation, working with the White House and the Secretary of Homeland Security, to **"operationalize" national resilience policies** throughout all Department programs and activities by **translating them into guidance, programmatic practices and procedures, funding criteria, and procurement processes to help cultivate a "culture of resilience**." The Department should incorporate resilience, as a high-level performance factor, into all aspects of transportation systems programs, including research and development, training and exercises, and major capital projects.

Putting national resilience policies into operational practice will require a whole-of-Nation approach that recognizes the complexity, diversity, and fractured ownership and responsibility of the transportation

sector. The Federal Government can lead by facilitating executive-level, cross-modal coordination and incorporating resilience into funding mechanisms and decisions, Federal program actions, and Federal guidance that builds the business case for resilience investments. Here are key actions for implementing Recommendation 3:

Recommendation 3.1: The White House and the Secretary of Transportation should work with Congress to **provide definitive resilience criteria for Federal funding actions and to remedy shortfalls in Federal infrastructure investment.** Broader use of loan programs, such as the Transportation Infrastructure Finance and Innovation Act (TIFIA) and Railroad Rehabilitation and Improvement Financing (RRIF), could enhance public transportation infrastructure and support resilience in public and private systems. The White House should also **explore the use of pilot programs for innovative project financing** that would enable state and local agencies to partner with private entities on joint public-private transportation projects that advance resilience. Congressional support for public-private partnerships not only broadens funding for partnerships, but also enhances the relationship between the public and private sectors. For example, Congress could provide substantial funding for a competitive multi-modal freight infrastructure grant program, designed to mitigate resilience gaps between modes, for projects of national or regional significance. Prioritization of projects that meet resilience performance criteria could provide important public benefits while supporting private-sector competitiveness.

Recommendation 3.2: The Secretary of Homeland Security and the Secretary of Transportation should **implement a cross-modal Transportation Sector Coordinating Council as a senior executive body for addressing strategic cross-modal risks** that could cause catastrophic infrastructure disruptions. Participants might consider adopting the model used by the Electricity Sub-Sector Coordinating Council, which consists of CEO members who meet with their senior executive government counterparts from the Sector Specific Agency (e.g., Deputy Secretary of Energy or higher) and other senior agency executives. In establishing one cross-modal SCC, the agencies should also re-examine the effectiveness of each existing transportation modal sector council to determine how to more actively engage owners and operators, particularly executives. To address cross-sector priorities, representatives from the Transportation SCC should also be encouraged to participate in the Strategic Infrastructure Executive Council, a council of CEOs and senior executive decision-makers proposed by the NIAC in its 2015 report, *Executive Collaboration for the Nation's Strategic Infrastructure*. Recognizing the key roles of state and local owners and operators, the agencies should work with groups such as the National Governors Association, the National League of Cities, and the National Association of Counties to promote and strengthen transportation systems resilience, particularly on cross-jurisdictional risk issues. An examination of the collaboration model established by the Committee on Marine Transportation Systems (CMTS) could provide best practices for strengthening cross-agency and cross-modal collaboration and coordination.

Recommendation 3.3: The Department of Transportation should fund the National Academy of Public Administration **to assess government and industry best practices for implementing resilience policies within organizations and to propose appropriate actions for the Department of**

Transportation to implement this recommendation. This would help quantify resilience and establish performance metrics in administrative and executive practices.

Recommendation 3.4: The Department of Transportation should **require state, local, and regional partners to conduct a simple "resilience impact assessment" as a prerequisite for receiving Federal funding for major capital investment projects**. The assessment should identify how the proposed project will mitigate current and future infrastructure risks and advance resilience objectives. The assessment should analyze the benefits and cost of the project's resilience features, including an analysis of the "cost and risks of doing nothing." Such an assessment will help embed resilient features into built infrastructure and encourage organizations to consider resilience in business decisions.

Recommendation 3.5: The Department of Transportation, in coordination with the General Services Administration, should **conduct a study of public procurement practices for Federally funded transportation projects** to identify best practices for making resilience as a criteria for awarding grants and contracts. The study **should examine how cybersecurity and cyber resilience are reflected in the procurement process**.

Recommendation 3.6: The Department of Transportation should fund the Transportation Research Board to **work with the insurance industry and the academic community to build, test, and validate models to accurately price insurance coverage based on resilience practices and mitigation taken by owners and operators** to prepare for anticipated risks. These models could serve as planning and decision tools for guiding resilient actions by insurance companies; Federal, state, and local jurisdictions; and private-sector companies.

Recommendation 3.7: The Department of Transportation and Environmental Protection Agency should **identify safety and environmental quality regulations that could be temporarily waived to facilitate recovery following disruptions, and ensure that recovery incorporates resilience best practices**. This effort should include an examination of appropriate waivers to the Jones Act and the Hours of Service requirements within the Federal Motor Carrier Safety Regulations.

The Council also references and reaffirms its previous recommendations in these areas:

Identifying and Understanding Emerging Risks

- The President should task the NIAC to identify the highest-priority cross-sector risks affecting national security and resilience and produce a written report to the President within 18 months recommending potential executive-level, cross-sector action. (Regional Resilience, 2013)
- The President should establish the goal for all critical infrastructure sectors: No later than 2015, control systems for critical applications will be designed, installed, operated, and maintained to survive an intentional cyber assault with no loss of critical function. (Physical and Cyber Convergence 2007)
- Develop real-time cybersecurity risk analysis and management tools. Establish new architectures to "bake in" self-healing and self-protected cyber systems. Develop automated security analysis and data collection tools and methods. Understand cross-sector connections that could cause cascading effects. Measure the effectiveness of security. (R&D Study 2014)

Federal Standards and Guidance to Address Risks

- Determine design standards and best practices for replacing, upgrading, and maintaining critical infrastructure systems. (R&D Study 2014)
- The Federal Government should work with owners and operators to clarify agency roles and responsibilities for cyber security in the electricity sector, including those for cyber emergencies and highly sophisticated threats (Resilience Goals Framework 2010).

Modeling, Data, Tools, and Exercises

- Department of Homeland Security should support modeling and analysis studies of the cross-sector economic impacts of CIKR failures using tools such as input-output analysis. (Resilience Goals Framework 2010)
- Develop and integrate modeling and simulation tools. Develop, scale, and integrate interdependency and consequence modeling, and simulations to support operational decisions to predict and prevent cascading failures. (R&D Study 2014)

Strengthening Public-Private Leadership and Coordination

- The Department of Homeland Security should facilitate the development of cross-sector partnerships within selected regions to improve the region's resilience to very-large scale events that could impact national security, resilience, and economic stability. (Regional Resilience, 2013)
- The President should direct the Secretary of Homeland Security to work with the Sector Specific Agency heads for the Electricity Sub-Sector, Water, Transportation, Communications and Financial Services to establish a Strategic Infrastructure Executive Council under CIPAC, composed of CEO or Senior Executive Decision-Makers from the sectors and their counterpart agencies, to identify national priorities and develop joint or coordinated action plans and agreements to implement them. (CEO Engagement Study, 2015)

The Council also references and reaffirms its previous recommendations in these areas:

Integrating Resilience into Government Practices and Procedures

- The President should require that Federal agencies: (a) explicitly consider and address the differences among regions when promulgating security and resilience rules, programs, or guidance; and (b) expressly state how they have customized implementation to each region if there is not generic applicability. (Regional Resilience, 2013)

Promoting a Skilled Workforce to Manage Critical Infrastructure Risks

- Identify and apply best practices. Identify innovative, cost-efficient and accelerated approaches to develop a skilled workforce. (R&D Study 2014)

Building a Case for Infrastructure Investment and Resilience

- Identify and apply best practices. Identify and establish the elements for business and public justification for investments from lessons learned. (R&D Study 2014)
- Address role and impact of regulation, public policy, and consolidation within sectors on resilience and innovation. Identify essential elements of enabling policies and regulations that would encourage and facilitate owner and operator investment and gain public acceptance of such investments. (R&D Study 2014)
- The Council of Economic Advisors and OSTP should help to create a strong and enduring value proposition for investment in resilient lifeline infrastructures. (Regional Resilience 2013)
- For critical infrastructure owners and operators, the value proposition [for senior-level engagement with the government] would be to assure business and sector assets function sustainably. (CEO Engagement, 2015)
- Address role and impact of regulation, public policy, and consolidation within sectors on resilience and innovation. Research and analyze the labyrinth of regulations and policies across all levels of government that impedes and dis-incents investments in security and resilience. (R&D Study 2014)
- Identify and apply best practices. Develop an effective model of shared industry funding. (R&D Study 2014)
- Identify and apply best practices. Establish resilience metrics. (R&D Study 2014)

Moving Forward: A Sense of Urgency for Action

Urgent action is needed now to provide the necessary public funding to rebuild our transportation infrastructure that has suffered from decades of neglect. The need is stark—frequent reports highlight the vulnerability of the Nation's aging infrastructure to major disruptions. Achieving transportation resilience will require a long-term, systematic approach that must be embedded into transportation assets, structures, and operating cultures. The Federal Government needs to act now to implement the standards, tools, planning, and investment decisions that will ensure the resilience of systems decades

into the future. Important investment decisions are currently being made in the Administration and in Congress. These represent opportunities to begin and sustain the long and difficult journey ahead of us.

We believe our findings and recommendations will help guide the fundamental decisions and actions to make the Nation's transportation system efficient, safe, *and resilient.* The Council also notes that with spending on public infrastructure in steady decline, resilience is just part of the greater challenge to build and maintain a competitive, 21st-century infrastructure. Our recommendations lay the foundation for resilience to be addressed as a fundamental part of this greater challenge.

Finally, we strongly believe that support at the highest levels of government, including the Executive Office of the President, and the private sector is needed. Unless there is a shared political will across parties and partners to sustain a policy of resilience and back it with resources, the Nation's transportation system will remain vulnerable to a spiral of increasing disruption and continuing deterioration.

Appendix A: Acknowledgements

Transportation Resilience Working Group Members

Dr. Beverly Scott (Co-Chair)
CEO,
Beverly Scott Associates, LLC

Jack Baylis (Co-Chair)
President and Chief Executive Officer,
The Baylis Group, LLC
Los Angeles, California

Glenn S. Gerstell (Co-Chair)
Partner,
Milbank, Tweed, Hadley, & McCloy LLP
Washington, DC

Constance Lau
President and Chief Executive Officer,
Hawaiian Electric Industries, Inc. (HEI)
Honolulu, HI

Margaret E. Grayson
President,
MTN Government Services
Leesburg, VA

James B. Nicholson
President and Chief Executive Officer,
PVS Chemicals, Inc.
Detroit, MI

Study Group Members

Ted Basta (Chair), Chief, Strategic Business Initiatives and Innovation, Massachusetts Bay Transportation Authority, Boston, MA

Rick Houck (Vice Chair), Vice President, Enterprise Project Management, Hawaiian Electric Company, Honolulu, HI

Cherrie Black, U.S. Department of Homeland Security Program Manager and Critical Infrastructure Strategist, Idaho National Laboratory, Idaho Falls, ID

Leslie Blakey, President and Executive Director, Coalition for America's Gateways and Trade Corridors, Washington, DC

John Contestabile, Assistant Program Manager, Homeland Security, Johns Hopkins University Applied Physics Laboratory, Laurel, MD

Joan Gehrke, Consultant, PVS Chemicals Inc., Detroit, MI

Brian Kane, Director, Policy, Performance Management, and Process Re-Engineering, Massachusetts Bay Transportation Authority, Boston, MA

Catherine Melquist, Vice President, Market Development, MTN Government, Leesburg, VA

Frances Paulson, Senior Counsel, FedEx Express, Memphis, TN

Cosmo Perrone, Principal, Cosmo Perrone and Associates, Los Angeles, CA

Tamara Powell, Chief of Staff to the General Manager and MassDOT Rail & Transit Administrator, Massachusetts Bay Transportation Authority, Boston, MA

Martin Rojas, Vice President, Security and Operations, American Trucking Associations, Arlington, VA

Interviewees and Contributors

Richard Baratta, Director, Risk Management, Port of Long Beach, Long Beach, CA

Steven Bayless, Senior Director, Telecommunications and Telematics, Intelligent Transportation Society of America, Washington, DC

Chris Bidwell, Vice President, Security and Facilitation, Airports Council International – North America, Washington, DC

Ed Carbaugh, Director of Infrastructure Security and Facility Security Officer, Norfolk Southern Corporation, Norfolk, VA

Scott Cooper, Transportation Security Administration, U.S. Department of Homeland Security, Washington, DC

Benjamin De Alba, Assistant Secretary for Rail and Ports, California state Transportation Agency, Sacramento, CA

Michael Dinning, Director, Transportation Logistics and Security Technical Center, Volpe National Transportation Systems Center, U.S. Department of Transportation, Cambridge, MA

Mortimer Downey, Senior Advisor, Parsons Brinckerhoff, Washington, DC

Thomas Farmer, Assistant Vice President of Security, Association of American Railroads, Washington, DC

Paul Feenstra, Senior Vice President, Government and External Affairs, Intelligent Transportation Society of America, Washington, DC

Stephen Flynn, Director, Center for Resilience Studies, Northeastern University, Boston, MA

Stephen Godwin, Director, Studies and Special Programs Division, Transportation Research Board, Washington, DC

William Golden, Executive Director, National Institute for Coastal and Harbor Infrastructure, Boston, MA

Jeremy Greenberg, Program Manager, National Response Program, U.S. Department of Transportation, Washington, DC

Steve Heminger, Executive Director, Metropolitan Transportation Commission, Oakland, CA

Joshua Holtzman, Director, Office of National Security Programs and Incident Response, Federal Aviation Administration, Washington, DC

Daniel Kane, Manager, Emergency Management, Port of Long Beach, Long Beach, CA

Richard Larrabee, Director, Port Commerce Department, Port Authority of New York and New Jersey, New York, NY

Robert Lee; Deputy Director; Office of Intelligence, Security and Emergency Response, U.S. Department of Transportation, Washington, DC

Donald Lumpkins, Director, National Integration Center, Federal Emergency Management Agency, U.S. Department of Homeland Security, Washington, DC

Greg Maier, Chief Information Security Officer, Office of Information Technology, Transportation Security Administration, U.S. Department of Homeland Security, Washington, DC

Deborah Matherly, Principal Planner, The Louis Berger Group, Baltimore, MD

Michael Meyer, Consultant, Parsons Brinckerhoff, New York, NY

William Minear, Director, Infrastructure Protection Program, West Virginia Intelligence Center, Charleston, WV

Jeff Morales, Chief Executive Officer, California High-Speed Rail Authority, Sacramento, CA

Patricia Mutschler, Executive Secretariat, Committee on the Marine Transportation System; U.S. Army Corps of Engineers Liaison to U.S. Coast Guard, Washington, DC

Drew Orndorff, Acting Associate Chief Information Officer and Chief Information Security Officer, U.S. Department of Transportation, Washington, DC

Chris Oswald, Vice President, Safety and Regulatory Affairs, Airports Council International – North America, Washington, DC

Stephan Parker, Senior Program Officer, Transportation Research Board of the National Academies, Washington, DC

John Porcari, Senior Vice President and National Director of Strategic Consulting, Parsons Brinckerhoff, Washington, DC

Dana Reynolds, Deputy Director, Division of Homeland Security and Emergency Management, Colorado Department of Public Safety, Centennial, CO

Ivin Rhyne, Manager of the Supply Analysis Office, California Energy Commission, Sacramento, CA

Jennifer Roberson, Program Manager for Training and Exercise, U.S. Department of Transportation, Washington, DC

Peter Rogoff, Under Secretary of Transportation for Policy, U.S. Department of Transportation, Washington, DC

Julie Dean Rosati, Program Manager, Coastal Inlets Research Program, U.S. Army Corps of Engineers, Mobile, AL

Adam Rose, Research Professor, Sol Price School of Public Policy, and Coordinator for Economics, Center for Risk and Economic Analysis of Terrorism Events, University of Southern California, Los Angeles, CA

Michael Rush, Senior Vice President of Safety and Operations, Association of American Railroads, Washington, DC

Gordon Schremp, Senior Fuels Specialist, California Energy Commission, Sacramento, CA

Stephen Sullivan, Managing Director, R.L. Banks & Associates, Washington, DC

Donald Synder, Director of Business Development, Port of Long Beach, Long Beach, CA

Michael Taborn, Senior Consultant, Boyd, Caton & Grant Transportation Group Inc., Earlysville, VA

Jill Taylor, Manager, Homeland Security, Port of Los Angeles, Los Angeles, CA

Andrew Tucci, Chief, Office of Port and Facility Compliance, U.S. Coast Guard, Washington, DC

Vinn White, Senior Policy Advisor, Office of the Secretary, U.S. Department of Transportation, Washington, DC

Department of Homeland Security Study Support Resources

Jack Eisenhauer, Nexight Group

Jim Carey, Nexight Group

Kate Finnerty, Energetics Incorporated

Lindsay Kishter, Nexight Group

Martin Lasater, Energetics Incorporated

Keeley McCoy, Energetics Incorporated

Bradley Sinkaus, Nexight Group

Corey Thompson, VetFed, Inc.

Andrea Gagliardi, VetFed, Inc.

Appendix B: The Resilience Challenge: Key Aspects of the Problem

The NIAC engaged a variety of transportation experts for the purpose of this study, conducting dozens of interviews with national leaders in transportation resilience and regional, state, and local subject matter experts in transportation systems, state and local cross-jurisdictional coordination, cross-modal integration and management, and the planning and operation of infrastructure assets. The sections below present an analysis of recurring themes. The information collected from the interviews and open-source research were synthesized into four categories:

I. Transportation Risks
II. Infrastructure Investment and Funding
III. Policies and Practices
IV. Leadership and Coordination

I. Transportation Risks

The scale, scope, and diversity of the Nation's transportation system creates the need for effective risk management to successfully confront the broad range of challenges it faces. Four factors contribute to the complex risk environment faced by the Nation's transportation systems:

- Limited understanding of the risks created by sector interdependencies in tightly integrated and networked regional systems
- Limited redundancy and critical points of failure
- Limited intermodal, cross-sector, and cross-jurisdictional coordination of regional systems
- Poor ability to address emerging risks such as aging infrastructure, extreme weather and rising sea levels, workforce deficiencies, and cyber attacks

Limited Understanding of Risks Present in Interdependent Infrastructures

As regional transportation systems and global supply chains have become tightly optimized for efficiencies, they have wrung out much of the excess capacity and ended up weaving together new interdependencies and vulnerabilities that are not well mapped. The components of our transportation networks are highly interconnected across modes, but also with other critical sectors within each region. Lifeline sectors—transportation, energy, communications, and water—provide indispensable services to nearly all other infrastructures, but in particular to each other, creating dependencies and risks that individual operators cannot clearly anticipate.

The growing complexity of cross-sector interdependencies creates hidden risks within regional and national infrastructures that may not be revealed until a major disaster hits. In the aftermath of Superstorm Sandy, unforeseen and severe shortages of liquid fuels in New Jersey exposed the government's limited understanding of the intricacies of the supply chain. The shortage cascaded to

other lifeline sectors and delayed restoration: without a steady source of gasoline and diesel for utility vehicles, repair crews were slowed in their ability to repair downed power lines that were needed to pump fuels at local service stations. These types of hidden risks were highlighted in our 2013 NIAC report *Strengthening Regional Resilience.*

Interdependencies with other lifeline infrastructures are inherently regional, requiring a region-wide approach to understanding how different modes and sectors interconnect, and planning how individual operators react during disruptions. This creates a challenge for operators and stakeholders that are organized along local, state, and Federal jurisdictions. System-wide visibility is crucial for accurately measuring and managing risk throughout the transportation system.

Examples of dependencies and interdependencies with the Transportation Systems Sector are:

- Major ports such as the Port of Los Angeles and Port of Long Beach. These gateway ports rely on smooth interdependent relationships between the energy sector (fuel and electricity), the water sector (flood control, sewage, and drinking water), the rail and highway modes (moving cargo into and out of the ports), the maritime mode (bringing and taking cargo across the ocean), commercial facilities (terminal buildings and warehousing), financial services (banking transactions and insurance), IT and communications (coordination and data processing), food and agriculture (produce to export), and other sectors. Also, port operations themselves are dependent upon agreement between labor unions and port management so that work can progress smoothly on the docks.
- Pipelines, natural gas, and electricity. The aging of coal generation units, the retirement of certain nuclear units, and the increased availability and low price of natural gas for electric generation in many parts of the United States is presenting operational challenges in that pipeline congestion can result in interruptions of gas deliveries.
- Railroads and crude oil. With the opening up of new reserves in North America, the shipment of crude oil by rails has increased dramatically over the past few years. In large measure, this is due to the lack of crude oil pipelines running north to south across the Midwest: one of the drivers for consideration of the Keystone XL Pipeline project. However, the increased use of rails for crude oil shipment has resulted in fewer opportunities for northern plains grain producers to ship their crops by rail and in greater expense for them to ship grain to barges on inland waterways. Moreover, data from the Pipeline and Hazardous Materials Safety Administration has shown that, in 2013, more oil was spilled from trains than in the previous four decades combined.[6]
- Fuel and electricity. The 2013 NIAC study *Strengthening Regional Resilience* uncovered many examples of interdependency that surfaced in the aftermath of Superstorm Sandy. Power outages to pipeline pumps and fuel terminals that could then no longer accept fuel forced the northern part of the Colonial Pipeline to shut down, effectively cutting the region off from a 2.4 million-barrel-per-day supply of petroleum. Without power, several refineries were unable to

[6] Curtis Tate, "More oil spilled from trains in 2013 than in previous 4 decades, federal data show," *McClatchy Washington Bureau* (January 20, 2014).

refine fuel for the region, receive fuel, or access their existing supply of fuel for supply and distribution. Also, without commercial power, even well-stocked gasoline service stations were unable to pump fuel to customers. Service stations with power quickly depleted resources as demand rose, and suppliers experiencing power outages or infrastructure damage could not refuel them.

- Some dependencies, such as on liquid-fuel supplies, have repeatedly been shown to be major barriers to response and recovery. Despite this, there appears to be little progress in risk reduction, due in large part to underlying complications. For example, even if potential fuel supplies seem to be available, factors such as fuel specifications, taxation issues and other jurisdiction-related conditions may inhibit fuel delivery.

In general, while these dependent or interdependent relationships are increasingly recognized, there appears to be a comparative lack of understanding of the underlying dynamics. System-wide analysis – based on reliable data sets of sufficient depth and breadth – is needed to elucidate the root causes of weakness and identify risk-management actions to mitigate them.

Owners and operators often lack the tools that draw upon real-world experience to model "what if" scenarios and simulate how cascading disruptions play out within a particular region. One of the challenges in mitigating disruptive risk is not just understanding the systems themselves, but also the many forces that can act on those systems. Practitioners need models that are geographically and functionally accurate from a systems engineering standpoint, yet also protect proprietary data and sensitive information about system operations. While input-output models can help us to understand the national economic impacts of certain types of disruptions, regional models lack the granularity to accurately simulate the flow of people and passengers that can reveal hidden risks and gaps in resilience. Even with such tools, however, there is limited understanding of the complex decisions made at the local, state, regional, and national levels as an event unfolds. Creating effective models and tools requires a coordinated effort to collect regional systems data from owners and operators, many in the private sector.

As a result, today's models often lack the ability to account for behavioral, regulatory, and human factors that affect decision making at the local level, where mapping of supply chains and cascades is incomplete. Because of the potential consequences to communities, Achieving system-wide visibility should be a government activity. The public sector will need to drive model development and engagement with owners and operators to acquire the necessary data for regional models. Even without detailed regional data, we can use models to analyze impacts at the national level to assess the effects of long-term, disruptive risks.

Limited Redundancy and Critical Points of Failure

Transportation system optimization reduces redundancy and may create critical choke points within regions. Risk mitigation efforts need to prioritize the maintenance of service continuity at intermodal transportation hubs, particularly in major metropolitan areas. These locales have the potential to become single points of failure due to the number of transportation services that would be incapacitated in a disruption. These can be large, multi-modal transportation hubs, such as coastal ports,

but also key bridges or tunnels in high-traffic regions, such as the North River Tunnels beneath the Hudson River that Amtrak and New Jersey transit trains use between New Jersey and Manhattan. For the first time in a hundred years, one of the tunnels flooded during Superstorm Sandy, and last year, Amtrak CEO Joe Boardman indicated that the tunnels had less than 20 years before one or both would need to be shut down.

Other examples of possible single points of failure within the Transportation Systems Sector are:

- The Federal GPS satellite navigation system, which – if it were substantially disrupted – could have serious impacts across all modes of transportation. As noted in testimony to Congress in February 2014: "In 2009, authorities at Newark International Airport noticed that a newly installed landing system would periodically malfunction, but were at a loss to explain why. After two years of effort by the airport, the FAA and the FCC, they finally traced the problem to a man with a GPS jammer regularly driving past the airport on I-95. The driver had purchased the inexpensive and illegal jammer on line and was using it to keep his employer from tracking his movements each day.[7]"]
- The Portal Bridge crosses the Hackensack River halfway between Manhattan and Newark. Some 450 trains carrying more than 150,000 riders a day pass over the century-old bridge, which is in desperate need of replacement at the cost of an estimated $900 million. Amtrak President and CEO Joe Boardman says the bridge is the busiest in the Western Hemisphere and is critical to the U.S. economy, yet it is the "Achilles heel that we have on the Northeast Corridor….when a train stacks up here, it can stack up all the way down to Washington and all the way back up to Boston. This is a single point of failure.[8]"
- For the Ports of Los Angeles and Long Beach, the Henry Ford/Badger Avenue Bridge across the Cerritos Channel provides the only railroad link to Terminal Island from the mainland, feeding directly into the Alameda Corridor. It runs parallel to the Commodore Schuyler F. Heim Lift Bridge, which carries trucks and automobiles into and from the ports.[9] Should this bridge be closed and freight rail traffic be denied access to the ports, an essential link in the intermodal transportation and delivery of transcontinental freight loaded into marine cargo containers would be disrupted.
- The Ambassador Bridge across the Detroit River is part of the Detroit-Windsor Corridor. More than 10,000 vehicles traverse the family-owned bridge every weekday. It is North America's busiest international border crossing in terms of both traffic and trade volume. With the two countries being each other's largest trade partner, a quarter of all trade between the U.S. and Canada passes through this border crossing. In February 2015, the United States, Canada, and

[7] U.S. Congress, House of Representatives. Testimony by Dana A. Goward to House Transportation Committee, Subcommittee on Coast Guard and Marine Transportation, Hearing on "Finding Your Way – the Future of Federal Aids to Navigation," (February 4, 2014).

[8] Joe Boardman, interview on CBS News, 60 Minutes (November 23, 2014).

[9] Port of Los Angeles (POLA), "CA-103 Commodore Schuyler F. Heim/Henry Ford Bridge."

the State of Michigan signed an arrangement regarding a proposed New International Trade Crossing (NITC) linking the two cities.[10]

While many potential single points of failure are well known, the actions required to mitigate the associated risk may not be well understood. Until this is addressed, both the potential loss of service and the likely extensive time frame for restoring service will remain critical shortfalls in resilience.

Resilience strategies take many forms. In addition to building redundancy, "substitutability," in which alternative services are used to accomplish the same outcome, can help prevent disruptions from cascading to other parts of the transportation system. The degree that one facility or asset can be substituted for another is a key factor when examining dependencies in the transportation sector. For example, when flooded subway tunnels forced the suspension of trains between Brooklyn and Manhattan during Sandy, the MTA ran "bus bridges" as a replacement service along this key route. Substituted services offer functional redundancy and enable transit continuity while damaged assets are restored. Cross-modal substitution must consider all functions, however. In the event of a major disruption of the San Francisco Bay Bridge, for example, public transit can provide an effective substitute for the movement of people, but not the shipment of goods.

Limited Intermodal, Cross-Sector, and Cross-Jurisdictional Coordination of Regional Systems

Regional coordination is imperative as control over the transportation system is highly fractured. Without effective coordination, logical decisions made by independent system components or jurisdictions could ultimately exacerbate an initial disruption or delay recovery on a regional scale. For example, schools often serve as shelters for displaced people following natural disasters, but a crucial part of the larger regional recovery includes getting kids back to school as quickly as possible.

Planning for resilient strategies and rapid recovery at a regional scale requires pre-disruption coordination among highly disparate groups that may not have traditionally partnered in the past. Regional stakeholders must work not only across modal, sector, and jurisdictional divisions, but also across fields of study. Engineers, long-range system planners, and capital investors must now coordinate with first responders and emergency operations personnel to determine the requirements of a resilient infrastructure and bake resilience capabilities into the built infrastructure and into operations and management strategies.

FEMA Administrator William Craig Fugate emphasizes a "whole community" approach to planning. Our interviews echoed this sentiment. Intermodal and cross-sector planning and coordination are crucial in responding to and mitigating disruptions. When the San Francisco Bay Bridge was closed for repairs, for example, transportation officials developed multimodal contingency plans that were widely publicized well before the closure, successfully preventing an extended period of confusion and traffic congestion. Even without the benefit of foresight, the transportation sector effectively uses advance coordination

[10] Detroit Historical Society, "Ambassador Bridge," in *Encyclopedia of Detroit*; and DHS, "DHS Announces New International Trade Crossing" (February 18, 2015).

within modes to enable resilient response to multiple hazards. For example, the speed with which the FAA handled the fire set as an intended suicide at a control center outside of Chicago in September 2014 reflected efficiency, adaptability, and quick response on the part of the air traffic controllers, who evacuated the affected facility and issued a ground stop on all flights bound for Chicago airports, including O'Hare and Midway.[11,12]

Poor Ability to Address Emerging Risks

One expert asserted that our infrastructure was built for a different reality to safeguard against high-risk, low-probability events that have now evolved into high-risk, inevitable events. The Nation is facing a set of emerging risks that one expert called the "triple threat:" rising sea levels, extreme storms, and aging infrastructure. The greater frequency by which these events and other risks are occurring necessitates the incorporation of resilience into design standards, long-term planning, and planned investments. Yet in the last decade, several risk factors have outpaced the abilities of the transportation systems workforce and built infrastructure to respond.

II. Aging Infrastructure

Following World War II, the United States jumped ahead of the world in creating advanced infrastructure, but much of that infrastructure has since deteriorated over time with insufficient will to re-invest, particularly in transportation. A majority of the Nation's roads are in less than good condition, and a quarter of our Nation's bridges are in need of repair.[13] The Federal gas tax is no longer sufficient to sustain the Highway Trust Fund, and as a result, surface transportation needs a long-term commitment from Congress to sustain infrastructure for the future. The risks posed by aging infrastructure are not limited to the transportation systems sector: the U.S. electric grid loses power 285 percent more often than it did in 1984, according to DOE data.[14] Blackouts can cause up to billions of dollars in economic losses[15], including debilitating transportation networks dependent on electricity.

Rising Sea Levels and Extreme Weather

Coastal flooding is both a security and economic threat to our transportation system. There are at least 12 U.S. international airports at risk for coastal flooding[16], in addition to several chokepoints in the Northeast Corridor where flooding could disrupt multiple modes of transportation simultaneously. In

[11] Alex Davies, "A Single Fire Can Cripple America's Aging Air-Traffic System. Here's Why," *Wired* (September 30, 2014).
[12] Chandrika Narayan, Ted Rowlands, and Ralph Ellis, "Air travel still hobbled after Chicago fire," *CNN* (September 29, 2014).
[13] DOT. *Beyond Traffic* (2015).
[14] Meagan Clark, "Aging US Power Grid Blacks Out More Than Any Other Developed Nation," *International Business Times* (July 17, 2014).
[15] DOE. *The Smart Grid: An Introduction* (2008).
[16] Andrew Freedman, "U.S. Airports Face Increasing Threat from Rising Seas," *Climate Central* (June 18, 2013).

2010, 39 percent of our Nation's population resided in counties directly on the shoreline, with that number expected to rise by 8 percent by 2020.[17]

Cybersecurity and Cyber Mechanical Systems

Cybersecurity has become a foremost area of concern across all modes of the transportation sector. Especially worrisome has been the growing role of industrial control systems that are used to remotely monitor and/or control critical, sensitive processes and physical functions. In the sector, these systems include supervisory control and data acquisition (SCADA) systems, distributed control systems, programmable logic controllers, and general-purpose controllers that are increasingly becoming interconnected. These computer-based systems monitor the system environment and control physical objects and devices such as switchgears, message signs, and valves. If they are disrupted or fail, lives, property, and services are at risk.[18] One example is ports, where networked systems undergird port operations, but no cybersecurity standards for U.S. ports have been promulgated.[19]

The Nation's transportation networks – while highly varied in form, assets, and operations – none-the-less all rely on cyber systems to varying degrees. While some modal assets and operators are highly sophisticated with respect to identifying and managing cyber threats, it appears that the majority are unprepared to function effectively and safely in a world of proliferating cyber threats. In all too many cases, these systems were not originally designed to work in a connected environment, as they may be decades old, employ common and open-source sets of coding and structure, and may have originally operated as stand-alone systems. In addition, the operating personnel responsible for them may not have the requisite cyber expertise. While today most people are familiar with the threats to "enterprise" systems, those that mange money, personal data, and consumer transactions, few are aware of the potential threats to control systems. Where the threats *are* recognized, the resources – human and capital – do not appear to be available to address them.

The transportation systems sector is keenly aware of cyber threats to the system, yet generally lacks the knowledge, experience, and workforce to foster cyber resilience. As in many other sectors, cybersecurity expertise is not within the core competency of a typical transportation agency, making the field a new territory for operators. In many cases, the transportation workforce does not have the cyber systems expertise and capability to design secure systems and mitigate cyber attacks.

Workforce Deficiencies

Resilience is an emerging field, and creating the cultural shift will require investing in a workforce that is aware of resilience principles and practices. At the same time, employees who have worked in the transportation industry for decades are retiring, leaving behind a knowledge and experience gap that the new workforce is unable to account for without proper training. Finally, the transportation system is

[17] DOC, NOAA, National Ocean Service, "What percentage of the American population lives near the coast?"
[18] Transportation Sector Working Group, *Roadmap to Secure Control Systems in the Transportation Sector* (2012).
[19] Joseph Kramek, *The Critical Infrastructure Gap: U.S. Port Facilities and Cyber Vulnerabilities* (2013).

becoming increasingly dependent on digital operations and control, requiring a highly skilled workforce of system operators and cybersecurity professionals who understand cyber threats.

Transportation system are accelerating, and there is a considerable amount of uncertainty associated with the risk evolution. Without good data that allows practitioners to understand disruptive risk going forward, it is difficult for entities to devise market tools for creating incentives, and it is increasingly difficult to develop the mitigation measures themselves. The government can play an important role in developing analytical tools that allow us to project risks against real infrastructure so that owners and operators can make informed decisions and develop accurate cost-benefit analyses for investment.

III. Infrastructure Investment and Funding

Transportation infrastructure has been chronically underfunded. Experts estimate $13 billion more per year is needed to maintain highway and transit systems and reduce the risk posed by aging infrastructure.[20] Peter Rogoff, Under Secretary for Policy at the Department of Transportation (DOT), has said we are facing a "new normal" of risks for our transportation system, and we need to adjust our current funding mechanisms accordingly. However, several key factors have biased investment decisions *against* resilience:

- Disaster recovery policy creates disincentives to invest in resilience.
- Aging infrastructure and gaps in investment
- The inability to monetize the benefits of resilience leads to least-cost investment decisions.
- A lack of political will to invest now for future returns postpones public spending until after a disaster.
- Insurance may create the right incentives for infrastructure investment.

Disaster Recovery Policy Creates Disincentives to Invest in Resilience

There are no effective public funding mechanisms to encourage or require resilient infrastructure designs; in fact, the opposite may be true. The level of Federal assistance provided to disaster-affected regions under the Stafford Act is not only unsustainable, given the rising cost and frequency of major events, but creates unintended disincentives to mitigate infrastructure risks. Title IV of the Stafford Act allows Federal administrators to cover up to 75% of the restoration bills for eligible facilities, provided that the community implements measures that will address future disasters of a similar nature. In the event that State and local governments fail to implement sufficient hazard mitigation measures, the Federal Government still has provisions to pay for up to 25% of restoration costs. Why should communities invest in infrastructure improvements if the Federal Government has appropriated funds for communities that do not prioritize resilience?

Emergency relief funds should be only supporting recovery from disasters above and beyond expected risks. For this to happen, transportation agencies—as a matter of due course—should be assessing their asset risk, assigning a value to that risk, and making insurance or infrastructure investments to

[20] Ken Orski, "Needed: A Fresh Approach to Funding America's Infrastructure," *GovTech,* (February 20, 2015).

reasonably mitigate it. There is an opportunity for the Federal Government to create incentives for risk mitigation by awarding a lower percentage of disaster relief funds unless the community can demonstrate it has taken reasonable steps to improve resilience based on expected risks. Yet many jurisdictions often must inventory and value their public assets in a hurry after a disaster to derive an accurate cost estimate and request for recovery funds—which indicates an inability to monetize the cost of risk and benefits of resilience.

Aging Infrastructure and Gaps in Investment

An undeniable challenge is the gradual aging of the national infrastructure, an issue highlighted every four years by ASCE in its Report Card series. The *2013 Report Card for America's Infrastructure* gave America's infrastructure an overall grade of D+ and estimated that it would cost $3.6 trillion in investments by 2020 to keep up with expanding needs for infrastructure repair and improvement.[21] In its analysis, ASCE found that major investments are required in all the transportation modes, especially aviation, bridges, inland waterways, urban highways, and mass transit.

Infrastructure Investment: Public vs. Private Contributions

The two major U.S. infrastructure booms of the 20th century—throughout the Great Depression and during the 1950s and '60s—saw significant public investment in infrastructure, exemplified by projects as sizable as the Hoover Dam and as extensive as the Eisenhower Interstate Highway System.

In the period since, public infrastructure investment as a share of GDP has declined, and the United States is now spending less on infrastructure than at any point in the last 20 years, with this drop in investment generating a $1.7 trillion deficit in transportation infrastructure investment.

In contrast, private infrastructure investment has steadily increased in the U.S. since the 1980s, when transportation, energy, and other infrastructure industries were largely deregulated after it became increasingly difficult for governments to provide funding. Today, transportation modes such as rail and pipelines are almost entirely privately funded. As of 2012, private infrastructure investment in the U.S. is five times larger than non-defense public infrastructure investment. That year, private infrastructure investment was $2 trillion, compared to Federal, state, and local government investment of $367 billion (excluding defense).

While President Obama's FY 2016 Budget calls for $478 billion in infrastructure investment over six years, the American Society of Civil Engineers estimates that $3.6 trillion dollars is needed by 2020 to sustain America's infrastructure, and even with current spending levels, the Nation's surface transportation systems face a funding gap of about $94 billion a year.

Sources: "America's transport infrastructure: Life in the slow lane," *The Economist* (April 28, 2011); "America's crumbling infrastructure: Bridging the gap," *The Economist* (June 28, 2014); ASCE, *2013 Report Card for America's Infrastructure*; ASCE, *Authorization of the Nation's Surface Transportation Program: A Blueprint for Success,* (2013); Rodrigue et al., "The Financing of Transportation Infrastructure," (2013); Schwartz, "Remarks Prepared for Delivery at Third Way & The Atlantic's Infrastructure 2.0 Panel," (2013); U.S. Congress, Testimony by Chris Edwards to the Committee on Finance (July 24, 2013); U.S. Congress, Testimony by Jayan Dhru to the Committee on Finance, (May 6, 2014); U.S. OMB, "Fiscal Year 2016 Budget Overview." *The Budget.*

The gap between transportation expenditures (e.g., building, operating, and maintaining publicly owned transportation facilities, as well as implementing public policy in such areas as safety and security) and revenues (primarily user taxes and tolls) has widened from around $50 billion in 1995 to more than $87

[21] ASCE, *2013 Report Card for America's Infrastructure.*

billion in 2009. In 2009, transportation revenues covered only about 64 percent of expenditures—a gap that can be filled only by general tax receipts (sales and property taxes) and by borrowing. The President's FY 2015 request for the Department of Transportation is $90.9 billion. It includes the President's plan for a four-year $302 billion surface transportation reauthorization proposal.[22]

Compared to our international counterparts, the U.S. is investing significantly less in transportation infrastructure. Currently, the U.S. allocates 2.4 percent of GDP to infrastructure (transport and water) spending, compared to Europe at 5 percent and China at 9 percent of GDP. While the U.S. invested approximately the same amount of money on roads as Sweden, nations such as Australia and Canada spent approximately two and half times more money than the U.S. on roads in 2011. Also, there is a distinct divergence in the investment patterns of privately owned and operated systems versus their public analogs. Over the past decades, in contrast to public investment that has steadily declined, private investment has steadily increased, as seen in the rail and pipelines modes.

Inability to Monetize Resilience Benefits Leads to Least-Cost Investment Decisions

Without the ability to appropriately monetize or quantify the value of resilience investments, transportation agencies have little choice but to approve the least-cost solution, which likely removes resilience features from the project. One expert recalled a state that was in the early stages of redesigning a road in a coastal area. During the value engineering portion of development, resilience improvements to better prevent future flooding were taken out due to cost. In this case, the cost-benefit analysis likely did not assign an accurate cost to the threat of flooding, given its likelihood over the life of the road, nor did it assign an accurate value to the benefits of the resilient features. Resilience benefits extend beyond the avoided cost of repairs to include the public safety and economic benefits of reduced disruptions.

Owners and operators lack the data, tools, and guidance to accurately measure the lifecycle risks of their existing and planned assets and assign an appropriate value to the benefits of resilience improvements. System planners are being asked to examine risks the transportation infrastructure will face decades into the future, where the effects of climate change are uncertain. While transportation agencies may adopt resilience policies in name, they struggle to make the business case to follow through.

Lack of Political Will to Invest Today for Future Returns

As a nation, we have consistently lacked the political and social will to make capital investments in infrastructure that may not pay off for decades, particularly when they are designed to mitigate risks that may never materialize. Experts frequently cite an average four-fold return on capital infrastructure improvements made before anticipated disasters, yet our infrastructure continues to fall into disrepair. One expert called the reluctance to invest without short-term returns "the disease of the public sector."

[22] DOT, *Budget Highlights: Fiscal Year 2015*, 3.

States and regions are now working to design coordinated long-term investments with multiple benefits across the risk spectrum that generate far greater than a 1:4 return. For example, the Metropolitan Transportation Commission (MTC) in San Francisco has been planning for earthquakes, performing seismic retrofitting, and protecting the rail infrastructure for decades, as the city was born of disaster. Considering San Francisco International Airport is one of the twelve U.S. airports vulnerable to rising sea levels, it would not be a stretch to examine what could be done as part of the same infrastructure projects to reduce the risk of flooding. The challenge intensifies, however, when in cities, states, and regions that are not as familiar with long-term risk planning.

The business case for resilient infrastructure may grow as risks emerge and intensify. One resilience expert pointed to the surge barrier constructed on the Thames River in London as a model for coastal cities in the United States. Since its inception, the London surge barrier has been used roughly 140 times, and over 40 of those cases have been in the last two years. Following Sandy, Mayor Bloomberg suggested a surge barrier for New York, though the idea was ultimately discarded due to feasibility and cost.

Resilience investments may also become more attractive when communities can successfully design projects to reap multiple economic benefits. Following a Superstorm in Holland, the country put together a "Waterworks Commission," a single agency to examine potential efforts to prevent further damage from similar storms. The constructed surge barrier was converted into a highway and connected two underdeveloped areas of the country, creating tremendous economic development. Framing infrastructure investments as positive economic and community developments could foster consensus around spending more money to invest for the future.

Insurance May Create the Right Incentives for Resilient Infrastructure Investment

Combining policy and regulatory tools with other market drivers, such as disaster insurance plans, can create the right incentives to change investment behavior. Many experts we interviewed identified the opportunity to integrate resilience measures into the requirements for Federal and state grants, capital investments, and disaster relief funding. Requiring agencies and companies to obtain catastrophic insurance on a portion of their assets before receiving government funds may create economic incentives for resilience improvements.

Before Superstorm Sandy, the Metropolitan Transportation Authority (MTA) in New York had a substantial amount of insurance that aided recovery. Following the storm, the MTA found it difficult to re-insure its assets at a price the agency could afford. To confront this challenge, the MTA purchased a "catastrophe bond," an insurance product built around a parametric trigger or storm surge at a specific level. For instance, if the storm surge reaches 8 feet at Battery Park in Manhattan, the insurance bond pays out immediately. This coverage not only supports rapid recovery, it provides strong financial incentives for the transit agency to invest in measures that mitigate the threat up to that threshold. This type of insurance policy encourages a number of benefits:

1) It helps owners and operators focus on assessing and mitigating real risk, as opposed to political or other kinds of risk.
2) Insurers almost always compel the use of mitigation measures to receive a reasonable price.
3) Insurers are able to make resources available quickly following a disaster to expedite recovery.

IV. Policies and Practices

Transportation policy and practices need to evolve from a disaster-relief centric model to one that emphasizes agile operations and resilient design and repair. The national shift in thinking over the last decade from infrastructure *protection* against specific threats to infrastructure *resilience* for evolving risks has been a gradual process driven by policy changes and national plans. While national policies for infrastructure resilience such as PPD-8 and PPD-21 have framed the need, achieving resilience requires significant changes in asset management and in the organization and operations of transportation agencies at the Federal, state, and local levels. This is no small feat. Yet key revisions in policies and operational practices could accelerate the integration of resilience and help put concepts into practice:

- A comprehensive national vision for resilience in the transportation systems sector could accelerate the operational sea change in transportation management that resilience requires.
- Long-term, lifecycle planning and a strong business case for pre-event spending are required.
- Resilient design and engineering practices must be determined in advance of adverse events to enable strong rehabilitation.
- Policies can help incorporate resilience concepts into existing asset management practices.
- Regions need to identify and address regulations that unintentionally hamper resilience efforts following a disruption.

A Comprehensive National Vision

National policies such as PPD-21 and EO 13636, and frameworks such as the *National Freight Strategic Plan* and DOT'S *Beyond Traffic*, created the high-level guidance and concepts to make resilience a top priority for transportation agencies and owners and operators. Yet these policies do not create a unified national vision for what resilience looks like in the transportation systems sector. What constitutes resilience in aviation may differ greatly from what resilience means for freight and passenger rail. A national vision for cross-modal incorporation of resilience in the sector is needed.

Achieving resilience requires thoughtful coordination and innovation across modes and sectors on all infrastructure management aspects: regulation, planning, engineering, design, operations, maintenance, and emergency response. Responsibility for the transportation system is divided across multiple agencies; there are 30 Federal agencies and offices engaged with marine transportation alone. Federal and state agencies lack the organizational structure, resilience knowledge, and capacity to put current policy into action.

Over the past few years, many recommendations have been made without a specific plan for implementation, nor a lead agency to provide guidance across the board. One transportation expert suggested that the Department of Transportation (DOT) should be the lead entity on transportation

resilience, with designated groups within DOT handling long-term issues and providing focus for all agencies within the department.

Incorporating Resilience into Lifecycle Planning and Design

There are far more cost-effective opportunities to bake resilience into system designs than to retrofit transportation systems to meet evolving risks. Transportation assets are planned with 50-year lifecycles or more, making today's capital investments a key determining factor in the resilience of the transportation sector for decades to come. The benefits of more resilient designs over the lifecycle of a transportation asset should be an equally important element during engineering and design decisions as construction and maintenance costs. The lifecycle risks of extreme weather, rising sea levels, and storm surge need to be factored into a cost-benefit analysis of the transportation infrastructure built today.

Integrating resilience considerations as a routine part of project planning will take a cultural shift, but will prove more cost-effective over time. Achieving a handicapped accessible built environment once seemed a herculean task; now it is simply another design principle. Developing resilient design standards and practices will require coordination by engineers, planners, operators, and emergency responders. For example, as a direct result of subway flooding, the transportation sector rapidly designed rudimentary covers for subway grates to minimize flooding during a storm. The larger challenge will be to integrate that need back into future system design. As the Community Resilience Planning Guide from the National Institute of Standards and Technology (NIST) states, "resiliency solutions for new and future construction should start in the project planning phase."

Identifying Resilient Design and Engineering Practices in Advance of Funding

State agencies that received Federal disaster relief funding after Sandy began questioning the logic of restoring damaged assets to the pre-existing design and condition, as the Stafford Act legislation required. (Following Hurricane Katrina in 2005, FEMA even instructed the New Orleans Regional Transit Authority to purchase twelve-year-old buses to meet this rule. After the rule was changed, FEMA provided the RTA with $44 million for new buses.[23]) Infrastructure planners recognized the unique if unfortunate opportunity the disaster provided to build in more resilient technologies and designs during rehabilitation. "Rebuild stronger" became a cultural catchphrase. It led to the passage of the Sandy Recovery Improvement Act of 2013, a significant legislative change to the way FEMA delivers disaster relief funds and how they can be used.

Disasters, however, provide an extremely short window of opportunity. System planners need to understand what a resilient design looks like long before they are in the position to rebuild. They will miss opportunities to invest smartly if resilient design standards, engineering practices, and long-term system asset improvement plans are not already in place.

[23] "New Orleans Getting New Biodiesel Buses," *Automotive Fleet* (October 11, 2008).

Individual transit agencies find it difficult to determine effective actions to address the potential effects of climate change and sea level rise. When replacing assets and building new system protections, transportation agencies and companies lack the data to determine what designs will be sufficient for the next 50 years of risks. This is an opportunity for the Federal Government to step in and provide the scientific and engineering data, analysis, and guidance to help owners and operators understand and manage emerging risks.

Integrating Resilience Concepts into Asset Management

Transportation system resilience is not merely about having the right assets in place; it is how those assets are managed. While public infrastructure improvements primarily focus on capital projects, asset operations and management play an equal role in determining system continuity and recovery from disruptions. Building decisions and actions into asset management that cultivate resilience requires fundamental operational and cultural changes for system operators.

State DOTs and transit agencies are required through MAP-21 to have a performance-based asset management system. This requirement provides an excellent platform to integrate resilience concepts and practices into the transportation system in a meaningful way without requiring drastic changes. Effective risk assessment and management is the bedrock of resilient asset management. Risk management is something many organizations attempt to do, but it requires rigorous science and analysis. In reality, effective risk management is still the exception. The Federal Government can play a role in requiring risk assessment in asset management and developing the risk management training and guidance practitioners will need.

Identifying Regulations that Create Resilience Barriers

There are a series of transportation and trade regulations that, when disaster strikes, consistently create immediate barriers to agile response and may severely exacerbate cascading disruptions if not quickly waived. Multiple NIAC studies over the past decade include recommendations to revise regulations or waiver processes, yet these problems persist in regional disasters of many kinds. Transportation regulation issues often arise because disaster response requires the rapid movement of resources across large geographical regions, where fleets may encounter new jurisdictional requirements at every city, county, state, and national border. The following examples illustrate how these regulations can hinder recovery efforts:

- In the aftermath of Hurricane Irene, utility trucks bringing in generators were stopped at some state borders because they did not have the state transportation approval to bring in the generators.
- Containerized cargo bound for New York during Hurricane Sandy was unloaded in Norfolk, VA, in an attempt to keep shipping schedules in place. However, the Jones Act prevented the cargo

from being picked up again by other vessels because no waiver was issued ahead of time to allow foreign flagged carriers to reload the cargo on their way to New York.[24]

While some regulations are automatically waived by emergency declarations, others are not, and those declarations may not come until days into a disaster. With advance coordination, governments within regions have an opportunity to identify consistently problematic regulations and develop rapid waiver processes ahead of time to remove regulatory barriers and expedite recovery efforts.

V. Leadership and Coordination

While financial investment is a crucial component of resilience implementation in the transportation system, decisions are ultimately made by leaders in both the public and private sectors. Engaging leaders in coordinating resilience efforts is an essential component that is often overlooked. Three things are needed to guide the transportation systems sector toward a resilient future:

1) Decisive leadership in the form of a "resilience champion" to leverage transportation resilience expertise from non-profits, think tanks, and academic institutions.
2) CEO and non-profit leadership engagement to enhance dialogue and build partnerships.
3) International collaboration to confront emerging, shared risks and generate new ideas for resilience.

Decisive Leadership in the Form of "Resilience Champions"

The United States needs a "resilience champion" to galvanize support across modes and bolster national consensus in the way former political leaders have, such as President Eisenhower, who pushed for the development of the Interstate Highway System when he saw the security and economic risks the country would face without a sound transportation infrastructure. The most comprehensive infrastructure investments our country has seen throughout history have arisen because a prominent leader championed the cause. Political will is needed to generate action.

Leaders can better broaden awareness, devise policy solutions, and educate public officials on resilience by leveraging expertise from non-profits like the Transportation Research Board and The National Institute for Coastal and Harbor Infrastructure, as well as academic institutions and think tanks such as the Mineta Transportation Institute and the Eno Center for Transportation.

In addition, non-profits are particularly suited for assembling the public and private sectors for collaboration in emergency planning. For example, the All Hazards Consortium and the Pacific Northwest Economic Region both excel at bringing together the private sector with government stakeholders to plan for scenarios from disasters such as power outages to special events such as the Olympics. We heard from multiple transportation and resilience experts that political disagreements at the Federal and state levels caused delays and debilitated efforts to agree on a best path forward for incorporating resilience and investing in transportation infrastructure.

[24] Kurt J. Nagle, "Letter to David V. Aguilar, Thomas S. Winkowski, and David Matsuda," *American Association of Port Authorities*, (March 25, 2013).

CEO and Non-Profit Leadership Engagement

CEO-level engagement plays a major role in securing a commitment to resilience by fostering constructive dialogue and building partnerships across sectors. The 2015 NIAC report *Executive Collaboration for the Nation's Strategic Infrastructure* found that CEOs play key roles in "advancing outcomes and unifying action across their institutions and their sectors." From a practical perspective, most CEOs are already championing resilience in terms of business continuity.

Transportation infrastructure resilience requires coordination with other lifeline sectors to address sector dependencies. Executives are best suited to build working relationships across modes and sectors to create and sustain long-term communication and coordination planning mechanisms.

Public-private partnerships can be a successful tool for incorporating resilience into transportation infrastructure. The challenge is devising good projects that motivate active engagement from both sides. The government can most effectively engage expertise and resources from the private sector on efforts that emphasize a unified approach to continuity of operations and rapid service restoration. In Pennsylvania, the state government and private sector recently joined together in order to replace over 500 bridges throughout the state, with the private sector taking ownership of the bridges following completion. Corporate leaders have a strong sense of stewardship—they care deeply about the business conditions they leave behind.

International Collaboration

There is no "national" transportation system in the United States. Rather, transportation networks are built around geographic regions, and many extend beyond our borders. As a result, our neighbors Canada and Mexico serve as two of our Nation's three biggest trading partners. Supply chain disruptions can not only directly affect the movement of goods to other nations, but they can affect the safety of residents as well. Recently, the U.S. and Canada came together to establish new rules for oil transport after the 2013 Lac-Mégantic rail disaster and other oil rail crashes in both countries compelled action.[25]

[25] David Schaper, "U.S., Canada Announce New Safety Standards for Oil Trains," *NPR* (May 1, 2015).

Appendix C: Infrastructure Investment in Decline

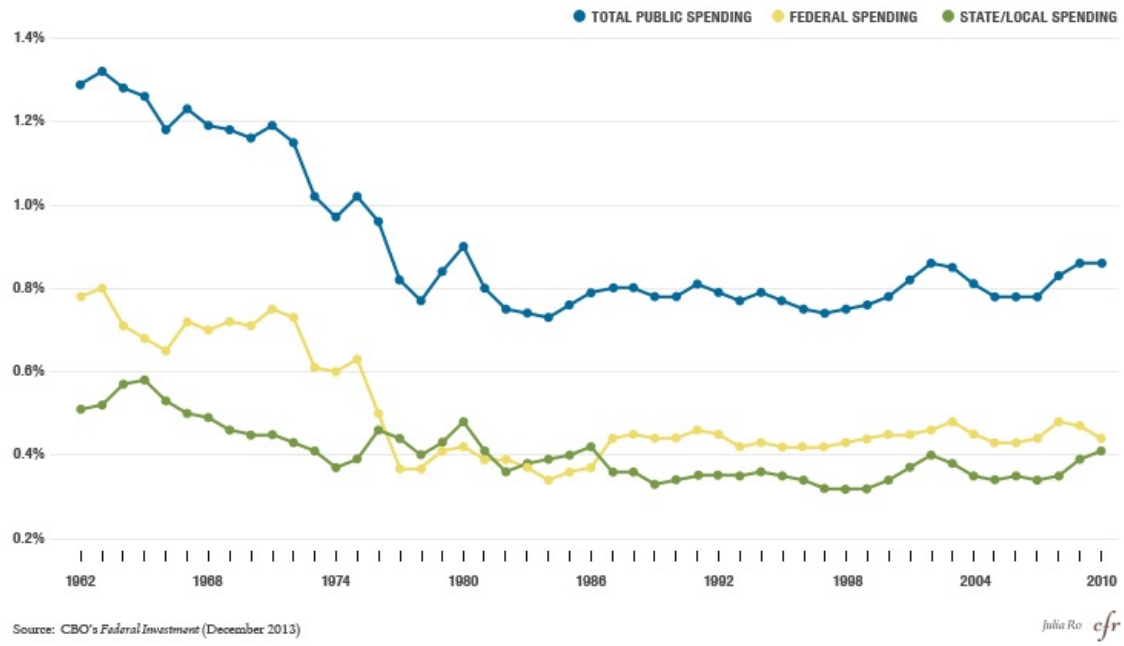
This appendix highlights declining trends in the nation's infrastructure spending, including transportation investments, and further compares U.S. investments in infrastructure with those of our global trading partners. It also provides an overview of the Federal Highway Trust Fund (FHTF) as a case study in transportation infrastructure spending.

I. Investment Trends

Transportation

Our nation has been chronically underspending on transportation infrastructure, especially when compared to our global counterparts. According to the Council on Foreign Relations, the United States spends 1.6 percent of its GDP on transportation infrastructure. By way of comparison, among countries in the Organization for Economic Cooperation and Development (OECD), the U.S. consistently ranks last or second-to-last in transportation infrastructure spending as a percentage of GDP. Since 1970, OECD countries have, on average, spent 52.7 percent more of their GDP on transportation infrastructure than the U.S.[26] Figure C-1 displays the decline of public transportation infrastructure spending as a percentage of GDP over the last fifty years.[27]

Figure C-1: Transportation Funding as a Share of GDP



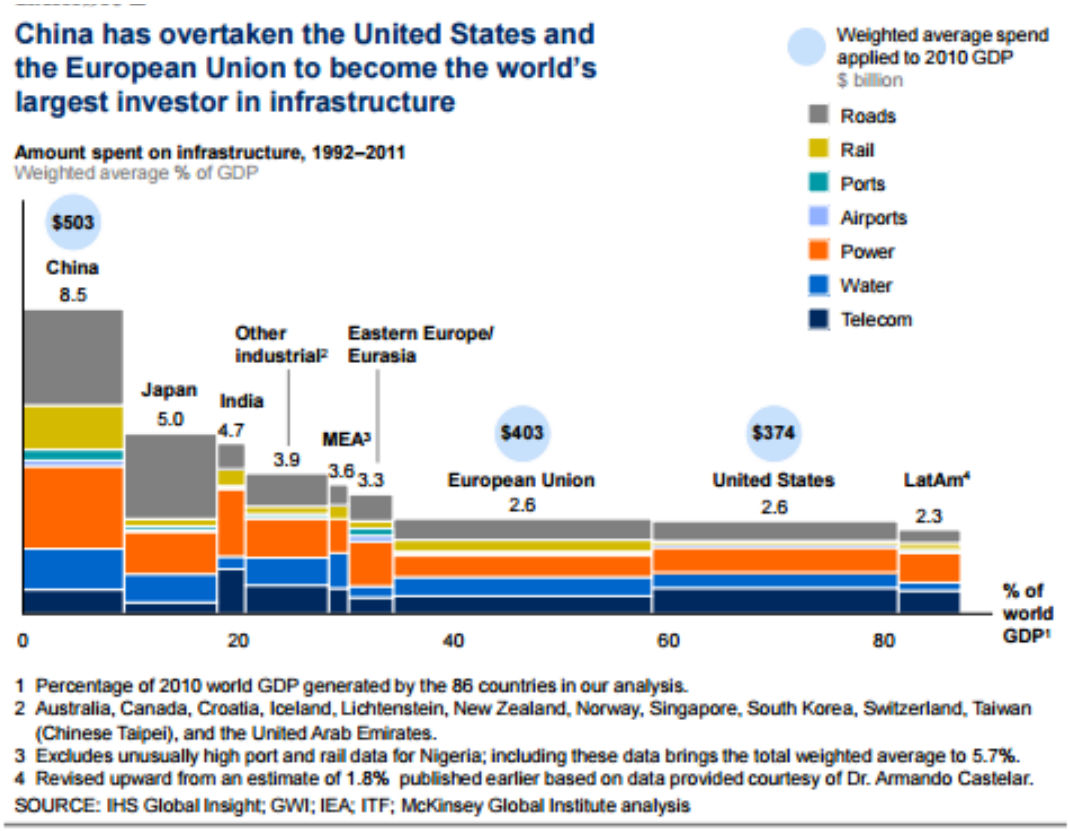
[26] Council on Foreign Relations, *Road to Nowhere: Federal Transportation Infrastructure Policy* (2012).
[27] Markovich, Steven J. "Transportation Infrastructure: Moving America." 2014.

In 2015, the American Association of State Highway and Transportation Officials (AASHTO) released a study on the status of the Nation's transportation system. The study reported that the World Economic Forum's Global Competitiveness Report found that the United States ranked 15th in the world in terms of transportation infrastructure, with the quality of its roads, railroad infrastructure, port infrastructure, and air transport infrastructure ranking 16-18th globally. The AASHTO study noted: "Inadequate supply of infrastructure is listed among the most problematic factors for doing business in the United States. All US transportation infrastructure quality elements are uniformly poor ranging from 16th to 19th in the world. The only service-level statistic, available airline seat miles, stands out in terms of its top rank."

All Infrastructure

Countries such as China, Japan, and India are significantly outspending the U.S. on infrastructure. The McKinsey Global Institute found that the US is investing at a rate of 2.6 percent of GDP in infrastructure; whereas, based on their estimate of needs derived from international norms and expected national economic growth rates, the US should be investing 3.6 percent of GDP.[28] Figure C-2 illustrates the various levels of infrastructure investment across countries.[29]

Figure C-2. Infrastructure Investment



[28] American Association of State Highway and Transportation Officials, *2015 AASHTO Bottom Line Report, 2015.*
[29] McKinsey Global Institute, *Infrastructure Productivity* (2013).

Most of our largest trading partners are investing two to five times more than the U.S., while we are at our lowest level of infrastructure investment since World War II.[30]

Table C-1: Global Infrastructure Spending

Country	Percentage of GDP
India[31]	10%
China[32]	9%
Europe[33]	5%
Mexico[34]	4.5-5%
Canada[35]	2.5-3%
United States	2.6%

Overall, U.S. infrastructure ranked 12th globally. However, its standing in transportation infrastructure is generally less competitive.

- The U.S. ranks 16th in quality of overall infrastructure and quality of roads.
- The U.S. ranks 15th on railroad infrastructure.
- The U.S. port infrastructure is ranked 12th globally.
- The U.S. ranks 9th in quality of air transport infrastructure.

Overall, U.S. spending on public infrastructure dropped 10.5 percent between 2003 and 2012.[36]

II. Case in Point: The Federal Highway Trust Fund

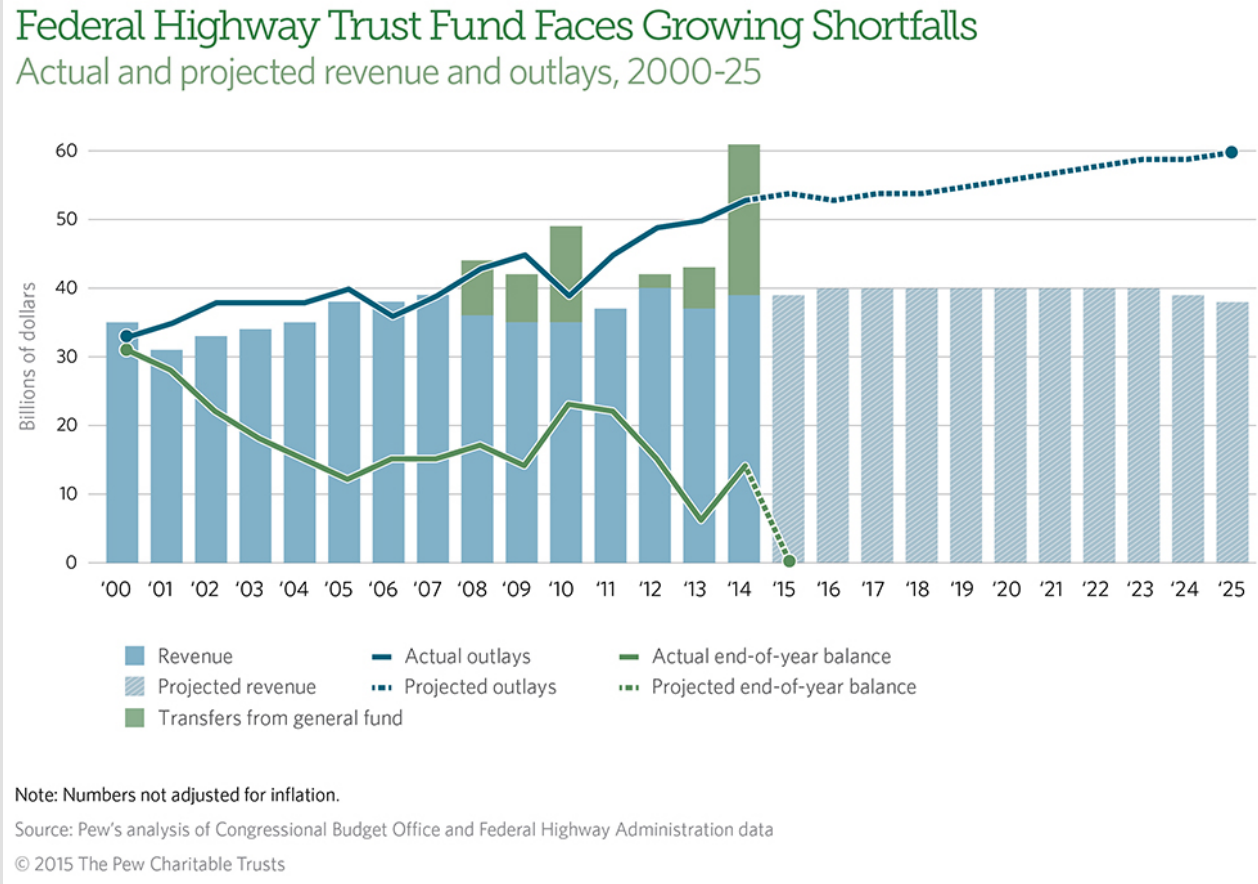
With the uncertainties surrounding replenishing the Federal Highway Trust Fund (FHTF), many states are finding their own solutions to the deficit in transportation infrastructure investment. Governors, state legislatures and local governments are taking steps to free themselves from Federal aid dependency. Examples of such efforts include increasing fuel taxes, passing local bond referenda, financing large-scale construction projects with long term credit, and entering into investment partnerships with the private sector. However, at an estimated $34 billion a year, Federal fuel taxes provide the states with vital aid in maintaining and modernizing the Interstate Highway System.[37]

[30] Financial Times, *US public investment falls to lowest level since war*, November 2013.
[31] Urban Land Institute, *Infrastructure 2013: Global Priorities, Global Insights.*
[32] World Economic Forum, *Competitiveness Rankings: 2014-2015,* 2014.
[33] The Economist, America's Transport Infrastructure: *Life in the Slow Lane*, April 2011.
[34] Bloomberg, *ICA CEO Sees Mexico Infrastructure Spending Rising 56%*, September 2012.
[35] Canadian Chamber of Commerce, *The Foundations of a Competitive Canada,* December 2013.
[36] National Association of Manufacturers, *Testimony from 2/25/15 Hearing from Tom Riordan*, 2015.
[37] Ken Orski, *The Changing Nature of State-Federal Relations in Transportation, 2014.*

In regards to the FHTF, a recent analysis by the Pew Charitable Trusts found:[38]

> "Revenue for the highway trust fund, the source of most Federal funding for roads and transit systems, has fallen short of expenditures for more than 10 years. These gaps are expected to continue to grow. The Federal Government has made up the difference through a combination of drawdowns from trust fund balances and, since 2008, transfers from the general fund."

Figure C-3. Trust Fund Shortfalls



The Pew study attributed the lack of transportation funding to the gas tax revenue, stating, "A major reason for the Federal and state governments' difficulty in maintaining funding is declining gas tax revenue, on which they rely heavily to pay for transportation. This revenue has fallen substantially in real terms over the past decade as a result of changing driving habits and increased fuel efficiency. In addition, the Federal and many state gas taxes remain at fixed per-gallon amounts, even as transportation construction costs increase."

As explained by the FHWA, "Receipts into the Federal Highway Trust Fund (FHTF) comes from a variety of taxes on highway fuel, tires, heavy vehicle use tax, and truck/trailer sales taxes. The motor fuel excise tax, currently 18.4 cents per gallon for gasoline/gasohol, and 24.4 cents for special fuel (primarily diesel)

[38]The Pew Charitable Trusts, *Funding Challenges in Highway and Transit*, 2015.

raises the majority of the revenue. This revenue is then placed into the Highway Trust fund by the US Treasury Department, after collection by the Internal Revenue Service. These funds are then distributed to the States based on formulas provided in Federal legislation."[39] Shortfalls in funding are financed from a variety of methods authorized by Congress, including transfers from the General Fund and the Leaking Underground Storage Tank Trust Fund.[40]

Currently, the FHTF is being temporarily funded through an extension of Moving Ahead for Progress in the 21st Century (MAP-21) authorization through July 31, 2015, signed by President Obama at the end of May 2015. The FHTF is estimated to be solvent through the end of August 2015.[41]

As of mid-June 2015, both Houses of Congress were holding hearings to try and find some way to come up with long-term cash flow to keep the FHTF trust fund afloat. Key congressional committees involved in this discussion included the House Ways and Means Committee (hearing scheduled for June 17 on the feasibility of various ideas to provide a sustainable long-term solution to the highway trust fund shortfall), and the Senate Finance Committee (hearing scheduled for June 18 on challenges to the future of highway funding). One of the major stumbling blocks in resolving the funding issue is whether to tie the FHTF into a comprehensive tax reform package.

POLITICO reported in its June 15, 2015 Morning Transportation brief that highway and transit policy expires in 47 days, while DOT appropriations run out in 108 days.[42]

[39] U.S. Department of Transportation, Federal Highway Administration, *Motor Fuel Data and the Highway Trust Fund.*

[40] U.S. Department of Transportation, Federal Highway Administration, *Status of the Highway Trust Fund.*

[41] Don Orseno, "Metra memo."

[42] POLITICO, *Morning Transportation,* 2015.

Appendix D: Indicators of Progress

Although transportation resilience is still a 'work in progress,' it is important to demonstrate the value of current efforts. For example, FEMA's implementation of PPD-8 and the National Preparedness Framework expands the traditional focus on emergency response by adding requirements and plans for prevention, protection, mitigation, and recovery. In addition, this framework has strong parallels with NIAC's resilience framework.

Other success stories in transportation underscore the progress made through programs in specific organizations. As such, these efforts may serve as effective models for promoting resilience. They are:

I. **Lessons from Implementation: PPD-8 and the National Preparedness Framework:** Perspectives and insights on building resilience
II. **TRB Transportation Resilience Projects and Studies**: Providing project funding and management for challenges in transportation resilience
III. **Beyond Bouncing Back**: Volpe forum exploring resilience in the Nation's transportation system
IV. **FEMA Disaster Mitigation Funding**: Support of mitigation activities to break the cycle of disaster damage
V. **NIST Cybersecurity Framework**: Widely accepted model for cybersecurity standards, guidelines, and practices
VI. **Incident Command System**: system designed to enable effective and efficient domestic incident management
VII. **The All Hazards Consortium Multi-State Fleet Response Working Group**: Working to develop processes to expedite cross-jurisdictional resource sharing
VIII. **USACE North Atlantic Coast Comprehensive Study**: Designed to identify and promote resilience strategies and provide a risk-reduction framework

I. Lessons from Implementation: PPD-8 and the National Preparedness Framework

As communities and the infrastructures that support them are inextricably linked, the FEMA experience in implementing policy, specifically PPD-8, *National Preparedness,* will likely provide valuable perspectives and insights on the process of building resilience into infrastructure as well as issues specifically related to freight transportation.

PPD-8 defines a National Planning Framework with five preparedness mission areas—Prevention, Protection, Mitigation, Response, and Recovery. These planning frameworks refocus government resources on mitigation and resilience — how communities can reduce the extent of disasters and improve the response and recovery from a disaster. Together, they describe how communities work with FEMA and others to achieve the National Preparedness Goal: "A secure and resilient nation with the capabilities required across the whole community to prevent, protect against, mitigate, respond to, and recover from the threats and hazards that pose the greatest risk." FEMA, Protection and National

Preparedness (PNP) is responsible for the coordination of preparedness and protection related activities throughout FEMA, including the implementation of PPD-8 and its component plans.

The NIAC methodology to help 'lifeline' sectors (energy, transportation, water, and communications) identify resilience goals stresses the importance of "building-in" resilience across the life cycles of systems and assets, and encompasses four aspects: robustness in preparing for an event; resourcefulness through training, exercises, and drills; rapid recovery; and adaptability through incorporating lessons learned.

There are strong parallels between the intent and structure of these two frameworks, and areas for convergence include:

- How the resilience needs of critical infrastructures are incorporated into planning through the 'whole of community' approach of the National Planning Framework.
- The FEMA role in enabling and encouraging resilience in the nation's transportation infrastructures.
- How FEMA works to ensure that owners and operators take full advantage of opportunities to build in resilience during the restoration of damaged infrastructure

Substantive lessons learned from community resilience may be derived and applied improving infrastructure resilience. These might include practices and procedures that have emerged that are particularly critical to success, gaps or particularly difficult aspects that have emerged, and specific insights with respect to resilience in transportation infrastructure. All of these could prove to be valuable contributors to the Federal effort to enable transportation resilience.

II. TRB Transportation Resilience Projects and Studies

The TRB is active in conducting and funding projects that explore the resilience challenges in transportation. Many TRB resilience projects are newly active, and seek to address both the existing and emerging transportation resilience challenges. Select TRB transportation resilience projects include:[43]

Transportation System Resilience

- *FloodCast: A Framework for Enhanced Flood Event Decision Making for Transportation Resilience*: Integrates available weather and climate technologies into a suite of tools and methods for enhanced flood event decision making, enabling state DOTs to manage risks, mitigate hazards, and respond to cascading and escalating impacts. Link: http://rip.trb.org/view/2014/P/1331583

[43] For more information, see TRB, "TRB Projects and Studies," http://www.trb.org/Projects/Projects2.aspx.

Intermodal Resilience

- *Traffic Capacity, Intermodal Transportation, Freight Transportation*: Builds a systematic model to define and measure the links and nodes of three major surface freight modes—highway, rail, and maritime—and their connections at the macro level. Link: http://rip.trb.org/view/2013/P/1264094
- *Making U.S. Ports Resilient as Part of Extended Intermodal Supply Chains*: Develops high level guidelines—illustrated by example studies—to coordinate port freight movements to withstand and bounce back from internal and external port disruptions. Link: http://rip.trb.org/view/2012/P/1331847
- *Methodologies to Estimate the Economic Impacts of Disruptions to the Goods Movement System*: Describes the impact of interruptions to goods movement through the Nation's freight corridors, capturing the full economic impact beyond the immediate disruption. Link: http://www.trb.org/Main/Blurbs/167969.aspx

Modal Resilience

- *Lessons from Hurricane Sandy for Port Resilience:* Discusses lessons learned by public and private stakeholders from the Port of New York and New Jersey and associated supply chain in how to quickly return the Port to full service in future disruptions. Link: http://rip.trb.org/view/2013/P/1234681
- *Climate Change Risk Assessment and Adaptation Planning at Airports*: Develops a guidebook that identifies potential climate change impacts, assesses related airport risks, and provides guidance to manage uncertainty and prioritize and implement actions. Link: http://rip.trb.org/view/2014/P/1335321

III. Beyond Bouncing Back

In 2013, the Volpe National Transportation Systems Center hosted a roundtable to explore resilience in the Nation's transportation system. The forum consisted of six national experts who each articulated their vision of resilience issues in the context of challenges facing the Nation's transportation system. Expert topics included the fracture-critical nature of the transportation system, the State and local perspective, and preparing transportation for extreme weather occurrences.

The roundtable of experts also conferred on the beginnings of a risk-based resiliency framework. The Volpe Center does not view the framework as a mechanism for preserving the status-quo but one that strategically builds or rebuilds a much less vulnerable transportation system that is better than the current system. The framework enables progress through the three foundations of a resilient transportation system: robustness, adaptation, and consequence mitigation. Resilience is not just a buzzword to characterize a system that recovers rapidly and resumes normal functions—it is beyond bouncing back. It is an overarching concept that includes physical, technical, social, and institutional elements and characterizes a complex system that is able to better withstand disruptions.

IV. FEMA Disaster Mitigation Funding

Mitigation efforts seek to break the cycle of disaster damage. In addition to Federal disaster recovery funds for individuals, FEMA maintains two additional primary funding areas for disaster mitigation:

- The Public Assistance Grant Program (PAGP) provides assistance to state, local, tribal, and territorial governments to repair and restore damaged public infrastructure. For example, the New Jersey Passaic Valley Sewerage Commission was awarded $260 million from FEMA after Superstorm Sandy to incorporate microgrid technology in their wastewater treatment facility to enable continued operations when the larger electric grid fails.
- Hazard Mitigation Assistance is primarily provided through the Hazard Mitigation Grant Program (HMGP), which aims to reduce the impact of and increase the resistance to future natural hazard disasters, and the Pre-Disaster Mitigation (PDM) grant program, which funds implementation of hazard reduction measures prior to a disaster.

Mitigation activities under the HMGP and PDM could include: structural retrofitting of existing buildings and infrastructure, installation of a permanent generator for a critical facility, or enforcement of stringent building codes and hazard-specific requirements and design standards in the new construction or repairing of facilities. With the exception of the PAGP, mitigation funding is available to improve the infrastructure resilience of both the public and private sectors—if governments apply on behalf of the private entity.[44]

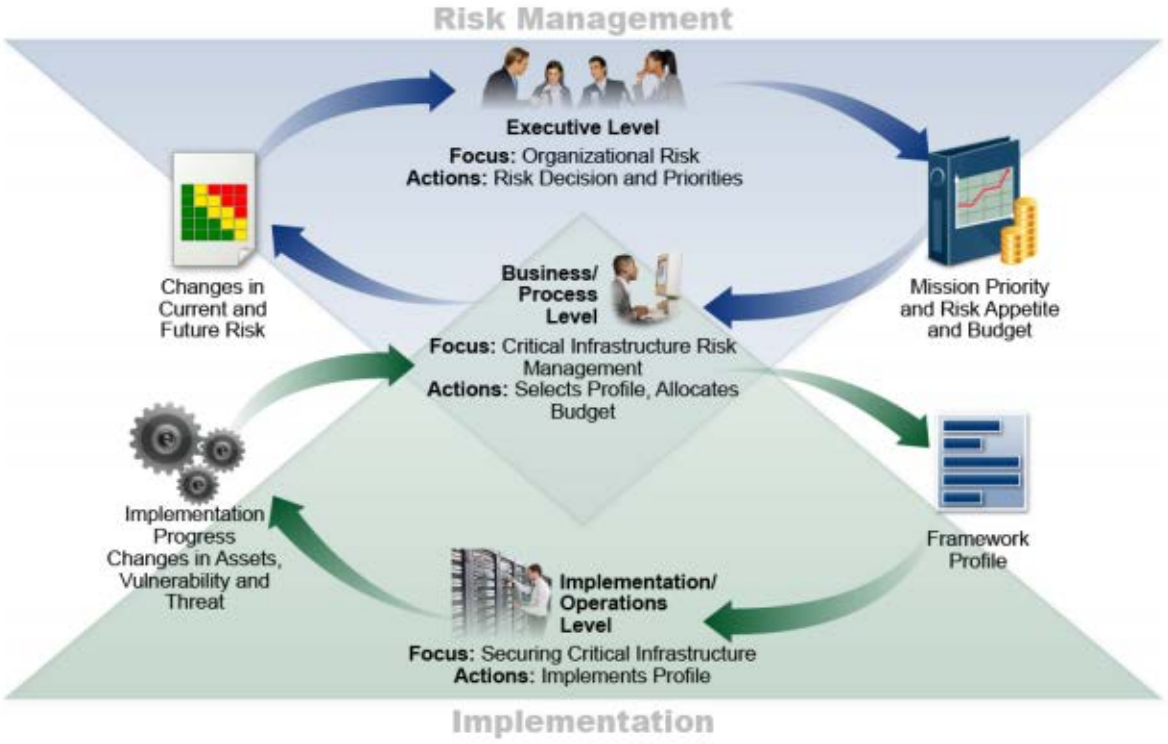
V. NIST Cybersecurity Framework

In February 2013, President Barack Obama issued Executive Order 13636, *Improving Critical Infrastructure Cybersecurity*, directing the National Institute of Standards and Technology (NIST) to work with stakeholders to develop a voluntary framework for reducing cyber risks to critical infrastructure. The goal was to improve IT and SCADA networks deployed in sensitive industries.

NIST released the first version of the *Framework for Improving Critical Infrastructure Cybersecurity* on February 12, 2014. Created through collaboration between industry and government, the framework consists of standards, guidelines, and practices to promote the protection of critical infrastructure. By being flexible, repeatable, and cost-effective, the framework is designed to help owners and operators of critical infrastructure to manage cybersecurity-related risk in a prioritized approach. The framework is based on existing standards, guidelines, and practices and is continually being updated. Figure D-1 illustrates the connection between the various levels of risk management within an organization. The first version of the framework can be accessed on NIST's website at the following link: http://www.nist.gov/cyberframework/.

[44] For more information, see FEMA, "Federal Insurance & Mitigation Administration Programs," https://www.fema.gov/what-mitigation/federal-insurance-mitigation-administration#4.

Figure D-1. Notional information and Decision Flows within an Organization



VI. Incident Command System

Incident Command System (ICS) is a standardized on-scene incident management concept applicable to multiple incidents across all levels of jurisdiction. Importantly, it promulgates a common organizational and operating approach that participating jurisdictions must employ to receive appropriate Federal support. As applied by FEMA, ICS enables effective and efficient domestic incident management by integrating a combination of facilities, equipment, personnel, procedures, and communications operating within a common organizational structure. ICS is structured to facilitate the functions of command, operations, planning, logistics, intelligence and investigations, finance and administration. The purpose of ICS is to enable incident managers to identify the key concerns associated with the incident—often under urgent conditions—without sacrificing attention to any component of the command system.

ICS is an essential tool used within FEMA's National Incident Management System (NIMS).[45] The systematic, proactive approach of NIMS guides departments and agencies at all levels of government, nongovernmental organizations, and the private sector to work together seamlessly for the

[45] For more information, see DHS, FEMA, "National Incident Management System," https://www.fema.gov/national-incident-management-system; and "Incident Command System Resources," https://www.fema.gov/national-incident-management-system/incident-command-system-resources.

management of incidents involving all threats and hazards—regardless of cause, size, location, or complexity—in order to reduce loss of life and property and harm to the environment.

NIMS and the ICS are whole-of-community approaches to managing incidents. The advantage of using ICS is that it provides standardization through consistent terminology and established organizational structures, thereby facilitating response and recovery operations anywhere in the country. FEMA makes available online many resources to help implement ICS procedures, including ways in which to request mutual aid.[46]

VII. All Hazards Consortium Multi-State Fleet Response Working Group

The Multi-State Fleet Response Working Group is a public-private working group that aids in effective critical infrastructure restoration by identifying processes and technologies that support expediting private sector fleet and resource movement across state lines in a disaster. This is accomplished through integrated planning, education and training, annual exercises, data sharing and situational awareness, and joint operational solution development. Of particular note are the following operational tools and services:[47]

- FLEET-MOVE: A data sharing system which centralizes necessary information (e.g. roadway usage/conditions, permits) across the Nation to support the coordination of multi-state commercial fleet movement.
- FLEET OPEN/CLOSED Service: A near-real time web application designed to locate open businesses providing essential services (e.g. fuel, food) during a disaster or prolonged power outage. It was developed during Superstorm Sandy in 2012, when the information was regionally circulated via Excel Spreadsheet through daily All Hazards Consortium e-mails.
- E-ZPass Commercial Account Guide: Helps private sector fleets expedite vehicle movement through the E-ZPass regional collection systems during disasters.

VIII. USACE North Atlantic Coast Comprehensive Study

As part of the Congressional response to increase coastal resiliency in the wake of Superstorm Sandy, the USACE is conducting the North Atlantic Coast Comprehensive Study to evaluate existing and planned measures to reduce flooding risk from future storm damages. The study covers 31,000 miles of Northeast coastline and will provide a risk reduction framework and promote coastal resilience strategies considering future sea level rise and climate change scenarios. The main study outcomes will

[46] See, for example, DHS, FEMA, *National Incident Management System (NIMS) Incident Command System (ICS) Forms Booklet*, *FEMA 502-2*, http://www.fema.gov/media-library-data/20130726-1922-25045-7047/ics_forms_12_7_10.pdf.

[47] For more information, see All Hazards Consortium, Multi-State Fleet Response Working Group, http://www.fleetresponse.org/

be supplemented by a geodatabase of collected data, identification of policy and institutional barriers to risk reduction implementation, and development of risk reduction measures and parametric costs by state. In addition, the USACE will validate the analysis through interagency collaboration sessions that connect Federal, state, local, and non-governmental organizations and private sector interests to coastal resilience.[48]

[48] For more information, see USACE, *North Atlantic Coast Comprehensive Study Report and Related Documents* (2015).

Appendix E: Overview of the National Transportation System

This appendix provides an overview of the freight and passenger components of the nation's transportation system.

I. The Freight Transportation System

Primary means of freight transport in the U.S. include air cargo, commercial trucks, pipelines, freight rail cars, and maritime vessels. Specific assets and movement of freight transport are shown in Table E-1 below.

Table E-1. Freight Transportation System Conveyance Statistics for 2012

MEANS OF TRANSPORT	NUMBER OF ASSETS
Air Cargo	
Air carrier passenger/cargo aircraft	6,911
Freight ton-miles	12.3 billion
All-cargo operations airports (top 25)	Handled 76% of landed weight of all cargo
Commercial Trucking	
Trucks, combination units	2.5 million
Trucks, single-unit	8.2 million
Pipelines	
Pipelines, oil and hazardous liquid	185,626 miles
Pipelines, natural gas gathering and transportation	320,031 miles
Pipelines, natural gas distribution	1,246,463 miles
Freight Rail	
Freight rail cars in service, Class I	364,025
Miles of rail operated, Class I freight railroads	95,394 miles
Ton-miles of freight moved by Class I railroads	1.7 trillion ton-miles
Maritime Vessels	
Non-self-propelled vessels (e.g., barges)	31,550
Self-propelled vessels (non-recreational)	8,927
U.S.-flag oceangoing privately owned fleet	198
Vessels calling at cargo-handling marine facilities	62,000 (two-thirds were tankers & containerships)

Freight Movement Facts

- Nearly three-fourths of all freight by weight is moved within 250 miles of where the shipment originated.
- Trucks carry the largest share of shipments moving 750 miles or fewer from their point of origin.

- Railroads and pipelines, combined, carry over half the tonnage shipped between 750 and 1,000 miles.
- Air cargo and shipments by multiple modes (e.g., shipments transferred from rail to truck) account for about half of the value of freight moving more than 2,000 miles.
- In terms of the value of transported goods, air transport carries high-value products such as electronics and precision instruments and quick-delivery products such as pharmaceuticals.
- Air cargo is expensive, valued at nearly $70,000 per ton. This compares to around $900 per ton for all modes combined.
- Trucks carry the highest percentage of tonnage and value of goods in the United States.
- Rail and water combined account for more than 15 percent of the total volume and nearly 5 percent of the total value of freight moved in the United States. The water mode, especially, carries low-value, bulk products.
- Pipelines move about 1.5 billion tons of goods valued at $768 billion (or $512 per ton) while rail moves about 2 billion tons values at $551 billion (or $275 per ton).

Figure E-1. Freight Flows by Highway, Railroad, Air, and Waterway: 2010

Source: DOT, BTS, "Figure 3-2," in Transportation Statistics Annual Report 2012, 38

NOTES: Air gateways include a low level (generally less than 3% of the total value) of freight shipped through small user-fee airports located in the same area as the gateways listed. Air gateways not identified by airport name (e.g., Chicago, IL) include major airport(s) in that area and small regional airports. Due to Census Bureau confidentiality regulations, courier operations are included in airport totals for only New York (JFK), Los Angeles, Chicago, and Anchorage.

SOURCES: **Air**—U.S. Department of Commerce, U.S. Census Bureau, Foreign Trade Division, USA Trade Online, **Land**—U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, TransBorder Freight Data, **Water**— U.S. Army Corps of Engineers, Navigation Data Center, personal communication, as cited in U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, National Transportation Statistics, table 1-51, available at http://www.bts.gov/publications/national_transportation_statistics/ as of October 2012.

Intermodal Freight

The Nation's transportation system has increasingly become intermodal, in large part driven by global supply chain requirements to move freight quickly, cost effectively, and reliably. In 2012, intermodal services accounted for about 10 percent of total freight tonnage in the United States, and nearly 20 percent of its value.

Rail has especially benefited from intermodal transport; its trailer and container traffic increased by 82 percent between 1990 and 2010. In 2011, intermodal traffic accounted for about 13 percent of Class I railroad revenue. However, coal, chemicals, and allied products account for a larger percentage of Class I revenues than do intermodal traffic.

Commodities

In 2012, bulk products (e.g., grain, natural gas, coke, asphalt, gravel, coal, waste/scrap, nonmetallic products, gasoline, fuel oils, crude petroleum, and natural sands) composed about 65 percent of freight by tonnage, but 16 percent of freight value. Top commodities by value included time-sensitive goods (e.g., electronics, pharmaceuticals, and textiles) and other high-value products such as machinery, motorized vehicles, and plastics/rubber. In 2012, these high-value commodities accounted for less than 15 percent of total tonnage, but nearly 60 percent of total value.

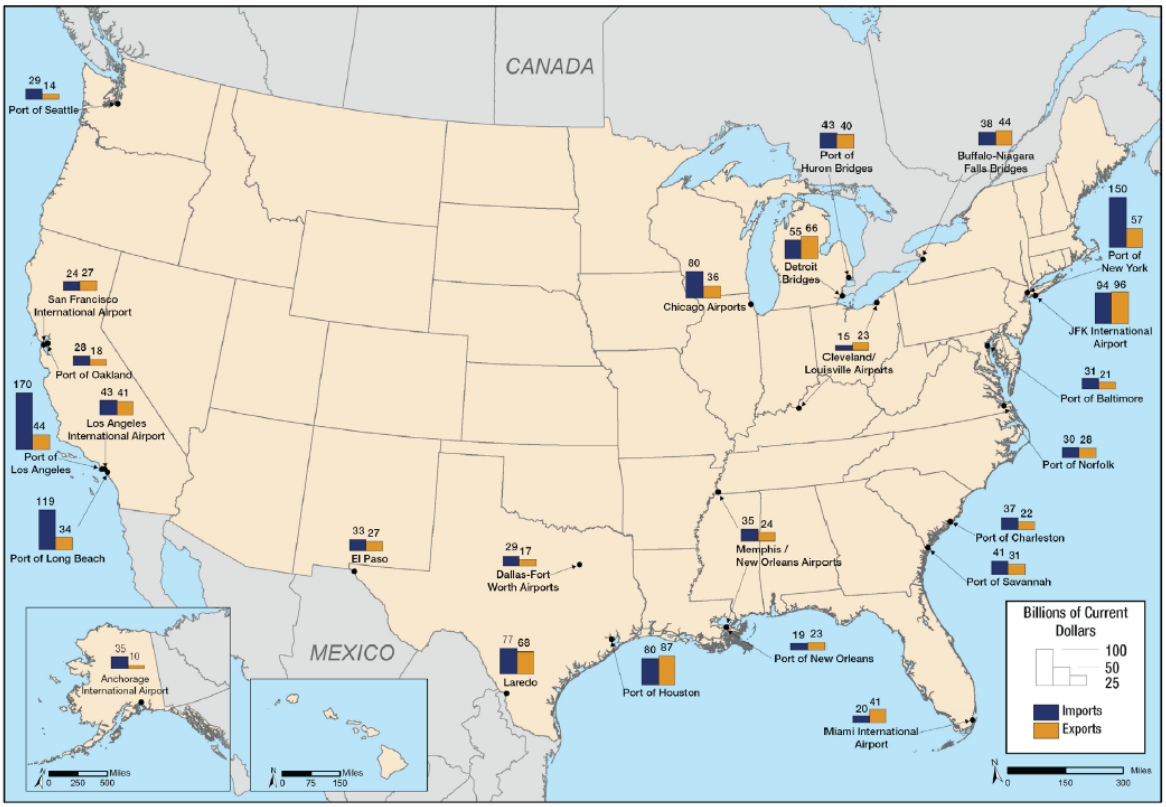
In terms of hazardous materials, trucks moved more than half of HAZMAT shipments, followed by pipelines (less than 30 percent), water (less than 7 percent), and rail (about 6 percent). Trucks and rail carried about the same amount (30 percent) of HAZMAT when measured by distance carried.

International Trade

International trade has increasingly become a vital component of the U.S. economy. The main drivers of this trend include, in part, a shift from manufacturing to a service economy, globalization of trade made possible by advances in information technology and supply-chain management, and the liberalization of trade practices around the world. The top five U.S. trading partners are Canada, China, Mexico, Japan, and Germany. Combined, Canada and Mexico account for about 30 percent of U.S. trade, most of which travels by truck and rail. Michigan is the leading state for trade with Canada, and Texas is the leading state for trade with Mexico.

Trade with other countries mostly passes through a few freight gateways—principally, for water: the Port of Los Angeles and the Port of New York and New Jersey, and for air: John F. Kennedy International Airport. Figure E-2 shows the top 25 U.S. foreign trade gateways by value in 2011.

Figure E-2. Top 25 U.S. Foreign-Trade Gateways by Value: 2011
Source: DOT, BTS, "Figure4-4," in Transportation Statistics Annual Report 2013, 73.



SOURCE: **Air**: U.S. Department of Commerce, Census Bureau, Foreign Trade Division, special tabulation, October 2012; **Water**: U.S. Army Corps of Engineers, Navigation Data Center, special tabulation, October 2012; **Land**: U.S. Department of Transportation (USDOT), Bureau of Transportation Statistics (BTS), TransBorder Freight Data, special tabulation, available at http://www.bts.gov/programs/international/transborder/ as of October 2012; as cited in USDOT/BTS, *National Transportation Statistics*, available at http://www.bts.gov as of October 2013.

Ships account for more than three-fourths of trade tonnage and nearly half of trade value. Air handles about 1 percent of trade tonnage but nearly a quarter of trade value. Trucks carry more than 10 percent of the tonnage and less than 20 percent of the value of U.S. trade between international gateways and inland locations. The use of containers in international trade has increased substantially, with the greatest concentration of U.S. container ports located on the West and East Coasts. Figure E-3 reflects the top 20 U.S. water ports by containerized cargo in 2011.

Figure E-3. Top 25 Water Ports by Containerized Cargo: 2011

Source: DOT, BTS, "Figure 4-6," in Transportation Statistics Annual Report 2013, 76.

Notes: The data include both government and non-government shipments by vessel into and out of U.S. foreign trade zones, the 50 states, District of Columbia, and Puerto Rico.
Source: U.S. Department of Transportation, *Maritime Administration, U.S. Waterborne Container Trade by U.S. Custom Ports*, based on data provided by Port Import/Export Reporting Service, available at *www.marad.dot.gov/library_landing_page/data_and_statistics/Data_and_Statistics.htm* as of September 13, 2013.

II. The Passenger Transportation System

Freight and passenger transportation are inextricably linked within and across modes. Accordingly, the following section presents an overview of passenger system assets and their use. The U.S. passenger transportation system is an interconnected network of highways, railroads, airports, public transit systems, and waterways that serves over 300 million U.S. residents and foreign visitors.[49] The total vehicle and passenger miles travelled in 2012 are shown in Table E-2.[50]

[49] Unless otherwise cited, the information in this section comes from DOT, BTS, *Passenger Travel Facts and Figures* (2014).

[50] DOT, BTS, "Figure 2-1" and "Figure 2-3" *in 2015 Pocket Guide to Transportation*, 6, 8; and American Public Transportation Association, "Table 35," in *2014 Public Transportation Fact Book*, 37.

TableE-2. Vehicle- and Passenger-Miles Traveled (millions) by Mode

MODE	2012 VEHICLE MILES	2012 PASSENGER MILES
Aviation		
U.S. Air Carrier, Domestic	5,956	580,501
Highway		
Light-Duty Vehicles *(passenger cars, light trucks, vans, and sport utility vehicles)*	2,664,445	3,669,821
Motorcycles	21,298	22,940
Trucks	268,318	268,318
Buses	14,755	312,797
Passenger Rail		
Amtrak	319	6,804
Commuter Rail	318	11,121
Heavy Rail	638	17,516
Light Rail	91	2,316
Waterway		
Ferry Boats	4	431

Aviation

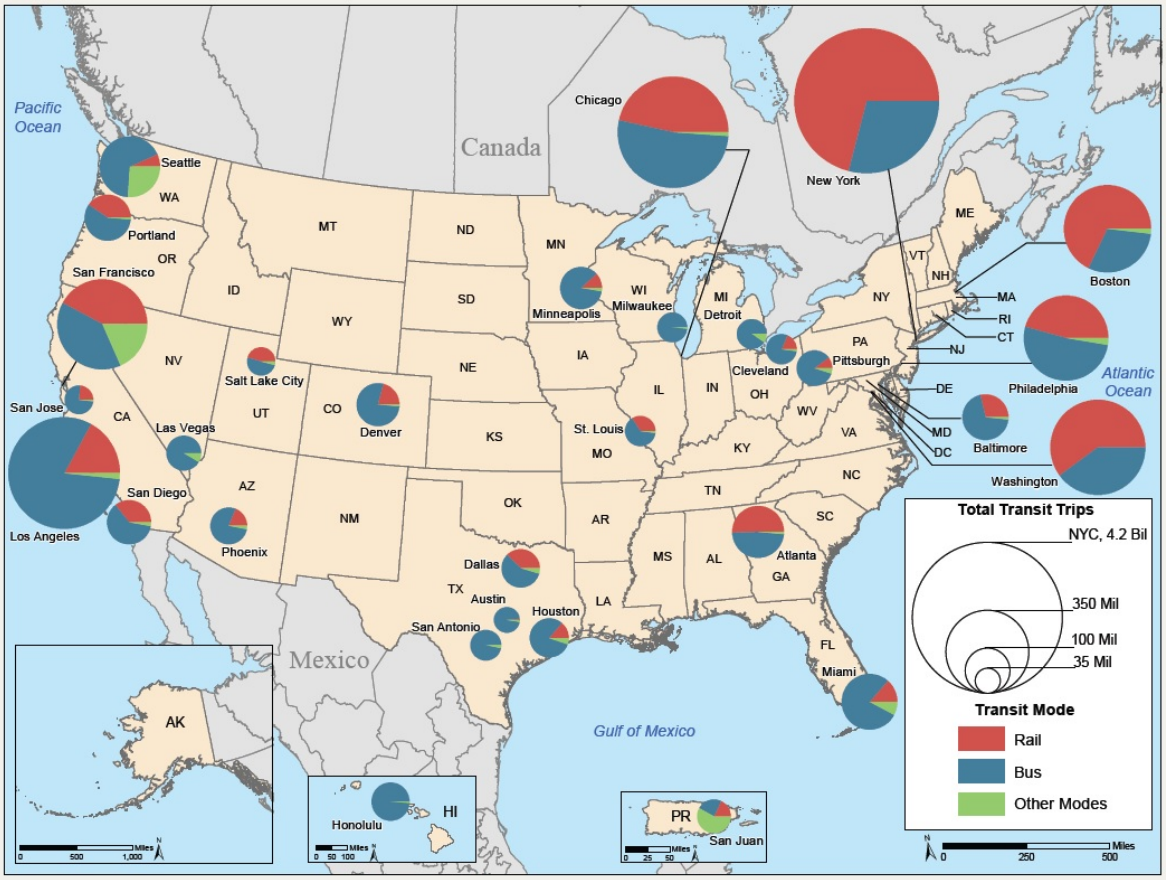
Air travel is an important component of the U.S. passenger transportation system, primarily for long distance travel. In 2012, there were slightly more than 642 million domestic airline passenger boardings in the United States, and about 170 million international boardings. New York City was the top market for domestic boardings at 46.5 million, followed closely by Atlanta at 45.1 million, and then Chicago at 39.3 million, Los Angles at 35 million, and Dallas/Fort Worth at 31.4 million.

Transit

Transit trips by mode in 2012 are illustrated in Figure E-4. The New York metropolitan area registered 4.2 billion transit trips in 2012, far more than any other U.S. metropolitan area. The rail system (commuter rail, subway, or light rail) accounted for more than 70 percent of New York area transit trips, while the bus system accounted for nearly 29 percent. The Los Angeles metropolitan area had the second most transit trips in 2012, approximately 671 million, with a little more than 81 percent travelling by bus.

Figure E-4. Transit Trips by Mode

Source: DOT, BTS, "Figure 3-8," in *Passenger Travel Facts and Figures 2014*, 47.



NOTES: Transit use in New York City (NYC) is much larger than elsewhere in the U.S., a larger but disproportionate circle was used to denote this. Rail includes commuter rail, subway, light rail, and streetcar rail.

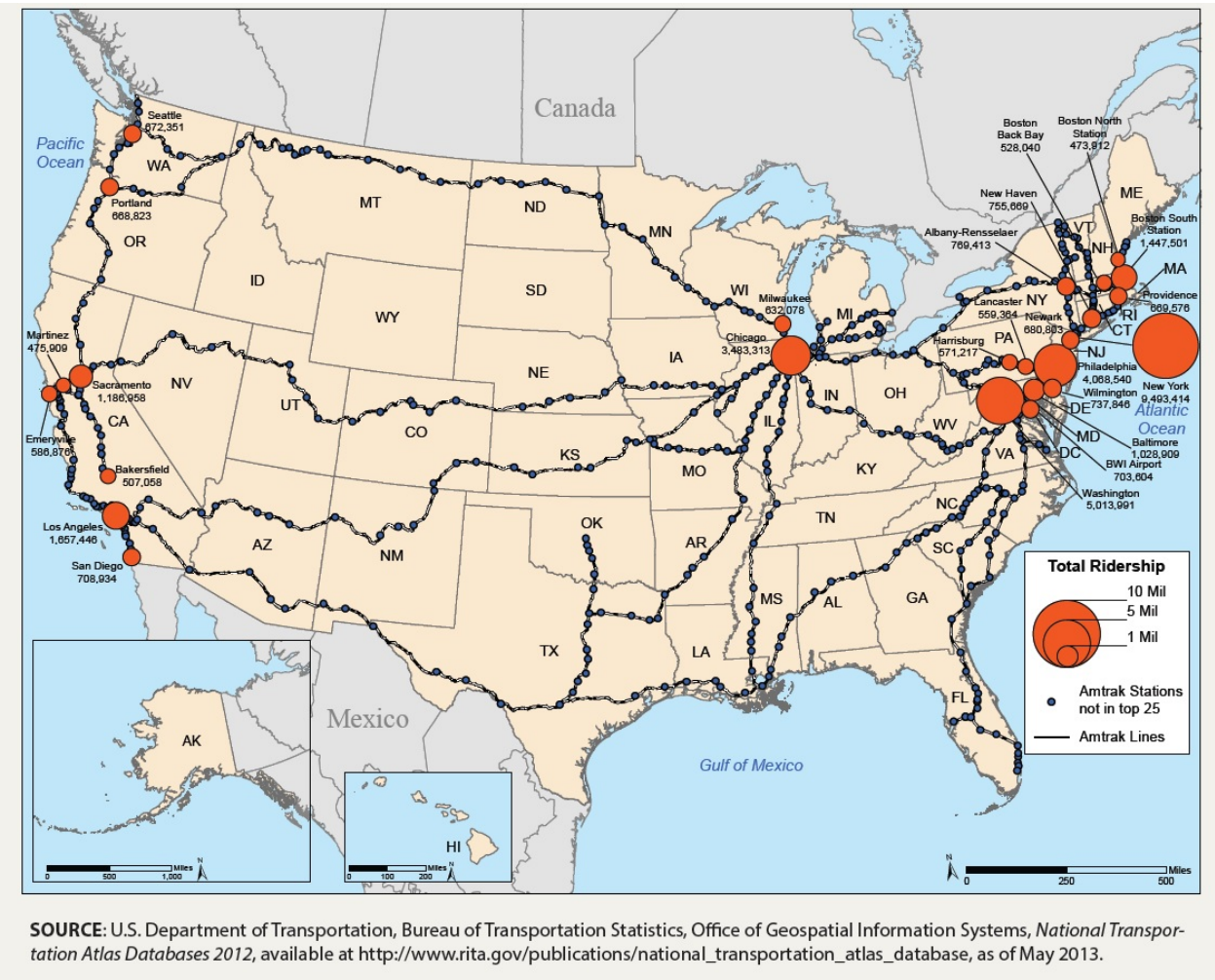
SOURCE: U.S. Department of Transportation, Federal Transit Administration, National Transit Database, http://www.ntdprogram.gov/ntdprogram/, as of May 2014.

Amtrak

The Amtrak network is shown below in Figure E-5. The busiest station in the Nation is New York City's Penn Station, and 12 of the Nation's busiest Amtrak stations serve the Northeast Regional route.

Figure E-5. The Amtrak Network

Source: DOT, BTS, "Figure 3-7," in *Passenger Travel Facts and Figures 2014*, 45.



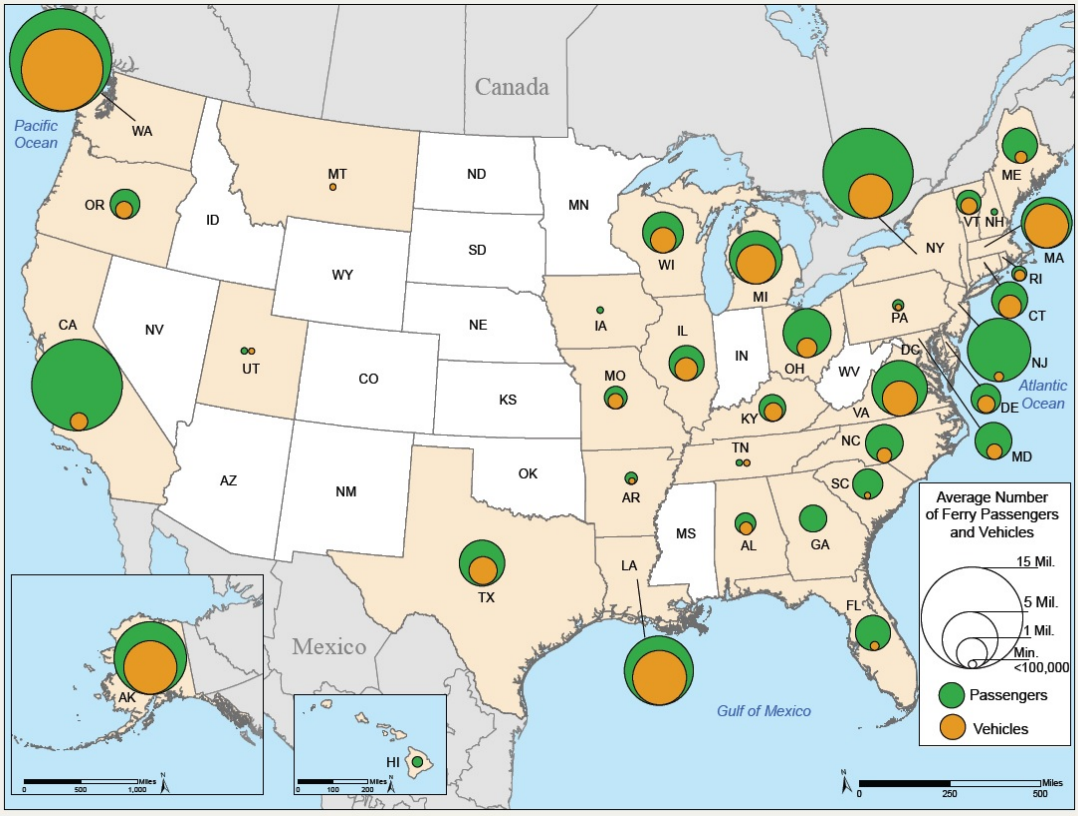
SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, Office of Geospatial Information Systems, *National Transportation Atlas Databases 2012*, available at http://www.rita.gov/publications/national_transportation_atlas_database, as of May 2013.

Ferry-Boats

As shown in Figure E-6, ferry-boats in Washington State, New York, and California had the greatest number of boardings in 2010, accounting for 15 percent, 6.8 percent, and 7.7 percent, respectively, of the Nation's total of nearly 53.5 million passengers.

Figure E-6. Ferry Passengers and Vehicles

Source: DOT, BTS, "Figure 3-9," in *Passenger Travel Facts and Figures 2014*, 51.



SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, National Census of Ferry Operators, as of September 2013.

Passenger Terminals

There are 7,200 passenger transportation terminals in the United States, 56 percent of which offer travelers the option to connect among the scheduled passenger transportation modes. The types of passenger transportation terminals include:

- Scheduled airline service airports
- Intercity bus stations (includes stations served by regular scheduled intercity bus service such as Greyhound and Trailways, code sharing buses such as "Amtrak Thruway" feeder buses, supplemental buses that provide additional frequencies along rail routes, and airport bus services from locations that are outside of the airport Metropolitan Area)
- Intercity and transit ferry terminals
- Light rail transit stations
- Heavy rail transit stations
- Passenger rail stations on the national rail network serving both commuter rail and intercity rail services

Appendix F: Federal Transportation Policy and Programs

I. Federal Policy and Programs

This appendix identifies examples of Federal law and policy that incorporate various aspects of resilience. It describes Federal groups with Sector Specific Agency (SSA) roles and responsibilities, as well as those that provide other forms of Federal action, including research, funding, and regulation. It highlights Federal research centers, programs, and projects related to transportation and resilience and identifies some significant areas of planning. Overall, while recent policy actions have stressed the importance of resilience, this emphasis has not yet been broadly translated into the funding, guidance, and other programmatic actions required for success.

Resilience in Federal Law and Policy

Critical infrastructure resilience has become an important goal in Federal law and policy over the past few years. In May 2010, the White House *National Security Strategy* (p. 1) recognized "the fundamental connection between our national security, our national competitiveness, resilience, and moral example."

The importance of critical infrastructure resilience is reflected in the evolving versions of the National Infrastructure Protection Plan (NIPP), developed by the U.S. Department of Homeland Security (DHS) to guide the national effort to manage risk to the Nation's critical infrastructure.

- The 2006 NIPP (p. 10) stated: "The great diversity and redundancy of the Nation's CI/KR [critical infrastructure/key resources] provide for significant physical and economic resilience in the face of terrorist attacks, natural disasters, or other emergencies, and contribute to the unprecedented strength of the Nation's economy."
- The 2009 NIPP (p. 28) elevated resilience to the level of protection: "nationally, the overall goal of CIKR-related risk management is an enhanced state of protection and resilience achieved through the implementation of focused risk-reduction strategies within and across sectors and levels of government."
- The 2013 NIPP (p. 15) established security and resilience of critical infrastructure as the primary aim in homeland security planning efforts: "The national effort to strengthen critical infrastructure security and resilience depends on the ability of public and private sector critical infrastructure owners and operators to make risk-informed decisions on the most effective solutions available when allocating limited resources in both steady-state and crisis operations."

Federal law and policy related to resilience may be found in key documents including:

- The 2012 Moving Ahead for Progress in the 21st Century Act (MAP-21)
- The 2013 Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act) *as Amended*

- The 2013 Disaster Relief Appropriations Act and Sandy Recovery Improvement Act (SRIA)
- Presidential Policy Directive (PPD) 8: *National Preparedness*
- Presidential Policy Directive (PPD) 21: *Critical Infrastructure Security and Resilience*
- Executive Order (EO) 13636: *Improving Critical Infrastructure Cybersecurity*
- Executive Order: *Promoting Private Sector Cybersecurity Information Sharing*

All of these touch upon one or more aspects of resilience as defined by the NIAC (p. 16): "Robustness includes the measures that are put in place prior to an event; resourcefulness includes the measures taken as a crisis unfolds; rapid recovery includes the measures taken immediately after an event to bring things back to normal; and adaptability includes the post-incident measures and lessons learned that are absorbed throughout the system."[51]

The Moving Ahead for Progress in the 21st Century Act (MAP -21)[52]

Signed into law by President Obama in July 2012, MAP-21 (Public Law 112-141) was the first long-term highway authorization enacted since 2005. MAP-21 creates a streamlined, performance-based, multimodal program to address the many challenges facing the U.S. surface transportation system. These challenges include improving safety, maintaining infrastructure condition, reducing traffic congestion, and improving efficiency of the system and freight movement. The U.S. Department of Transportation (DOT) maintains fact sheets explaining these and other provisions of the law. Among other provisions, the law requires the DOT to develop a *National Freight Strategic Plan*, due August 2015.

The Robert T. Stafford Disaster Relief and Emergency Assistance Act, as Amended

The Stafford Act (Public Law 93-288, as amended in April 2013, 42 U.S.C. 5121 et seq.) was enacted by Congress to provide an orderly and continuing means of assistance from the Federal Government to state and local governments in carrying out their responsibilities to alleviate the suffering and damage that result from disasters. In terms of resilience, three areas of assistance stand out:

- Encouraging the development of comprehensive disaster preparedness and assistance plans, programs, capabilities, and organizations by the states and by local governments;
- Achieving greater coordination and responsiveness of disaster preparedness and relief programs; and
- Encouraging hazard mitigation measures to reduce losses from disasters, including development of land use and construction regulations.

Following the severe damage in the Northeast resulting from Hurricane Sandy in 2012, the Stafford Act was amended to include provisions from the Disaster Relief Appropriations Act and the Sandy Recovery Improvement Act (SRIA). Disaster relief appropriations include up to $14.6 million for the Federal

[51] NIAC, *A Framework for Establishing Critical Infrastructure Resilience Goals* (2010).
[52] Moving Ahead For Progress in the 21st Century Act. Pub. L. No. 112-141, 126 Stat. 405. (2012); U.S. Department of Transportation, Federal Highway Administration, *Moving Ahead for Progress in the 21st Century Act (MAP-21): A Summary of Highway Provisions* (2012).

Aviation Administration (FAA), $32 million for the Federal Railway Administration (FRA), and $5.4 billion for the Federal Transit Administration (FTA). The Sandy Recovery Improvement Act, signed into law in January 2013, amends the Stafford Act with the aim to improve how FEMA delivers disaster assistance to governments and communities in need.

Several procedures and policies in the SRIA change how FEMA delivers Federal assistance to disaster survivors and their communities. In order for the Federal Transit Administration to receive the full appropriation of $5.4 billion, the SRIA requires the FTA to execute a Memorandum of Agreement with FEMA that outlines and defines the roles and responsibilities that each agency has in the repair and restoration of public transportation systems affected by a major disaster or emergency. Section 1111 of the Sandy Improvement Recovery act also tasked FEMA to make recommendations[53] that can be used to develop a national strategy to reduce the costs of future disasters and emergencies, particularly in the areas of addressing gaps and duplications of emergency preparedness and response at all levels of government; addressing vulnerabilities to damage from natural disasters or emergencies; and improving resilience of states, local, and tribal communities. The SRIA also includes a provision which allows governments and communities to use all or part of excess Federal relief funds toward activities that mitigate future risks.

Presidential Policy Directive (PPD) 8: National Preparedness

PPD-8 of March 30, 2011, strengthens the security and resilience of the United States by mandating systematic preparation for the threats that pose the greatest risk to the Nation's security, including acts of terrorism, cyber attacks, pandemics, and catastrophic natural disasters. The Directive calls for the development of a national preparedness goal that identifies the core capabilities necessary for preparedness, as well as a national preparedness system to guide activities that will enable the Nation to achieve the goal.

Presidential Policy Directive (PPD) 21: Critical Infrastructure Security and Resilience

PPD-21 of February 12, 2013, aims to strengthen and maintain secure, functioning, resilient critical infrastructure. It calls for a national effort to share threat information, reduce vulnerabilities, minimize consequences, and hasten response and recovery efforts related to critical infrastructure. It also identifies 16 critical infrastructure sectors. The PPD specifies that the Federal Government shall work with critical infrastructure owners and operators and state, local, tribal, and territorial entities to take proactive steps to manage risk and strengthen the security and resilience of the Nation's critical infrastructure, considering all hazards that could have a debilitating impact on national security, economic stability, or public health and safety. PPD-21 sets forth three strategic imperatives to drive the Federal approach to strengthening critical infrastructure security and resilience:

1. Refine and clarify functional relationships across the Federal Government to advance the national unity of effort to strengthen critical infrastructure security and resilience

[53] DHS, FEMA, *National Strategy for Recommendations: Future Disaster Preparedness* (2013).

2. Enable effective information exchange by identifying baseline data and systems requirements for the Federal Government
3. Implement an integration and analysis function to inform planning and operations decisions regarding critical infrastructure

Executive Order (EO) 13636: Improving Critical Infrastructure Cybersecurity

EO 13636 of February 12, 2013, calls for the Federal Government to closely coordinate with critical infrastructure owners and operators to improve cybersecurity information sharing and collaboratively develop and implement risk-based approaches to cybersecurity. The EO directs the Federal Government to develop a technology-neutral cybersecurity framework to reduce cyber risk to critical infrastructure; promote and incentivize the adoption of strong cybersecurity practices; increase the volume, timeliness, and quality of information sharing related to cyber threats; and incorporate protection for privacy and civil liberties into critical infrastructure security and resilience initiatives.

Executive Order – Promoting Private Sector Cybersecurity Information Sharing

The Executive Order of February 13, 2015, builds upon EO 13636 of February 12, 2013 (Improving Critical Infrastructure Cybersecurity) and PPD-21 of February 12, 2013 (Critical Infrastructure Security and Resilience). Its purpose is to encourage the formation of organizations engaged in the sharing of information related to cybersecurity risks and incidents, to establish mechanisms to continually improve the capabilities and functions of these organizations, and to better allow these organizations to partner with the Federal Government on a voluntary basis. The Information Sharing and Analysis organizations are intended to work closely with the DHS National Cybersecurity and Communications Integration Center.

Federal Agencies with Major Transportation Roles

The Sector Specific Agencies (SSAs) for the sector reside in DHS and DOT; among other duties they lead the collaborative effort to develop the Sector Specific Plan (SSP), which details the application of NIPP concepts to the unique characteristics and conditions of the sector. The SSAs are establishing Transportation Systems Sector goals, some of which relate to resilience, in an updated Transportation Systems SSP, as required by the 2013 NIPP.

The most current available document, the 2010 SSP (p. 25-26), specified four sector goals:

1. Prevent and deter acts of terrorism using, or against, the transportation system.
2. Enhance the all-hazard preparedness and resilience of the global transportation system to safeguard U.S. national interests.
3. Improve the effective use of resources for transportation security.
4. Improve sector situational awareness, understanding, and collaboration.

U.S. Department of Homeland Security

Within DHS, and outlined in the SSP (p. 18), the Transportation Security Administration (TSA) and the United States Coast Guard (USCG) share SSA responsibilities for ensuring the sector's security and for

ensuring freedom of movement for people and commerce. The Federal Emergency Management Agency (FEMA) has key transportation roles during national disasters.

Transportation Security Administration

TSA has a lead role for security of the aviation and surface transportation modes and supports the USCG as the lead for maritime security. As part of its mission, TSA is responsible for assessing intelligence, issuing and enforcing security directives, ensuring the adequacy of security measures at transportation facilities, and ensuring effective and timely distribution of intelligence to sector partners. TSA collaborates with DOT to manage protection and resilience programs for all hazards. The total TSA budget request for fiscal year (FY) 2014 was about $7.4 billion. For FY 2015, the request was about $7.3 billion.

United States Coast Guard

The USCG is a multi-mission maritime service and one of the Nation's five Armed Forces. Its mission is to protect the public, the environment, and U.S. economic interests in the Nation's ports, on navigable waterways inland, along the coast, on the high seas, and in any maritime region, as required to support national security. In the event of a maritime incident, the USCG will often act in a first-responder capacity. The USCG has the primary responsibility for the security of the maritime domain, including coordinating mitigation measures to expedite the recovery of maritime infrastructure and transportation systems and to support incident response in coordination with the U.S. Department of Defense (DoD). The total USCG budget request for FY 2014 was about $9.8 billion. For FY 2015, the request was also about $9.8 billion.

In addition to the SSA organizations, DHS has several other components that have roles that are generally related to resilience in transportation systems.

Federal Emergency Management Agency

FEMA's mission is to support efforts to prepare for, protect against, respond to, recover from, and mitigate all hazards. Part of that effort involves the coordination of transportation services to ensure Federal aid moves into an area before an event occurs and continues to arrive in a timely and efficient manner to assist in rapid response and recovery during and after the event. FEMA coordinates and communicates across all levels of government and private-sector partners to achieve the 2011 National Preparedness Goal: "A secure and resilient Nation with the capabilities required across the whole community to prevent, protect against, mitigate, respond to, and recover from the threats and hazards that pose the greatest risk." FEMA has developed extensive documentation to advance this goal, including five National Planning Frameworks:

- National Prevention Framework
- National Protection Framework
- National Mitigation Framework
- National Response Framework
- National Disaster Recovery Framework

In addition, FEMA proactively plans for response to future disasters with a focus on strengthening community resilience.[54] FEMA does much of this work through its Strategic Foresight Initiative project. The total FEMA budget request for FY 2014 was about $13.45 billion. The request for FY 2015 was about $12.5 billion.

Science and Technology Directorate

The mission of the Science and Technology Directorate (S&T) is to help strengthen America's security and resiliency by providing assessments, analysis and reports, and by developing innovative technology solutions for the Homeland Security Enterprise. One of S&T's visionary goals is to build resilient communities:

"Critical infrastructure of the future will be designed, built, and maintained to withstand naturally occurring and man-made disasters. Decision makers will know when a disaster is coming, anticipate the effects, and use already-in-place or rapidly deployed countermeasures to shield communities from negative consequences. Resilient communities struck by disasters will not only bounce back, but bounce forward."[55]

S&T is home to the DHS Centers of Excellence, which work collaboratively to develop multidisciplinary, customer-driven, science and technology solutions and to train the next generation of homeland security experts. The S&T Resilient Systems Division (RSD) has as its mission to rapidly develop and deliver innovative solutions to enhance the resilience of individuals, communities, and systems. Focus areas of RSD include resilience in communities, critical infrastructure, and cyber-physical systems. The Centers of Excellence program, also known as University Programs, has had several accomplishments. These include:[56]

- Piloted the Disaster Recovery Tracking Tool in four communities in the New York City area impacted by Superstorm Sandy, led by the University of North Carolina, Chapel Hill
- Piloted the resiliency planning scorecard, designed to evaluate the effectiveness of local plans (hazard mitigation, land use, climate action) in supporting reduction of the vulnerability of populations and urban development, led by Texas A&M University
- Developed and demonstrated a cell-phone signal based GPS-denied navigation system capable of generating a Position, Navigation and Time (PNT) solution in GPS-denied environments, led by the University of Arizona.

National Cybersecurity and Communications Integration Center

The National Cybersecurity and Communications Integration Center (NCCIC) is a 24x7 cyber situational awareness, incident response, and management center that is a national nexus of cyber and communications integration for the Federal Government, intelligence community, and law

---

[54] DHS, FEMA, *Crisis Response and Disaster Resilience 2030: Forging Strategic Action in an Age of Uncertainty* (2012).

[55] DHS, Science and Technology Directorate, "Visionary Goals."

[56] DHS, *Results of Fiscal Year 2014 Research and Development. Fiscal Year 2015 Report to Congress* (2015). 34-40.

enforcement.[57] The NCCIC shares information among the public and private sectors to provide greater understanding of cybersecurity and communications situation awareness of vulnerabilities, intrusions, incidents, mitigation, and recovery actions. The NCCIC is comprised of four branches:

- NCCIC Operations and Integration
- United States Computer Emergency Readiness Team
- Industrial Control Systems Cyber Emergency Response Team
- National Coordinating Center for Communications

These integrated branches lead a whole-of-Nation approach to addressing cybersecurity and communications issues at the operational level.

U.S. Department of Transportation

With DOT, the component responsible for serving as the designated SSA for the Department is the Security Policy and Plans Division, located within the Office of Intelligence, Security, and Emergency Response, which is part of the Office of the Secretary of Transportation. In addition to its SSA responsibilities, the Policy and Plans Division develops DOT policy and coordinates DOT participation in interagency policy development related to intelligence, security, and all-hazards preparedness. The Division coordinates DOT-wide interaction with the National Security Council and its interagency policy committees. The Division also serves as the Secretary's public health advisor, and is focal point for both Departmental and interagency response and recovery planning.[58]

In addition to the SSA, there are multiple components within DOT—outlined in the 2010 SSP (p. 93)—with responsibilities for ensuring a fast, safe, efficient, accessible, convenient transportation system:

Federal Aviation Administration

The Federal Aviation Administration (FAA) is charged with safely and efficiently operating and maintaining the Nation's aviation system. The FAA's major roles include regulating civil aviation to promote safety; encouraging and developing civil aeronautics, including new aviation technology; developing and operating a system of air traffic control and navigation for both civil and military aircraft; researching and developing the National Airspace System; developing and conducting programs to control aircraft noise and other environmental effects of civil aviation; and regulating U.S. commercial space transportation.

Federal Highway Administration

The Federal Highway Administration (FHWA) is responsible for ensuring that the Nation's roads and highways continue to be safe and technologically up-to-date. Although state, local, and tribal governments own most of the Nation's highways, FHWA provides financial and technical support for constructing, improving, and preserving the U.S. highway system through administration of the Federal Aid and Federal Lands Highway Programs.

---

[57] DHS, "About the National Cybersecurity and Communications Integration Center."
[58] DOT, "Security Policy and Plans Division."

Federal Motor Carrier Safety Administration

The primary mission of the Federal Motor Carrier Safety Administration (FMCSA) is to reduce crashes, injuries, and fatalities involving large trucks and buses. FMCSA also has responsibility for overseeing safe and secure highway transportation of hazardous materials and compliance of movement of household goods. FMCSA accomplishes its mission through a strong partnership with U.S. law enforcement.

Federal Railroad Administration

The Federal Railroad Administration (FRA) promulgates and enforces railroad safety regulations, administers railroad assistance programs, conducts research and development (R&D) in support of improved railroad safety and national railroad transportation policy, provides for the rehabilitation of Northeast Corridor railroad passenger service, and consolidates government support of railroad transportation activities.

Federal Transit Administration

The Federal Transit Administration (FTA) works to secure the Nation's transit infrastructure. FTA has undertaken an aggressive nationwide security program in cooperation with every transit agency. FTA conducts risk and vulnerability assessments and deploys technical assistance teams to help strengthen security and emergency preparedness plans. It also funds emergency response drills conducted in conjunction with local fire, police, and emergency responders. FTA has also implemented programs to improve public transit by training all transit employees and supervisors, improving emergency preparedness, and increasing public awareness of security issues.

Maritime Administration

The Maritime Administration (MARAD) promotes development and maintenance of a Marine Transportation System (MTS) sufficient to move the Nation's waterborne commerce and capable of serving the deployment requirements of DoD. It engages in outreach and coordination activities in order to assist the maritime industry in emergency preparedness and response and recovery efforts related to maritime transportation security incidents and natural disasters. Outreach and coordination activities include interaction with MTS stakeholders in planning and training forums, conferences, workshops, exercises, and real-world response and recovery efforts. MARAD provides a range of MTS information and emergency coordination capabilities.

National Highway Traffic Safety Administration

The National Highway Traffic Safety Administration's (NHTSA's) mission is to save lives, prevent injuries, and reduce economic costs due to road traffic crashes through education, research, safety standards, and enforcement activity. NHTSA also serves as the lead Federal agency for Emergency Medical Services coordination and houses the National 9-1-1 Implementation Coordination Office.

Pipeline and Hazardous Materials Safety Administration

The Pipeline and Hazardous Materials Safety Administration (PHMSA) oversees the safety of more than 1.2 million daily shipments of hazardous materials in the United States and 2.3 million miles of pipeline, through which two-thirds of the Nation's energy supply is transported. PHMSA works toward the elimination of transportation-related deaths and injuries in hazardous materials and pipeline

transportation, as well as promotes transportation solutions that enhance the resilience of communities and protect the natural environment.

Saint Lawrence Seaway Development Corporation

The Saint Lawrence Seaway Development Corporation (SLSDC), a wholly owned government corporation and an operating administration of DOT, is responsible for the operations and maintenance of the U.S. portion of the St. Lawrence Seaway between Montreal and Lake Erie. The SLSDC coordinates its activities with its Canadian counterpart, the St. Lawrence Seaway Management Corporation, to ensure that the U.S. portion of the St. Lawrence Seaway is available for commercial transit during the navigation season (usually late March to late December of each year). In addition, the SLSDC performs trade development activities designed to enhance the utilization of the Great Lakes St. Lawrence Seaway System.

DOT Research and Innovative Technologies Administration (RITA)

RITA coordinates DOT research programs and is charged with advancing the deployment of crosscutting technologies to improve the Nation's transportation system. RITA leads DOT in coordinating, facilitating, and reviewing the Department's R&D programs and activities; advancing innovative technologies, including intelligent transportation systems; performing comprehensive transportation statistics research, analysis, and reporting; and providing education and training in transportation and transportation-related fields.

Other Federal Agencies

In addition to the SSAs and other components in DHS and DOT, there are other entities within the Federal Government that play important roles that may affect the resilience of the transportation sector.[59] A brief description of some of these entities follows:

Surface Transportation Board

The Surface Transportation Board (STB) is an economic regulatory agency that Congress has charged with resolving railroad rate and service disputes and reviewing proposed railroad mergers. The STB makes independent decisions, although it is administratively affiliated with DOT. The STB may, for up to 270 days, direct the handling, routing, and movement of the traffic of a rail carrier and its distribution over its own or other railroad lines, as well as give directions for preference or priority in the transportation of traffic. One such situation is when STB determines that there is a shortage of equipment, traffic congestion, unauthorized cessation of operations, or other failures of traffic management that create an emergency situation of such magnitude as to have substantial adverse effects on shippers or on rail service in a region of the United States.

[59] DHS, *Transportation Systems Sector-Specific Plan: An Annex to the National Infrastructure Protection Plan* (2010). 91-98.

National Institute of Standards and Technology

The National Institute of Standards and Technology (NIST) is a non-regulatory Federal agency within the U.S. Department of Commerce. NIST's mission is to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve quality of life. NIST has developed numerous minimum performance standards related to homeland security, participates in standards-setting bodies related to homeland security, has extensive experience in designing and developing test and evaluation programs, provides nationally recognized accreditation of testing laboratories, and maintains memoranda of agreement with other nations regarding reciprocity of accreditation acceptance. NIST guidance aids in improving information systems security by raising awareness of information technology risks, vulnerabilities, and protection requirements, as well as informs measures and metrics that can be included in a full risk management framework.

Environmental Protection Agency

The Environmental Protection Agency (EPA)'s Office of Transportation and Air Quality plays an important role in the NTS because it regulates GHG emissions and is instrumental in implementing climate change adaptation strategies. The transportation sector is one of the largest sources of U.S. GHG emissions, representing approximately 27 percent of total U.S. GHG emissions. EPA enforces a host of regulations related to clear air, clean water, hazardous waste, and runoff pollution.

United States Army Corps of Engineers

The United States Army Corps of Engineers (USACE) oversees maintenance of inland waterways and dredges the Nation's ports. Part of the U.S. Department of the Army, USACE shares oversight, permit, and approval of offshore renewable energy installations. USACE oversees several research programs that develop engineering resilience strategies and plans for coastal systems.

Federal Research Centers, Programs, and Projects

Academic Centers, Research Centers, and Think Tanks

Several notable academic and research centers play important roles in identifying technologies, methodologies, and processes that can increase resilience in the transportation sector. These include the following:[60]

The John A. Volpe National Transportation Systems Center

The John A. Volpe National Transportation Systems Center (Volpe) assists Federal, state, and local governments, as well as industry and academia, in areas including human factors research; system design, implementation, and assessment; global tracking and situational awareness of transportation assets and cargo; and strategic investment. Volpe's Federal staff, supplemented by a cadre of support contractors, provides technical expertise on conducting assessments of transportation systems, related

[60] DHS, *Transportation Systems Sector-Specific Plan: An Annex to the National Infrastructure Protection Plan* (2010). 97.

critical infrastructure, and government facilities on behalf of DOT, DHS, DoD, and other transportation sector partners.

U.S. Coast Guard Research and Development Center

The Research and Development Center of the USCG is their sole facility for performing research, development, test, and evaluation efforts in support of the USCG's missions, including homeland security.

National Laboratories and Technology Centers

National laboratories and technology centers including the U.S Department of Energy's (DOE) National Infrastructure Simulation and Analysis Center, at Los Alamos National Laboratory, provides advanced modeling and simulation capabilities for analyzing critical infrastructure and its interdependencies, vulnerabilities, and complexities.

Homeland Security Centers of Excellence

Homeland Security Centers of Excellence, HS-Centers, under DHS S&T, enable DHS to invest in university-based partnerships to develop centers of multidisciplinary research where important fields of inquiry can be analyzed and best practices can be developed, debated, and shared. HS-Centers bring together the Nation's best experts and focus its most talented researchers on a variety of threats, including those related to the transportation network.

Turner Fairbank Highway Research Center

The Turner Fairbank Highway Research Center (TFHRC) is the research arm of FHWA on all aspects of highways, including safety appurtenances, intelligent transportation systems, bridges and other highway structures, pavements, and human factors. Research is conducted through TFHRC's 22 laboratories and through contract and cooperative research programs. TFHRC assists individual state departments of transportation and provides products to develop a safer and more reliable highway transportation system for the general public.

National Research Council, Transportation Research Board

The National Research Council of the Transportation Research Board (TRB) facilitates the sharing of information on transportation practices and policy by researchers and practitioners, providing expert advice on transportation policy and programs, including security and infrastructure protection policy and program development. TRB, while not a Federal organization, works very closely with many Federal groups.

In addition to TRB, other non-Federal research centers include the following:

Mineta Transportation Institute

The Mineta Transportation Institute (MTI), based at California's San José State University, conducts research, education, and information and technology transfer, focusing on multimodal surface transportation policy and management issues. It was established by Congress in 1991 as part of the Intermodal Surface Transportation Efficiency Act.

The Intermodal Transportation Institute

The Intermodal Transportation Institute, located at the University of Denver in Colorado, focuses on educating future leaders and executives in managing intermodal transportation systems that integrate all modes.

The Eno Center for Transportation

The Eno Center for Transportation (Eno), in Washington, DC, is a non-partisan think-tank seeking continuous improvement in transportation and its public and private leadership in order to increase the system's mobility, safety, and sustainability. A non-profit charitable foundation, Eno often works in partnership with government agencies, professional organizations, and other private organizations. Ongoing projects include working groups focused on the Next Generation Air Transportation System (NextGen) and on public-private partnerships as an alternative to direct public investment in transportation systems. In addition, Eno's Freight Working Group brings together truckers, railroads, ports, and shippers to discuss proposals for funding a multimodal freight program.

Programs and Projects

A significant number of Federal programs, projects, and publications related to resilience are produced by the aforementioned entities and other centers.[61] The programs of Volpe and TRB are examples.

Volpe National Transportation Center

Volpe's mission is to improve transportation by anticipating and addressing emerging issues and advancing technical, operational, and institutional innovations across all modes. Volpe has seven technical centers that focus on a particular facet of transportation. Within each technical center, there are multiple divisions that specialize in a particular facet or discipline of that center's focus. The centers and their focus areas are the following:

- **Advanced Transportation Technologies:** Explores innovative applications of advanced communications, navigation, and information technologies to enhance transportation safety, mobility, and energy/environmental performance. Divisions: Advanced Vehicle Technology; Technology Innovation & Policy.
- **Air Traffic Systems and Operations:** Develops aviation systems and procedures to improve the efficiency and safety of aviation. Divisions: Air Navigation and Surveillance; Air Traffic Management Systems; Aircraft Wakes and Weather; Aviation Facilities and Business Service; Aviation Systems Engineering; NextGen Systems Development Program Office.
- **Environmental and Energy Systems:** Specializes in the analysis and measurement of climate variability, air quality, and noise, and focuses on environmental engineering and sustainability.

[61] Among the best transportation-related libraries and databases are (1) DOT, Research and Innovative Technology Administration (RITA), "National Transportation Library," http://ntl.bts.gov/; (2) DOT, John A. Volpe National Transportation Systems Center (Volpe), "Volpe Library," http://www.volpe.dot.gov/library; and (3) National Research Council, Transportation Research Board (TRB), "Transportation Research International Documentation," http://trid.trb.org/.

Divisions: Corporate Average Fuel Economy; Energy Analysis & Sustainability; Environmental Measurement & Modeling; Environmental Science & Engineering.

- **Infrastructure Systems and Engineering:** Applies technical knowledge of surface, ground-based aviation, as well as marine transportation systems, to enhance safety, operational efficiency, and sustainability. Divisions: Infrastructure Engineering & Deployment; Structures & Dynamics; Systems Safety & Engineering.
- **Safety Management and Human Factors:** Improves transportation safety by developing and applying innovative safety management and human factors processes and principles. Divisions: Aviation Human Factors; Aviation Safety Management Systems; Safety Information Systems; Safety Measurement & Analysis; Surface Transportation Human Factors.
- **Transportation Logistics and Security:** Specializes in physical and cybersecurity issues, emergency management, logistics, and situational awareness systems from an all-hazards approach. Divisions: Security & Emergency Management; Situational Awareness & Logistics.
- **Transportation Policy and Planning:** Focuses on providing transportation information to make smart investments in the planning, development, management, operations, and financing of transportation systems and agencies. Divisions: Economic Analysis; Organizational Performance; Transportation Planning.

Volpe makes available to the public thousands of documents dealing with transportation issues. These documents can be accessed through the following sources:

- **Volpe Library:** A library of more than 40 years of Volpe-authored reports, journal articles, and conference papers and presentations. Includes more than 4,000 Volpe-authored publications, 27,000 books, technical reports, and 150 journal subscriptions. Volpe-authored reports, journal articles, and conference presentations and papers are accessible online: http://www.volpe.dot.gov/library.
- **Special Collections:** Accessible online and within the Volpe Library, Volpe has a total of 11 special collections that include publication listings, collected publications, annotated bibliographies, and searchable reference libraries.
- **Featured Works:** Current work and projects by the seven technical centers can be accessed at http://www.volpe.dot.gov/featured-work.

Transportation Research Board

TRB's mission is to promote innovation and progress in transportation through research. Major divisions within TRB include the following:

- **Technical Activities:** Supports standing committees and task forces; organizes the TRB Annual Meeting and other conferences and workshops; and conducts field visits to transportation agencies, organizations, and research institutions. The Marine Board, which provides a forum for the exchange of information on maritime transportation and related issues, is administratively housed within the Technical Activities Division.
- **Studies and Special Programs:** Convenes expert committees to conduct policy studies and program reviews, maintains TRB's extensive databases, provides library services, prepares

synthesis reports on behalf of the Cooperative Research Programs, and manages the Innovations Deserving Exploratory Analysis programs. The division conducts policy studies requested by Congress, executive branch agencies, states, and other sponsors.

- **Cooperative Research Programs:** Manages the National Cooperative Highway Research Program (NCHRP), the Transit Cooperative Research Program (TCRP), the Airport Cooperative Research Program (ACRP), the National Cooperative Freight Research Program (NCFRP), and the Hazardous Materials Cooperative Research Program (HMCRP).

Similar to Volpe, TRB has thousands of documents available to the public. Most of these can be accessed through the extensive TRB databases and other information-collection and information-sharing mechanisms, which include the following:

- **TRB Transportation Research E-Newsletter:** A weekly electronic newsletter designed to keep individuals up-to-date on TRB activities, as well as highlight selected transportation research taking place at the Federal and state levels and within the academic and international transportation communities. Links to articles from 2009 to the present are available here: http://www.trb.org/Publications/PubsTRBENewsletter.aspx.
- **Cooperative Research Programs Division:** Administers a number of major research programs sponsored by other organizations. Links to the programs can be found here: http://www.trb.org/AboutTRB/Public/AboutCooperativeResearchPrograms.aspx. Current programs and their research focus include the following:
    - NCHRP: Acute problems that affect highway planning, design, construction, operation, and maintenance nationwide.
    - TCRP: All aspects of public transportation, including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.
    - ACRP: Near-term, practical solutions to problems faced by airport operators.
    - National Cooperative Rail Research Program: Problems shared by freight, intercity passenger (including high-speed rail), and commuter rail operators, including design, construction, maintenance, operations, safety, security, policy, planning, human resources, and administration.
    - NCFRP: Improvements to the efficiency, reliability, safety, and security of the Nation's freight transportation system. *(No longer funded, but will complete existing projects.)*
    - HMCRP: Researches day-to-day operational issues in hazardous materials transportation with near- to mid-term time frames. *(No longer funded, but will complete existing projects.)*
- TRB typically has more than 200 active research projects and studies underway at any given time. Links to most of the projects can be found here: http://www.trb.org/Projects/Projects2.aspx. The majority of these are contract research projects administered by TRB's Cooperative Research Programs Division. Smaller-scale projects include synthesizing current practices in the NCHRP, TCRP, and ACRP, as well as a separately administered Commercial Truck and Bus Safety Synthesis Program. Links to the contacts

responsible for the synthesis and their deliverables can be found here: http://www.trb.org/SynthesisPrograms/SynthesisProgram.aspx.

While there are scattered efforts that either directly address resilience or may have an ancillary relationship, there appears to be no broad, focused effort to understand, assess, and mitigate the risk associated with system vulnerabilities to service recovery after disruption. With the current policy emphasis as a solid foundation, the implementation process requires significant work before resilience can become an engrained aspect of transportation planning and execution. While this delay between policy and funding and program action is not unusual in Federal processes, a sustained, high-priority focus is needed to ensure that progress to date is not lost and resilience does not simply become the "flavor of the month" within the Federal bureaucracy.

Research and Development

Both DHS and DOT have sponsored R&D programs to address NTS challenges and strengthen overall resilience in transportation systems.

For example, the DHS Science & Technology Directorate's Centers of Excellence (COE) program includes the National Transportation Security COE, featuring participation by the Connecticut Transportation Institute, which studies bridge structures and new materials design, and the Mack Blackwell Natural Rural Technologies Study Center in Arkansas, which focuses on highway design, construction, and health monitoring.[62] The FAA sponsors the NextGen Test Bed for the NAS at Embry-Riddle Aeronautical University's Daytona Beach campus.[63] USCG also actively promotes resilience in the maritime domain through its own programs.

DOT supports extensive R&D programs, many of which are part of DOT's RITA. In addition, the FAA, FHWA, Federal Transit Administration, Federal Railroad Administration, and Maritime Administration all have ongoing projects designed to improve the safety and performance of their respective modes. Links to the various DOT academic and research institutes can be found in Appendix M, References and Research Resources.

Both Argonne National Laboratory and Oak Ridge National Laboratory, under DOE, have transportation R&D programs. The national laboratories have been especially important in developing various models showing the interdependencies of critical infrastructure, including transportation and its modes.[64] Also, the USACE, which has many responsibilities for port and waterway maintenance, has focused considerable attention on resilience in recent years.[65]

---

[62] DHS, "Science & Technology Directorate Centers of Excellence" (2014).

[63] Embry-Riddle Aeronautical University, *Next Generation ERAU Applied Research* (2014).

[64] L. Carlson, *Resilience: Theory and Applications* (2012); Idaho National Laboratory, *Critical Infrastructure Interdependency Modeling: A Survey of U.S. and International Research* (2006); and F. D. Petit, *Resilience Measurement Index: An Indicator of Critical Infrastructure Resilience* (2013).

[65] For example, Julie Dean Rosati, *Method to Assess Resilience of the Marine Transportation System* (2014), PowerPoint presentation provided to the NIAC; and Martin T. Schultz, *The Quantification and Evolution of Resilience in Integrated Coastal Systems* (2012).

II. Planning for the Future

The SSAs for the Transportation Systems Sector are using multiple approaches to address the resilience challenge to ensure that the Nation's transportation system is safe, efficient, *and* resilient over the next several decades. In view of emerging challenges, DOT is updating its strategic plan as well as developing a National Freight Strategic Plan for delivery in October 2015 as required by MAP-21. Examples of modernization efforts within the transportation sector include MAP-21, targeted investment in key infrastructure, the Next Generation Air Transport System, and efforts by state and local governments to upgrade and improve their own transportation systems.

MAP-21 and the National Freight Strategic Plan

On July 6, 2012, President Barack Obama signed into law P.L. 112-141, MAP-21, which transforms the policy and programmatic framework for investments to guide the growth and development of the country's vital transportation infrastructure. MAP-21 creates a streamlined, performance-based, multimodal program to address the many challenges facing the U.S. highway system by establishing national performance goals for Federal highway programs. Goals to meet these challenges include the following:

- **Safety**: To achieve a significant reduction in traffic fatalities and serious injuries on all public roads
- **Infrastructure condition**: To maintain the highway infrastructure asset system in a state of good repair
- **Congestion reduction**: To achieve a significant reduction in congestion on the National Highway System
- **System reliability**: To improve the efficiency of the surface transportation system
- **Freight movement and economic vitality**: To improve the national freight network, strengthen the ability of rural communities to access national and international trade markets, and support regional economic development
- **Environmental sustainability**: To enhance the performance of the transportation system while protecting and enhancing the natural environment
- **Reduced project delivery delays**: To reduce project costs, promote jobs and the economy, and expedite the movement of people and goods by accelerating project completion through eliminating delays in the project development and delivery process, including reducing regulatory burdens and improving agencies' work practices[66]

MAP-21 includes a number of provisions to improve the condition and performance of the national freight network and support investment in freight-related surface transportation projects. It establishes a policy to improve the condition and performance of the national freight network to provide the foundation for the United States to compete in the global economy and achieve goals related to

[66] DOT, FHWA, *Moving Ahead for Progress in the 21st Century Act (MAP-21): A Summary of Highway Provisions* (2012).

economic competitiveness and efficiency; congestion; productivity; safety, security, and resilience of freight movement; infrastructure condition; use of advanced technology; performance, innovation, competition, and accountability in the operation and maintenance of the network; and environmental impacts.

It directs DOT to, within three years of enactment of MAP-21, develop a national freight strategic plan in consultation with states and other stakeholders, and to update the plan every five years. The plan must:

- Assess the condition and performance of the national freight network
- Identify highway bottlenecks that cause significant freight congestion
- Forecast freight volumes
- Identify major trade gateways and national freight corridors
- Assess barriers to improved freight transportation performance
- Identify routes providing access to energy areas
- Identify best practices for improving the performance of the national freight network and mitigating the impacts of freight movement on communities
- Provide a process for addressing multistate projects and strategies to improve freight intermodal connectivity

As resilience is a key component of the law's intent, the strategic plan will be opportunity—and perhaps a litmus test—for DOT's focus on transportation resilience.

Identifying Key Areas for Investment

One of the inherent complexities of the Nation's transportation system is the impact funding sources have on the incorporation of resilience. Understanding patterns of investment from the public and private sector is a crucial first step for understanding the challenges of integrating resilience throughout the entire sector. The following section describes representative areas of government investment.

The Federal Government seeks to target investment in transportation infrastructure projects through studies and grants. One example of a targeted study is the FHWA's report on national gateways and freight corridors. This report identified multimodal corridors and gateway needs, trends, and opportunities with a view toward better aligning U.S. economic competitive interests with new infrastructure.[67]

An example of the use of grants to improve resilience in new transportation infrastructure is DOT's Transportation Investment Generating Economic Recovery (TIGER) discretionary grant program. Since 2009, Congress has dedicated more than $4 billion to fund projects that have a significant impact on the nation, a region, or a metropolitan area. Many applicants compete for the grants to help build and repair critical pieces of freight and passenger transportation networks in five outcome categories: safety, economic competitiveness, state of good repair, livability, and environmental sustainability.[68]

[67] DOT, FHWA, *FHWA National Gateways and Corridors Concepts* (2013).
[68] DOT, "About TIGER Grants" (2014).

Another key to proper investment in infrastructure resilience is the identification of specific needs and requirements. One cabinet-level effort along these lines is the U.S. Committee on the Maritime Transportation System (CMTS). Established for the purpose of assessing the maritime transportation system as a whole, CMTS draws together the most important Federal agencies concerned with the system to address strategic, long-term issues such as climate change and resilience. It also has developed a handbook on Federal funding sources for MTS-related infrastructure.[69]

Another Federal effort to identify and quantify the cost of infrastructure repair and improvement is the 2014 *National Risk Estimate: Aging and Failing Critical Infrastructure Systems*, developed by the DHS Office of Cyber and Infrastructure Analysis (OCIA). The OCIA analysis includes specific assets such as navigation locks, highway bridges, railway bridges, commercial aviation, and natural gas and hazardous liquid pipelines.

Next Generation Air Transport System

The Next Generation Air Transport System (NextGen) is a major systemic modernization of the National Airspace System (NAS) that utilizes satellite-based technology and procedures as well as new air traffic management tools. Key components of NextGen include Performance Based Navigation capability—such as Required Navigation Performance procedures that ensure specific levels of aircraft navigation accuracy—and Automatic Dependent Surveillance-Broadcast, which determines an aircraft's location. New operational tools for air controllers include the Terminal Flight Data Manager and Time Based Flow Management, both of which help controllers and airports stage arrivals and departures more efficiently.[70]

State and Local Efforts

State and local governments have also been active in upgrading their transportation systems, often as a result of some devastating natural event, such as a hurricane, or large-scale exercises based on realistic scenarios for a particular region, such as a large earthquake along the southern portion of the San Andreas Fault in California. Among the best examples of state and local plans are those developed by the State of New York and New York City after the crippling impact of Superstorm Sandy in October 2012.

These and other state and local plans often place great emphasis on building resilience into transportation upgrades and new construction projects.[71] Nonetheless, these plans are highly

---

[69] CMTS, *Federal Funding Handbook for MTS Infrastructure* (2013).

[70] DOT, FAA, "NextGen Update 2014" (2014).

[71] New York State 2100 Commission, *Recommendations to Improve the Strength and Resilience of the Empire State's Infrastructure* (2013); and City of New York, *A Stronger, More Resilient New York* (2013). Examples of other state and local plans designed to enhance resilience in transportation infrastructure are California Maritime Security Council, *Port Recovery and Business Continuity Planning Considerations Guide* (2010); and Gulf Coast Research Center for Evacuation and Transportation Resiliency, *Resilient Transportation Systems in a Post-Disaster Environment: A Case Study of Opportunities Realized and Missed in the Greater New Orleans Region* (2010).

dependent on Federal leadership and resources. These include governance structures to align Federal and jurisdictional approaches and capabilities, funding and funding guidance to develop resilience in programs and projects, and associated guidance, lessons learned, and best practices. In 2013-2014, the FHWA partnered with State Departments of Transportation (DOTs), Metropolitan Planning Organizations (MPOs), and Federal Land Management Agencies (FLMAs) to pilot approaches to conduct climate change and extreme weather vulnerability assessments of transportation infrastructure and to analyze options for adapting and improving resiliency.[72]

[72] DOT, FHWA, "Climate Change Resilience Pilots" (2015).

Appendix G: Overview of Transportation Modes and Resilience Practices

Resilience is best achieved through effective risk management. Risk management has evolved as an important element to the overall transportation system, with each transportation mode displaying unique resilience practices in furtherance of risk management. The NIAC Resilience Framework incorporates various aspects of risk management and includes the following:

- Robustness in preparing for an event
- Resourcefulness through training, exercises, and drills
- Rapid recovery
- Adaptability through incorporating lessons learned

While there is no commonly used definition of resilience in the transportation sector, as both the content of resilience and its lexicon varies, resilience attributes and actions are slowly emerging. Each transportation mode approaches resilience differently based on its construct and current practices. The following information presents an overview of each transportation mode, in addition to a compendium of practices that may contribute to resilience, organized by components of the NIAC Resilience Framework. It presents a sample list of practices, and information was extracted from subject matter expert interviews, panel discussions, and approximately 50 open source resources.

I. Freight Rail Mode

The following overview describes the assets, ownership structure, funding sources, regulation, interdependencies, and resilience status of the mode.

Table G-1. Freight Rail Mode Overview

Freight Rail Mode
ASSETS AND INFRASTRUCTURE
• **Physical Assets:** 1,335,639 freight cars in service as of 2014: 373,838 (Class I freight cars); 88,122 (Non-Class I freight cars); and 873,679 (freight cars owned by car companies and shippers). Over 25,000 Class I locomotives in service. 574 freight railroads: 7 Class I railroad systems; 23 regional railroad systems; and over 500 local railroad systems. Generally, Class III carriers are referred to as short lines, and Class II carriers are referred to as regional railroads. Class II and Class III railroads account for 31% of U.S. freight rail mileage and 10 percent of employees. The more than 550 short line and regional railroads operate in every U.S. state except Hawaii.
• **System Assets:** Centralized Traffic Control networks, electronically controlled brakes, on-board computers and network systems, automated equipment identifiers, global positioning system (GPS) tracking, car scheduling and train order systems, locomotive remote controls, and communications systems (e.g. two-way wireless connections, commercial communications cables for signal control).
• More than 138,500 freight railroad mileage, with about 52,300 miles of primary rail corridor
• DoD has more than 35,000 miles of rail line designed as part of the Strategic Rail Corridor Network

Freight Rail Mode

- Hazardous materials (HAZMAT) traverse more than 72 billion ton-miles on rail
- Information systems and communication technologies, such as onboard computers, local area networks, automated equipment identifiers, and global positioning system (GPS) tracking
- Top 5 commodities transported: intermodal, coal, chemicals, farm products, and food products

OWNERSHIP AND OPERATION STRUCTURE

- Freight rail system (assets, facilities, services) is primarily privately owned, operated, and maintained
- Primary corridor miles are owned and operated by the 7 Class I freight railroads: BNSF Railway, Canadian National (Grand Trunk Corporation), Canadian Pacific (Soo Line), CSX Transportation, Kansas City Southern, Norfolk Southern, and Union Pacific. As of 2008, 94,000 miles of rail were owned by just the 7 Class I rail companies, with the primary rail corridor nearly owned entirely by the Class I rail.
- 69% of all railroad mileage is operated by the 7 Class I rail companies, with a minority operated by non-Class I rail companies.
- Of the freight cars in service, approximately 63% are owned by private car companies and shippers, 30% are owned by the private Class I railroad companies, and 7.5% are owned by non-Class I railroads.
- Freight rail system is in a long-term process of consolidation among the major Class I freight railroads.

FUNDING SOURCES

- Funded almost entirely by income from private sector operations (e.g. BNSF announced a $5B program, including positive train control, intermodal expansion, intermodal expansion, and acquisition)
- Federal freight rail funding is discretionary and awarded on a competitive, nationwide basis through DOT grants ($5B devoted to FRA from President's FY2015 budget)
- Some states provide freight infrastructure investment funding (e.g. WA provides $52 million in funding and PA provides $10.5 million)

REGULATION

- DHS (focus on security); key division is the Transportation Security Administration, esp. the Freight Rail Security Division with key mission areas of vulnerability reduction and attack consequences
- DOT (focus on safety, standards, coordination of systems, and regulation); key divisions include the Federal Railroad Administration, Pipeline and Hazardous Materials Safety Administration, and Surface Transportation Board

KEY INTERMODAL DEPENDENCIES

There are approximately 2,270 rail facilities in the U.S. performing some intermodal functions, with only 20% handling significant intermodal volume. Most of the freight rail intermodal movement is associated with trucks (**highway mode**). However, most intermodal terminals are located near major **maritime** gateways (Los Angeles, New York) and inland ports (Chicago, Kansas City); suggesting a strong maritime mode interdependency. Passenger rail (**mass transit mode**) operates on some track owned by freight rail and both share bridges and tunnels.

CROSS-SECTOR INTERDEPENDENCIES

Freight rail is dependent on the **Energy Sector** for fuel and this sector also depends on freight rail. In 2013, U.S. Class I railroads originated 407,761 carloads of crude oil (up from 9,500 in 2008). The **Defense Industrial Base** requires 30,000 miles of rail. Rail has become increasingly reliant on **information technology** systems and **communications** technologies. A combined total of almost 5 million carloads of **chemicals** and **food and agriculture** products were transported by rail in 2011.

Freight Rail Mode
CYBERSECURITY AND RESILIENCY STATUS
Cybersecurity mechanisms and efforts are lacking in the freight rail mode. The freight rail **industry has not created a cybersecurity standard** or cyber evaluation metrics, which may be related to Federal regulation views and the density of private ownership/operation of assets. However, in a 2013 DHS report, one of the major Class I railroad companies stressed it was willing to formulate cyber evaluation metrics, which can be used as a baseline for an industry standard. Aging equipment, economic pressures, operational efficiencies, operator downsizing, and installation of train control systems translate to the **freight rail industry increasingly looking to technological solutions**.

Practices Contributing to Freight Rail Resilience

Robustness

- Develop a strategic security plan for freight rail
- Conduct ongoing toxic inhalation hazardous (TIH) material rail tank car vulnerability assessments
- Continue the Transportation Security Administration (TSA) TIH Rail Risk Reduction Program to assess potential risk of TIH shipments in high-threat urban areas
- Develop annual freight rail threat assessments
- Conduct vulnerability and consequence assessments of 13 specific TIH materials
- Conduct regular Rail Corridor Reviews to determine vulnerabilities and consequences of TIH cars
- Carry out Corporate Security Reviews to analyze freight rail company security plans and procedures
- Develop a critical infrastructure risk assessment tool for freight rail bridges
- Maintain prioritized critical infrastructure lists, including freight rail assets
- Address, via the Federal Government and private industry, cybersecurity challenges through conferences and security briefings
- Promote the development of new technology to improve system performance and resilience
- Initiate and continue a rail investment planning effort for the Northeast Corridor, including the development of resilient and redundant systems
- Develop strategic plans to assess statewide freight system resilience
- Use rails themselves as communication channels for alerts from signal controllers and trackside signals
- Ensure locomotives and rail cars are tagged with automatic identification transponders to automatically record locations
- Lead peer-to-peer-based safety programs for private industry
- Provide programs to mitigate fatigue-caused accidents
- Improve rail inspection procedures using new state-of-the-art inspection techniques
- Support Confidential Close Call Reporting System (C3RS), pilot programs with freight railroads
- Conduct gap analysis and determine present modeling capabilities for tank car consequence analysis and plume modeling

Resourcefulness

- Host specialized training and hands-on field exercises for emergency responders on how to manage crude oil train accidents
- Develop multiple scenarios involving freight train derailing
- Conduct a scenario drive tabletop exercise focusing on information flow during a freight rail security incident
- Regularly conduct Intermodal Security Training Exercise Program (I-STEP) activities
- Sponsor and administer full-scale rail tank car exercises for fire departments
- Conduct a multi-jurisdictional functional exercise simulating a hazardous material derailment in Texas
- Routinely commission social engineer hackers to try to hack network systems and determine network strength
- Provide CD-ROM-based training on improvised explosive devices (IEDs) at railroads
- Develop, enable the customization of, and disseminate the TSA freight rail security brochure to companies
- Provide online emergency responder training for freight rail companies

Rapid Recovery

- Utilize the TSA TIH material tank car consequence analysis/validation project, which predicts the behavior of TIH material release after an attack on rail tank cars
- Develop, in collaboration with TSA and railroad associations, the Transit and Rail Intelligence Awareness Daily (TRIAD) Report—providing near-real-time information
- Put in place preparedness measures, for extreme weather events and initiate a coordinated response, enabling rapid recovery
- Host a Chemical Release Emergency Response and Preparedness Strategy Session to improve local emergency response and preparedness
- Obtain regional command vehicles to provide command and communications integration response capabilities
- Utilize railroad industry security threat level alert systems
- Maintain and use the freight rail portal on the Homeland Security Information Network for Critical Infrastructure (HSIN-CI)
- Ensure a regional primary and alternate point of contact for intelligence and security information for freight rail carriers in High Threat Urban Areas
- Provide 24/7 threat warning and incident reporting through the American Railroads Security Operations Center
- Harden rail cars through the ongoing U.S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T) efforts
- Develop railroad emergency plans for states and agencies to cover response and recovery
- Conduct major city roundtables with the emergency response community to enhance planning and response procedures for a catastrophic release of toxic materials

Adaptability

- Update the General Code of Operating Rules based on lessons learned from a 2004 derailment of a chemical-carrying railcar
- Facilitate network strength by incorporating companies' "ethical hackers'" efforts into the companies' network security practices
- Construct equipment to better withstand destructive forces through the Next Generation Rail Tank Car Effort
- Collaboratively engage in tank car safety and security research associated with TIH material transport through the Advanced Tank Car Collaborative Research Program
- Conduct testing of large quantities of TIH releases to better understand TIH impact through the DHS S&T Chemical Security Analysis Center
- Adopt and implement security action items by freight railroads through TSA's Best Practices and Security Action Items Implementation Surveys
- Conduct an Ammonium Nitrate Detonability Study to assess outcomes of a terrorist attack on rail car with agricultural-grade ammonium nitrate and address gaps
- Conduct dispersion modeling analysis and validate dispersion modeling results through information from DHS S&T TIH material exercises

II. Mass Transit and Passenger Rail Mode

The following overview describes the assets, ownership structure, funding sources, regulation, interdependencies, and resilience status of the mode.

Table G-2. Mass Transit and Passenger Rail Mode Overview

Mass Transit and Passenger Rail Mode
ASSETS AND INFRASTRUCTURE
• **Transit Modes:** Buses, rail (commuter, heavy, and light rail; trolleys; streetcars), long-distance rail, cable cars • **Physical Assets:** Vehicles, guideways (tunnels, bridges, tracks, etc.);fare revenue collection equipment; maintenance facilities; passenger stations; administration buildings; and service vehicles • **System Assets:** Train control and supervisory control and data acquisition (SCADA) systems, automatic vehicle locator systems, automated dispatching systems, vehicle guidance systems, traffic signaling systems, automated fare boxes, security control systems, and communications systems (e.g. public address and information devices) • 6,000 transit systems, with 565 transit systems operating in major urban areas (50,000+ populations) • U.S. mass transit fleet comprised of 144,000 vehicles, of which 56 percent are buses • 525 bus agencies, 488 demand response/taxi agencies, 29 light rail agencies, 25 commuter rail agencies, 15 heavy rail agencies • Amtrak: 22,000 miles, 500+ stations in 46 States, and 300 daily trains
OWNERSHIP AND OPERATION STRUCTURE

Mass Transit and Passenger Rail Mode

- Mass transit facilities and services are primarily owned and operated by municipal transit authorities.
- Inter-city long-distance rail is privately-operated: Amtrak and Alaska Rail.
- Amtrak owns approximately 3.5% of the 22,000 miles of track utilized (primarily from Boston, MA, to Washington, DC); the remaining 21,250 miles are owned by privately-owned/operated freight railroads.
- Based on a sample of 50 transit rail agencies, serving populations greater than 1 million: 64% operated as a municipal authority, 14% operated as a city organization, 12% operated as a semi-public corporation or a subsidiary, 4% were operated by the State and 1agency operated as a non-profit.
- 2/3 of mass transit ridership concentrated to 'Northeast Corridor' (between Boston, MA, and Washington, DC). A majority of the agencies in this region are municipal transit authorities. Some of the major agencies (i.e. in New York and New Jersey) are either a semi-public corporation or a subsidiary.

FUNDING SOURCES

- Mass transit authorities are funded through:
  - State and local funding
  - Federal grants ($17.6B devoted to FTA from the White House FY2015 budget)
  - Operating revenue
  - Over the past 10 years, capital investment increased by 17.9% and the Federal Government accounted for 41.4% of all capital invested in transit during that period
- Amtrak: Operating revenue ($2.9B in FY2013), Federal funding ($1.39B appropriated FY2013), Amtrak Capital Grants $760M FY2015 Budget)

REGULATION

- DHS (focus on security); key division is the Transportation Security Administration, particularly the Mass Transit Division
- DOT (focus on safety, standards, coordination of systems, and regulation); key divisions include the Federal Transit Authority and the Federal Railroad Administration

KEY INTERMODAL DEPENDENCIES

Commuter rail operates on some track owned by freight rail (**freight rail mode**) and both share bridges and tunnels. The mass transit mode is fundamentally multi-modal (e.g. using light and long-distance rail, buses, and trolleys). In operating daily interconnectivity within the mode, the mass transit system can be dependent on the **highway mode** and connects to **all other transportation modes**.

CROSS-SECTOR INTERDEPENDENCIES

City subway systems and light rail draw on electricity (**energy sector**) as a power source and commuter rail cars can be powered by diesel and/or electricity. Mass transit information is interdependent with **information technology sector** for many purposes, such as: real-time information to the public, Web sites, IT-enabled transportation pricing systems, emergency alerts, intelligent speed adaptations, and other advanced transportation management systems. With GPS and dedicated communications technologies, the mass transit mode is also dependent on the **communications sector**.

CYBERSECURITY AND RESILIENCY STATUS

Increasingly, cybersecurity is a concern for transit agencies, as the control and management systems have become **more dependent on information technology**. Not only is there a high degree of dependency, but the IT infrastructure in the mass transit mode is made of complex and strongly interconnected components and services. The **mode is on track** for advancing industrial control system cybersecurity standards and has active

Mass Transit and Passenger Rail Mode

information sharing and analysis centers to support cyber threat information sharing. Due to the autonomous operation of intermodal transit types and the interconnectedness with other modes, this mode includes **unique cybersecurity challenges**, such as: different degrees of control systems, information technology business/management division, shared communications, and legacy control system upgrades to modern networks open to cyber vulnerabilities. A **holistic solution is needed** involving strategic action addressing transit operations, people, and facilities, alongside increased knowledge sharing and awareness.
To combat cyber threats and improve cyber-resilience, transit agencies should focus on: developing cybersecurity standards, policies, and procedures; ensuring the capability and interoperability of information system technology and transit infrastructure; promoting cybersecurity awareness, training, and education; and full integrating information security into the agency's risk management strategy.

Practices Contributing to Mass Transit and Passenger Rail Resilience

Robustness

- Ensure Federal Railroad Administration-approved emergency preparedness plan for intercity and commuter passenger service rail systems are in place
- Host, through TSA, annual Transit Security Roundtables to join state, local, tribal, and territorial partners; mass transit authorities; and industry to address terrorism prevention and response challenges
- Conduct security assessments of mass transit agencies through the TSA Surface Transportation Security Inspection Program
- Conduct Baseline Assessment for Security Enhancement assessments, through TSA
- Provide transit security directors and law enforcement with joint DHS Office of Intelligence and Analysis, TSA Office of Intelligence, and FBI mass transit security analysis
- Deploy secure lines to TSA for the largest mass transit agencies
- Disseminate, through TSA, Security Awareness Messages
- Conduct thorough risk assessments of key mass transit assets through the DHS Office of Infrastructure Protection's Protective Security Advisors program
- Assess mass transit systems' security plans/programs to identify concerns and improve efficiencies through TSA's Transportation Security Inspectors program
- Utilize a scenario-based cross-modal risk assessment based on threats, vulnerabilities, and consequences from TSA's Transportation Sector Security Risk Assessment (TSSRA) program
- Provide an industry-focused 24/7 information-sharing capability by way of the Public Transit Information Sharing and Analysis Center
- Engage with the Interagency Tunnel Risk Mitigation Working Group to reduce the likelihood and impact of a catastrophic breach of an underwater mass transit tunnel
- Conduct structural vulnerability assessments of 29 underwater tunnels in the rail and transit community
- Interface monthly, through TSA's Peer Advisory Group, to discuss transit security and anti-terrorism approaches

- Develop a comprehensive assets analysis, including risk based on climate effects
- Conduct flood vulnerability assessments on mass transit assets
- Conduct criticality analysis to assess climate vulnerability
- Initiate climate change risk assessments in major metropolitan area agencies
- Participate in a study of sea-level-rise impacts on transportation infrastructure
- Conduct an internal risk assessment of transit assets, as well as an initial cost/benefit screening of potential climate adaptation strategies
- Construct resilience facilities, such as through flood-proofing adaptation measures

Resourcefulness

- Train frontline officers and staff in security awareness, behavior recognition, and immediate threat response through TSA's Mass Transit Security Training Program
- Promote and engage with multi-phase workshops, tabletop exercises, and lessons learned working groups through TSA's I-STEP
- Execute the largest coordinated rail security operations exercise in the Northeast Corridor, with Amtrak and TSA
- Coordinate random, unpredictable security surges through multi-agency security sweeps with law enforcement and transportation authorities
- Conduct surged security inspections through, similar to the NY MTA Train Order Maintenance Sweeps
- Deploy Transit Shield in major metropolitan transit systems to create security patrols and sweeps
- Conduct joint, random security inspections
- Participate in TSA's Mass Transit Security Training Program basic training and follow-on levels
- Participate in the Bus Operator Awareness/Research and Development Training Program, focused on security awareness principles
- Provide exercise, training, and planning support to reinforce the mass transit mode implementation of TSA's I-STEP
- Conduct commuter rail car passenger egress tests
- Coordinate multi-jurisdictional security operations through Operation BusSafe
- Host scheduled emergency training exercises through public transportation agencies

Rapid Recovery

- Engage with a wide variety of mass transit partners to integrate available resources for enhanced response
- Ensure tabletop discussion themes include the coordination of multi-partner response, roles and responsibilities, and available resources
- Initiate preemptive service closures to protect customers and assets
- Upgrade communications technology and acquire the capacity to send out 1 million simultaneous email alerts

- Improve the website, server capacity, information feeds, public address systems, and information screens to operate under emergency conditions
- Install more ventilation for electrical equipment in response to heat waves
- Build a relay room that will keep electrical equipment cool using energy-efficient natural and mechanical ventilation systems
- Operate an evacuee pickup/delivery program as part of the city-assisted evacuation plans
- Ensure that a backup mobile command center is on ready alert (onboard systems include satellite communications, GPS tracking, dispatch, and control capabilities for eight person crew)
- Secure equipment safe havens for "out of region" positioning and storage
- Ensure ongoing fleet/equipment replacement and upgrade programs

Adaptability

- Produce projects similar to Amtrak's Hudson Yards Resiliency and Right-of-Way Preservation Project, which is an outgrowth of system interconnectedness lessons learned from Superstorm Sandy
- Test different tunnel liner materials for enhanced resilience, such as through the Interagency Tunnel Risk Mitigation Working Group
- Utilize TSA-led mass transit roundtables and coordinating councils to produce requirements submitted to DHS Science and Technology Directorate (S&T) for research and development
- Enable the realistic examination of how to improve car design for better protection and provide a training tool to improve response capabilities, such as through a passenger rail car emergency evacuation simulator
- Remove signal system components outside of the flood zone during post-hurricane activities
- Test prototype flood-prevention measures for station stairway entrances
- Build raised ventilation grates to prevent storm water incursion in response to past flooding
- Identify areas with frequent rail buckling and then develop expansion joints, permitting the rail to expand and stop buckling
- Acknowledge the complexities of the transportation system and identify the following transit-related future strategies:
    - Plan for temporary transit services in the event of subway system suspensions
    - Identify critical transportation network elements and improve transportation responses to major events through regular resilience planning exercises
    - Plan for and install new pedestrian and bicycle facilities to improve connectivity to key transportation hubs
    - Improve at all levels communications about the restoration of transportation services
- Establish a recovery and resiliency division after major disruptions, such as in the case of Superstorm Sandy
- Complete an earthquake retrofit effort, completed by the Bay Area Rapid Transit in 2013

III. Highway and Motor Carrier Mode

The following overview describes the assets, ownership structure, funding sources, regulation, interdependencies, and resilience status of the mode.

Table G-3. Highway and Motor Carrier Mode Overview

Highway and Motor Carrier Mode
ASSETS AND INFRASTRUCTURE
• **Physical Assets:** highways and roads, bridges, tunnels; automobiles, motorcycles, trucks carrying hazardous materials, other commercial freight vehicles, motor coaches, and school buses; does not include intra-city or mass transit buses; motorcoach companies, buses, terminals, repair facilities; motor carrier companies, trucks, trailers, terminals, repair facilities; rest areas • **System Assets:** electronic traffic signs; traffic management centers; business systems for individual companies; National Bus Traffic Association's computer network; Highway Information Sharing and Analysis Center; Automated Commercial Environmental/Truck eManifest system • 3.9 million miles of public roads; National Highway System is about 200,000 miles, including 47,000 interstate miles • 600,000 bridges over 20 feet of span; 366 highway tunnels over 100 meters in length • 1.2 million trucking companies operating 15.5 million trucks, including 42,000 HAZMAT trucks • 10 million licensed commercial vehicle drivers; 2.7 million HAZMAT drivers • 3,137 bus companies, 750 million passengers annually; 475,000 school buses, 25 million students daily
OWNERSHIP AND OPERATION STRUCTURE
• Consists mostly of privately owned vehicles operating predominantly on publicly maintained roads. • Ownership and operational control of highway infrastructure system rarely falls under one entity. Roads, bridges, and tunnels can owned and operated by states, counties, parishes, municipalities, tribal authorities, private enterprise, and other authorities. • More than 75% of U.S. highways are locally owned. Some highways are owned by states and even fewer are Federally-owned. • Most U.S. bridges are either locally- or state- owned, with some being Federally- or privately-owned. • Value of Private Fixed Assets, nonresidential transportation equipment: trucks, buses, and truck trailers: $382.6 billion (2012); autos: $169.1 billion (2012). • Value of Private Fixed Assets by Industry, Transportation and warehousing, truck transportation structures: $25.4 billion (2012). • Value of Government fixed assets: highways and streets: $1,126.8 billion (includes non-defense, Federal Government, highways and streets: $21.1 billion; non-Federal highways and streets: $1,105.7 billion).
FUNDING SOURCES
• 25% of U.S. highways paid for in part by Federal Government, the remaining portion is from State and local governments • Federal, state, and local governments spent $161B in 2009 to build and maintain highway infrastructure supporting 3 trillion vehicle miles of travel • Federal Highway Trust Fund

Highway and Motor Carrier Mode

- Motor fuel taxes fund 90% of the Highway Trust Fund, with most of the tax revenue directed to the Highway Account, not Mass Transit
- $51B authorized from the Fund to 4 DOT agencies in FY2013—81% of this was authorized to FHWA
- White House FY2015 budget requests $49B for the FHWA

REGULATION

- DHS (focus on security); key division is the Transportation Security Administration, particularly the Surface Division, Highway and Motor Carrier Branch
- DOT (focus on safety, standards, coordination of systems, and regulation); key divisions include the Federal Motor Carrier Safety Administration, FHWA, National Highway Traffic Safety Administration, and Surface Transportation Board

KEY INTERMODAL DEPENDENCIES

The Highway and Motor Carrier mode is **connected to all other modes of transportation through a vast network** of roadways, connectors, Interstates, other highway systems, and multiple kinds of carriers and surface vehicles. Passenger-driven modes, such as **mass transit** are closely dependent on the highways.

CROSS-SECTOR INTERDEPENDENCIES

Similar to all transportation modes, there is a strong connection to the **energy** sector for fuel supplies. The trucking component of the Highway and Motor Carrier mode uniquely connects to multiple sectors. Freight trucking moves goods from **critical manufacturing**, ports (**maritime**) and **freight rail** and moves **chemicals** and **food and agriculture.** The functioning of highway systems is also dependent on the **communications** and **information technology** sectors, such as in highway advisories or in GPS-based freight trucking tools.

CYBERSECURITY AND RESILIENCY STATUS

The Nation's roadway infrastructure is interconnected not just with asphalt and concrete, but by control systems which ensure the infrastructure's safe operation for motorists. These interconnected road networks are **controlled by numerous systems** composed of traffic signal controllers, ramp meters, dynamic message signs, roadway sensors, road weather information sensors, etc. These devices are frequently **connected into a traffic management center** where roadway operators monitor both traffic conditions and the status of the control systems to ensure safe and efficient transportation.

The **highway industry uses Intelligent Transportation Systems (ITS)** to improve performance in both operational efficiencies and roadway mobility. ITS leverages advance in communication and computer technologies to maximize safety, mobility, and environmental performance. The two most prevalent ITS are the traffic management and roadway subsystems, which link control systems from multiple agencies and multiple modes together to improve coordination. These control systems use information from traffic sensors to regulate the flow of traffic entering roadways and freeways by monitoring traffic flow and signaling traffic light changes based on current traffic conditions. Video surveillance systems are often used in tandem with signal systems to provide enhanced situational awareness to operation staff and for public information. Also, signal preemption systems exist for emergency vehicles, as well as signal priority for transit buses.

Modern ITS also include field devices to deliver sensor information from throughout a region's transportation network over multiple communications networks to various transportation management centers. These devices receive command and control instructions in response. In some parts of the county, the information network includes **distribution to individual consumers via advanced traveler information systems** (ATIS), which can deliver real-time, current traffic, weather, and other travel-related information to cars, drivers, and other

Highway and Motor Carrier Mode
travelers. **Challenges for ITS** include the use of old legacy control devices, the layering of modern IT and meshing of telecommunications systems with increasing reliance on wireless protocols, shared use of telecommunications networks, and location of much of the distributed ITS network in public domain areas.

Practices Contributing to Highway and Motor Carrier Resilience

Robustness

- Use the following assessment and security programs:
  - Highway Program Baseline Assessment for Security Enhancements (BASE) to assess the level of security across all transportation modes in the highway sector
  - Transportation Security Template and Assessment Review Toolkit to help stakeholders incorporate BASE recommendations
  - Visible Intermodal Prevention and Response (VIPR) program to augment security at key highway transportation facilities in urban areas as a deterrent
- Develop counterterrorism pocket guides for the school bus, trucking, motor coach, and highway infrastructure modes
- Conduct 3.5 million commercial motor vehicle roadside inspections each year
- Establish the Unified Registration System, which all motor carriers, property brokers, and freight forwarders engaged in interstate transportation of property or passengers are required to update
- Develop the Transportation Futures Project to study future uses of rights of way, travel trends, and the role of highway transportation in rural areas of the nation
- Sponsor Climate Resilience Pilots with several states, such as Tennessee, Michigan, Texas, Maine, Arizona, Alabama, Connecticut, Massachusetts, New York, Florida, Oregon, California, Washington State, Iowa, and Maryland
- Plan for all types of emergencies
- Establish mutual-aid agreements
- Develop procedures to guide actions to be taken early in an emergency
- Establish pre-selected incident command post locations
- Be prepared to communicate using various methods, such as fax, handouts, maps, cell phones, satellite phones, cable television, face-to-face, email, the Internet, and ham radio operators
- Maintain close ties with law enforcement entities
- Be prepared to activate the emergency alert system early
- Prepare for emergencies in advance to make day-of-event decisions earlier
- Set priorities as quickly as possible
- Use volunteers in a support role
- Know where you are going and how to get there
- Establish reliable backup power to maintain normal ITS functions

Resourcefulness

- Distribute the School Transportation Security Training DVD to public school districts for them to incorporate into the training of future drivers
- Conduct training exercises and drills and practice with other entities
- Practice cooperation and coordination between entities and during normal times
- Practice interagency cooperation
- Remember to practice for the expected and the unexpected
- Train first-, second-, and third-string staff for emergencies
- Have a redundant system of trained agency personnel and additional trained staff
- Conduct I-STEP tabletop exercises to explore prevention and protection capabilities of a cross section of trucking assets
- Train trucking owners/operators in procedures for transporting hazardous goods
- Develop and test emergency plans

Rapid Recovery

- Inform the community of any potential dangers prior to the incident
- Distribute maps and route evacuation information
- Prepare evacuation plans
- Use an incident command system and conduct incident planning
- Use information technology (IT) systems to monitor the situation
- Develop a joint information center, use various means—both internal and external—to communicate, and have call-out procedures and contact lists
- Develop action plans to include the use of buses to transport people who do not drive and for situations where roads are congested or fuel supplies are limited
- Have multiple agencies participate in statewide emergency and traffic incident response planning
- Learn from previous events and incorporate lessons learned into response plans
- Proactively plan for and coordinate activities related to special events
- Use advanced technology, such as information systems, to provide information on existing conditions to decision makers and communicate with other agencies involved in emergency response
- Determine how the public perceives the public messages regarding evacuations and notify the public in advance of potential problems
- Make the community aware of emergency incidents and use multiple ways to communicate with the public
- Provide pre-evacuation notices to homeowners in fire-prone areas and host evacuation information on the Internet
- Have pre-planned alternate routes for traffic and provide evacuation traffic management
- Use contra-flow lanes for evacuations

- Coordinate refuge-of-last-resort procedures
- Integrate emergency services centers with various functions and co-locate entities responsible for evacuations
- Use real-time information with law enforcement, fire, and rescue agencies and provide accurate, timely information
- Have agreements for electronic connectivity
- Have a pre-established internal coordination plan and system for external coordination
- Address potential traffic impediments
- Develop a reporting and incident-tracking scheme that is understood by all
- Evacuate people quickly out of the incident area to locations where family members can pick them up
- Have emergency transportation operation systems in place prior to an emergency event
- Have emergency evacuation routes and markings, alternate routes and markings, traffic control points, and reception centers and evacuee support facilities identified prior to an actual event
- Have one route in for responders and no mixing of evacuee traffic
- Stage resources along evacuation routes
- Develop redundancy in several areas: the regional transportation network, agency personnel, communications and utilities, control centers, and equipment and supplies
- Have an on-scene agency-in-charge
- Recognize that solutions can evolve
- Publish a transportation emergency response checklist, including categories of emergency transportation plans, inter-jurisdictional and intermodal cooperation, training preparedness, and transportation systems
- Conduct inventory of backup resources
- Expect loss of power and communications and establish backup power and communication supplies
- Realize a multimedia approach may be necessary
- Coordinate the response with others
- Utilize the resources of all participants
- Use available tools to aid in the decision to evacuate

Adaptability

- Develop the Framework for Improving Resilience of Bridge Design, incorporating lessons from past bridge failures, to help bridge designers perform failure analysis
- Adopt a mindset of resilience
- Assess the needs of an extended loss of the primary system versus a temporary interruption
- Consider the failure of even quadruple redundancy
- Do not ignore new technology solutions
- Review and learn from past events and review emergency plans after an event

- Use advanced IT systems (ITS), but also a mix of older technology
- Delegate decision making down
- Use incident management teams and have incident management teams work with infrastructure and utility personnel
- Maintain relationships (pre-existing relationships among agencies and personnel are key to emergency management success)
- Involve law enforcement and non-traditional agencies
- Conduct a collaborative post-incident review
- Identify and develop evacuation routes and remember that evacuations can cross state lines
- Modify evacuation routes as needed
- Realize priorities may conflict and that they will change over time
- Be ready to throw out the procedures if they do not work in an evacuation
- Delegate responsibility down to the appropriate level in the organization
- Overcome the need to take action without planning
- Develop clear procedures for evacuations based on experience
- Build redundancy into institutions and physical systems, including personnel, communications, utilities, and control centers
- Pre-position supplies and equipment (if the supplies and equipment can be identified)
- Remember the transit system can provide redundancy
- Have alternative emergency operations centers
- Adapt response plans to the incident
- Review and update crisis plans with training

IV. Aviation Mode

The following overview describes the assets, ownership structure, funding sources, regulation, interdependencies, and resilience status of the mode.

Table G-4. Aviation Mode Overview

Aviation Mode
ASSETS AND INFRASTRUCTURE
• **Physical Assets:** aircraft; commercial airports, general aviation airports, heliports, and landing strips; civil and joint use military airports, heliports, short takeoff /landing ports, and seaplane bases; terminals, vehicles, and supporting infrastructure • **System Assets:** air traffic control systems, NextGen technology, Safety Management Systems, TSA Pre-Check, Position-Navigation-Timing data, data networks, various wireless local area networks • National Airspace System (NAS) is part of the Aviation Transportation System (ATS). NAS includes 690 air traffic control facilities and 11,000 air navigation facilities; regulated components include air cargo, commercial airlines, commercial airports, general aviation, and flight schools • 19,453 U.S. landing facilities (including airports, heliports, seaplane bases), comprised of 14,009 being private-use facilities, 5,155 public-use facilities, and 289 military-facilities

Aviation Mode

- 506 commercial service airports, including 392 primary commercial service airports with more than 10,000 passengers boarding per year
- DHS manages 66 domestic airlines
- 7,185 aircraft in the U.S. commercial airline fleet (including regional carriers): 3,739 mainline air carrier passenger aircraft (over 90 seats), 879 mainline air carrier cargo aircraft, and 2,567 regional carrier aircraft (jets, turboprops, and pistons); 211,450 general aviation aircraft (representing 77% of all flights)
- U.S. air carriers fly 37.1 billion revenue-ton miles of air cargo annually: 13.8 billion domestically and 23.3 billion internationally

OWNERSHIP AND OPERATION STRUCTURE

- ATS infrastructure is owned, operated, or regulated by public and private sector entities both within and outside the U.S. Considerable portions of the infrastructure are owned and operated by state, local, and tribal governments, as well as private sector entities.
- Air-cargo services in the private sector operate in public airways and mostly public airports. Airports are typically owned by public authorities, although terminals are usually owned or managed by private operators. Air navigation is mostly controlled by the Federal Government, and safety is regulated by all levels of government.
- Guidelines and requirements are developed by international, Federal, state, and local authorities for specific aspects of aviation, passenger, baggage, and cargo operations.
- Value of Private Fixed Assets, nonresidential equipment: aircraft: $342.3 billion (2012); nonresidential structures: transportation, air: $35.8 billion (2012).
- Value of Private Fixed Assets by Industry, Transportation and warehousing, air transportation structures: $5.6 billion (2012).

FUNDING SOURCES

- White House FY 2015 budget request included $15.4 billion for the DOT Federal Aviation Administration
- State aviation funding is limited to funds through state aviation commissions & DOTs
- To fund infrastructure, many airports rely on the FAA's Airport Improvement Program grants, Federally authorized-Passenger Facility Charges, and non-aviation revenue (e.g. from parking, concessions)
- An estimate of airport's capital development needs between 2013–2017 was $14.3 billion annually

REGULATION

- DHS (focus on security); key division is TSA, particularly the Offices of Law Enforcement/Federal Air Marshal Service, Security Operations, and Security Policy and Industry Engagement; also Customs & Border Protection, Office of Air and Marine
- DOT (focus on safety, standards, coordination of systems, and regulation), key division is FAA, particularly the Offices of Airports, Air Traffic, and Aviation Safety; and NextGen

KEY INTERMODAL DEPENDENCIES

The ATS is **linked to all other modes** through freight and passenger terminals, which connect to the National Highway System, port terminals, truck/rail facilities, intercity bus terminals, truck/pipeline terminals, ferry terminals, public transit stations, multipurpose passenger facilities, and mass transit and AMTRAK stations.

CROSS-SECTOR INTERDEPENDENCIES

Aviation is used as a means of transporting people and freight, and connects to multiple sectors through personnel operating within those sectors or infrastructure or system linkages. Most importantly, the aviation sector depends on fuel (**energy**), **communications**, and **information technology** to support its daily operations.

Aviation Mode
The **emergency services sector** and the **public health sector** utilize general aviation airports for critical missions and **food and agriculture** utilize aviation for aerial application of crop protection products.
CYBERSECURITY AND RESILIENCY STATUS
The NAS has a **mature cybersecurity program** in place; however, there **may be vulnerabilities in aviation control systems** used to operate airlines, airline information services, and passenger information. One challenge is that, in the effort to reduce airplane weight, wiring within aircraft is being replaced with wireless systems, which are potentially more vulnerable to cybersecurity threats. Relatedly, aircraft navigation and communications functions are transitioning from isolated systems to being integrated into a centralized network system dependent upon digital information exchange between the e-enabled aircraft and external networks located on the ground and on other e-enabled aircraft. Aircraft systems are also **becoming more connected to external systems**, so two-way transfer of critical information is easier, but also more vulnerable to inaccurate information being transferred to and from the airplane.

Practices Contributing to Aviation Resilience

Robustness

- Implement risk-based approaches designed to deliver the most effective security in the most efficient manner
- Work to achieve a high level of safety through overlapping layers of operational procedures and robust infrastructure built for higher levels of reliability and redundancy
- Build awareness of interdependencies of cyber threats across both operations and mission support
- Implement the U.S. Department of Transportation's Climate Adaptation Plan through Federal Aviation Administration (FAA) projects intended to enhance the mode's resilience, including airport sustainability planning, navigation infrastructure assessment, and NextGen Network Enabled Weather systems
- Improve the resilience of the air navigation system's resistance to interruptions and signal loss
- Complete the TSSRA
- Utilize the Aviation Modal Risk Assessment to incorporate relevant threat, vulnerability, and consequence data to prioritize risks unique to the aviation mode
- Implement a layered approach to security and resilience in the aviation mode, including the following elements: intelligence, U.S. Customs and Border Patrol (CBP), joint terrorism task force, no-fly list and passenger pre-screening, crew vetting, VIPR, canines, behavior detection officers, travel document checker, checkpoint/transportation security officers, checked baggage, transportation security inspectors, random employee screening, bomb appraisal officers, Federal Air Marshal Service (FAMS), Federal flight deck officers, trained flight crew, law enforcement officers, hardened cockpit door, and passengers
- Center risk mitigation activities within the aviation mode on the following:
  - Security vetting of workers, travelers, and shippers
  - Securing of critical physical infrastructure

  - Implementation of risk mitigating operational practices
  - Implementation of unpredictable operational deterrence
  - Screening of workers, travelers, and cargo
  - Security awareness and response training
  - Preparedness and response exercises
  - Awareness and preparedness
  - Leveraging of technologies
  - Transportation industry security planning
  - Security programs and vulnerability assessments
  - Security of critical cyber infrastructure
- Enhance the effectiveness of international FAMS agreements
- Implement an enhanced insider threat mitigation program
- Implement improved flexible, unpredictable screening methods (e.g., VIPR, Playbook, Risk Emphasized Flight Screening, and Aviation Screening Assessment Program)
- Collaborate with other agencies and aviation modal partners to mitigate insider; cyber; and chemical, biological, radiological, nuclear, and explosive (CBRNE) threats
- Develop deployable sensor systems to detect and otherwise mitigate threats from hijacking/unauthorized diversion; explosive destruction; external attack; onboard CBRNE; or other attack of crew, passengers, or aircraft systems
- Develop Secure Airspace access and flight procedures based on a NextGen verification process that dynamically adjusts for aircraft performance and security considerations
- Enable dynamically adjustable airspace boundaries and access criteria of Security Restricted Airspace, Special Use Airspace, and Temporary Flight Restrictions
- Implement the remote terminal security screening concept to move the security perimeter farther away from the airport
- Develop security measures and practices for the emerging unmanned aircraft systems and expected commercial spacecraft or sub-orbital systems
- Continue the implementation of NextGen capabilities at 13 congested airports around the nation
- Continue the improvement in the NextGen En Route Automation Modernization program
- Continue planning the consolidation of the Air Route Traffic Control Centers and Terminal Radar Approach Control facilities into large, integrated facilities
- Continue the integration of Unmanned Aircraft Systems into the National Airspace System
- Improve FAA oversight for all U.S. repair stations

Resourcefulness

- Hold conference calls between airport, airline, FAA air traffic management, TSA, and CBP representatives to plan for evolving weather conditions, similar to communication efforts conducted in the anticipation of Superstorm Sandy

- Use alternate airports as logistics hubs away from major airports in order to bring in supplies for the region, such as when the Stewart International Airport was used when LaGuardia and JFK major airports were closed due to flooding during Superstorm Sandy
- Use fuel supplies from alternate locations to support first responders
- During emergency incidents, use alternate locations to support emergency functions:
  - Helicopter locations—for example, the Naval Air Station Joint Reserve Base New Orleans—as the principal helicopter staging area for rescue operations throughout the region
  - Small service airfield locations—for example, the airfield on the south shore of Lake Pontchartrain—as the processing and evacuation airport for medical critical transportation needs
- Continue to expand prevention, protection, response, and recovery capabilities across the aviation transportation system (ATS)
- Develop awareness and preparedness initiatives to enhance continuity of ATS operations
- Continue to identify technological opportunities to improve and expedite passenger and cargo screening capacity and capabilities
- Establish a process for long-range strategic planning to ensure research and development activity is coordinated and aligned with NextGen goals and objectives

Rapid Recovery

- Issue an annual hurricane and emergency preparedness and response procedures manual, with practices including the following:
  - Listed phone numbers for key command post positions, operational only when a storm is imminent; also listed names and office/cell phone numbers of key law enforcement personnel and emergency response offices in the county
  - Signed notice of activation of all personnel in the event of a hurricane warning; all law enforcement personnel are considered essential and required to be available for duty
  - Published and publicly distributed "Hurricane Safety Rules" for airport stakeholders
  - Clearly defined roles and responsibilities, including steps to take, for all operational, administrative, and support sections of the airport for different stages of the storm: pre-hurricane, hurricane advisory, hurricane watch, hurricane warning, during hurricane, and post hurricane
- Establish a seamless information-sharing process across modal segments
- Expand programs at state, local, tribal, and owner and operator levels to maintain awareness of employees and the traveling public regarding security threat identification and reporting
- Ensure emergency response communications through company management and public affairs personnel
- Coordinate response and recovery to disruptive incidents with Federal, state, and local governments
- Integrate security planning with disaster recovery planning, especially for aviation assets owned by the private sector

- Identify capacity and technology gaps in protection and prevention response capabilities
- Address multi-faceted challenges across the spectrum of aviation operations through a robust planning capability consisting of planners, processes, and procedures in order to prepare for rapid recovery
- Establish a unified multiagency command, including the direct involvement of aviation operations, and maintain command throughout response
- Verify the safety of disrupted aviation assets and operations to facilitate rapid recovery of airports

Adaptability

- Conduct research and testing of new designs at FAA's NextGen Test Bed for the National Airspace System at Embry-Riddle Aeronautical University
- Develop a usable cross-modal consequence model for evaluating threat impacts on sector-wide and ATS critical infrastructure
- Enhance awareness and assessments of interdependencies between modes and across sectors domestically and internationally
- Enhance international cooperation through partnerships with foreign governments and through international security standards for container security and collection of biometric data for incoming international passengers
- Build stronger international partnerships to raise overseas security levels for passengers, baggage, and cargo
- Develop plans and procedures to ensure continuity of operations for cyber information and control systems that support the operations of the aviation industry
- Conduct large and significant analysis of the way air traffic control risk, safety performance, and analysis of safety risks are managed in the United States, such as through the FAA Air Traffic Organization effort
- Establish the Fatigue Risk Management System to identify potential air controller cognitive performance and safety-related effects due to human fatigue
- Develop and implement a clearly defined plan on shutting down the airport at the time of projected gale force winds reaching the coast, and recalibrate plans after incidents, as needed
- Undertake adaptation and resilience activities in light of climate risk, such as the following:
  - At both Toronto Pearson and Oakland International Airports, managers in technical fields such as planning, engineering, and environment management reviewed and modified design criteria based on their understanding of potential climate change effects
  - Sensors embedded in pavement are used to monitor runway degradation from the sun or from standing water, thereby assisting in monitoring climate change
  - Several U.S. airports have participated in broad efforts by local, regional, or state stakeholders on the effects of climate change, resulting in awareness-raising and planning exercises, fact finding, and workshops

  - The Jacksonville Aviation Authority CEO commissioned a white paper to review the likely effects of climate change on the airport and its operations
  - The New York City Mayor directed the development of a risk-based response to climate change impacts; this effort identified a risk to airports from brownouts or blackouts at certain terminals, likely involving disruptions in baggage and security operations
  - In San Diego, the airport became engaged in a community effort to assess the impact of sea level rise
  - The Oakland International Airport participated in a sub-regional effort to review the impacts of sea level rise, which it used in determining decision criteria for modification of the runway perimeter dike
- Develop comprehensive climate adaptation plans, including the following:
  - Airport sustainability planning: FAA is evaluating ways to make sustainability a core objective at every airport through the Sustainable Master Plan Pilot Program
  - Navigation infrastructure assessment: FAA is analyzing aviation facility, service, and equipment profile data for vulnerability to a combination of storm surge impacts that climate change might bring
  - NextGen Network Enabled Weather: Part of an interagency effort to provide quick, easy, and cost-effective access to weather information, including seamless interagency access to the National Oceanic and Atmospheric Administration's 4-Dimensional Weather Data Cube

V. Maritime Mode

The following overview describes the assets, ownership structure, funding sources, regulation, interdependencies, and resilience status of the mode.

Table G-5. Maritime Mode Overview

Maritime Mode
ASSETS AND INFRASTRUCTURE
• **Physical Assets:** vessels, containers, cargo, commercial vehicles; port facilities; waterways and waterway infrastructure; Exclusive Economic Zone; offshore oil and natural gas facilities; railroads, highways, and tunnels within ports; bridges, dams, levies • **System Assets:** cyber connections; data systems; networks; cyber monitoring and control systems; Internet portals; networked logistics management systems; navigation equipment; decision support mechanisms; internal communications; power management • U.S. maritime trade represented 11% of global trade in 2008; 99% of U.S. overseas trade by volume enters or leaves the United States by ship; U.S. foreign and domestic waterborne trade amounted to 2.3 billion metric tons in 2008 • U.S. Maritime Transportation System (MTS) is a network of maritime operations interfacing with shoreside operations at intermodal connections; the MTS is part of global supply chains and domestic commercial operations • MTS consists of coastline, the U.S. Exclusive Economic Zone, ports, commercial waterways, and intermodal landside connections, which allow the various modes of transportation to move people and goods to, from, and on the water

Maritime Mode

- 95,000 miles of coastline; 3.4 million square miles of Exclusive Economic Zone; 25,000 miles of commercial waterways; 361 ports; more than 3,700 marine terminals; more than 1,400 intermodal connections; thousands of bridges, dams, and levees
- MTS includes the Great Lakes and the Saint Lawrence Seaway; as well as inland water systems such as the Mississippi River system, which extends for more than 12,000 miles through 17 states
- 64 million passenger-nights booked on North American cruises in 2008; 147 million ferry passengers

OWNERSHIP AND OPERATION STRUCTURE

- Ships in the private sector serve public waterways and both public and private port facilities. Harbors are typically owned by public authorities, although terminals are usually owned or managed by private operators. Water navigation is mostly controlled by the Federal Government, and safety is regulated by all levels of government.
- More than 70 deep-draft port areas, including approximately 40 that each handle 10 million tons or more of cargo each year.
- Within these ports are about 2,000 major terminals. Most of these terminals are owned by port authorities and are operated by the private sector.
- Value of Private Fixed Assets, nonresidential equipment, ships and boats: $75.5 billion (2012)
- Value of Private Fixed Assets by Industry, Transportation and warehousing, water transportation structures: $7.0 billion (2012)

FUNDING SOURCES

- In 2012, port authorities planned to invest $18.3 billion by 2016 on marine terminal-related infrastructure improvements; their private sector terminal partners planned to invest $27.6 billion
- The largest capital expenditures were for the Gulf port region ($22.1 billion), followed by the South Pacific port region ($8.1 billion) and the North Pacific port region ($7.7 billion)
- The Harbor Maintenance Tax (HMT) is collected to maintain Federal navigation channels
- White House FY 2015 budget requests $658.3 M to support DOT Maritime Administration operations

REGULATION

- DHS U.S. Coast Guard has jurisdiction anywhere within the MTS where maritime commerce is carried out
- Major authorities include:
  - 2002 Maritime Transportation Security Act
  - The SAFE Port Act of 2006
  - Coast Guard Authorization Act of 2010
- U.S. Army Corps of Engineers responsible for dredging and maintaining water access to ports
- DOT Maritime Administration focuses on the environment and mariner safety

KEY INTERMODAL DEPENDENCIES

The maritime mode is strongly connected to other modes through port infrastructure, which acts as a centralized hub of transportation connectors. Much port-generated cargo is transported beyond the port by **freight rail** and trucking (**highway mode)**, with some interconnection to the **aviation mode.** Many ports also have connections to **pipeline mode** due to the proximity of pipeline infrastructure nearby. Mass transit options within the maritime mode (e.g. ferries, cruises) may later connect passengers to **mass transit** hubs.

CROSS-SECTOR INTERDEPENDENCIES

Maritime Mode
The primary sector interdependency is based on fuel supplies (**energy**). Also, the maritime mode cannot operate without security, navigational, and cargo management systems which are dependent on the **communications** and **information technology** sectors.
CYBERSECURITY AND RESILIENCY STATUS
There is an **interagency (USCG, NPPD, TSA, industry) effort underway** to develop a methodology to identify and mitigate port cybersecurity risk. The intention is to **evaluate and then prioritize port cybersecurity risk**; shedding light on the cyber risk landscape in the maritime domain and evaluating cybersecurity posture. There is concern that **cybersecurity awareness in U.S. port facilities is generally low**, and that cybersecurity culture in U.S. port facilities is generally lacking.

Practices Contributing to Maritime Resilience

Robustness

- Promote recovery and resilience through a variety of steady-state and contingency activities, including the following:
  - Establishing and enforcing emergency equipment, training, and procedure requirements for commercial vessels and waterfront facilities
  - Establishing and enforcing security-focused requirements for vessels and facilities
  - Conducting search and rescue operations
  - Conducting pollution response operations
  - Establishing/maintaining aids to navigation
  - Operating vessel traffic services
- Participate in and support long-term planning to improve resilience through technical support for Federal Emergency Management Agency–administered port security grants, through participation in revisions to the National Response Framework (NRF), major exercises, and lessons learned
- Enable the U.S. Coast Guard (USCG) to support resilience internationally with its maritime partners
- Utilize Homeport as a publicly accessed and secure enterprise Internet portal that supports port security functionality for operational use
- Cooperate with the 43 Area Maritime Security Committees (AMSCs) active at the local port level to help achieve and sustain a robust maritime security regime to protect the Nation's maritime transportation system (MTS). The AMSCs assist and advise the Captain of the Port regarding the development and maintenance of the Area Maritime Security Plan (AMSP) by providing a framework to communicate, identify risks, and coordinate resources among key port stakeholders to mitigate threats and consequences within the area of responsibility
- Use the Maritime Security Risk Analysis Model as a tool for decision makers at various levels to make informed decisions and to identify and manage risk to infrastructure in the maritime domain
- Use voluntary security guidelines to strengthen the MTS, including the following:

- Container Security Initiative
- Customs-Trade Partnership Against Terrorism
- International Port Security Program

Resourcefulness

- Lead and support partnership organizations dedicated to preparing for response and recovery operations, including the following:
  - Harbor Safety Committee (general navigation safety)
  - Area Committee (pollution response)
  - Area Maritime Security Committee (security incidents)
- Capture and promote key lessons learned related to resourcefulness:
  - Safety of life is the prime consideration
  - Make plans beforehand to provide leadership across organizations with strong and redundant communication systems between the leadership team and the staff
  - The current designs and procedures must be reevaluated given the frequency of storms
  - Conduct drills and tabletop exercises

Rapid Recovery

- Focus on salvage issues related to security, when possible
- Ensure, as mandated by the SAFE Port Act, that AMSPs include a Salvage Response Plan to guide salvage activities and identify available resources to support clearing of waterways and restoration of commerce flow. USCG provides salvage planning guidance to ports on the following:
  - Roles and responsibilities of Federal, state, and local partners
  - Recovery-specific tasks to identify salvage response needs
  - Identification of local marine salvage providers for use when needed
- Require, through the USCG, Area Maritime Security Committees to plan and prepare for recovery operations, including a salvage response plan for each AMSP. As with other contingency plans, the USCG requires that these plans be exercised on a regular basis. During an incident, USCG-led Maritime Transportation System Recovery Units (MTSRUs), which include private companies and public agency members, plan, prioritize, and direct recovery operations
- Ensure that the CBP/USCG Protocols for the Expeditious Resumption of Trade include carrier and trade support groups and are enabled to provide insight with respect to post-incident recovery issues
- Develop an innovative tool, called the Common Asset Reporting Tool, to assist the MTSRUs capture and relay essential elements of information on critical infrastructure within their port areas that can be used at various levels within the USGC to manage the post-incident recovery/resilience efforts
- Plan for various phases (e.g., secondary, tertiary) of communication disruptions through maritime security committees

- Establish MTSRUs, led by the USGC, during a transportation security incident to provide support
  - MTSRUs are responsible for tracking and reporting status information, understanding critical recovery pathways, recommending courses of action, serving as a venue for input to the local response organization, and recommending recovery priorities
  - The specific responsibilities of an MTSRU can vary by port area; some port areas are better able to leverage the information-sharing abilities of established collaborative bodies

Adaptability

- Promote key success lessons learned from Superstorm Sandy, such as the following:
  - **Coordination within the port:** Inter-organizational coordination was especially important with regard to port closings and the post-storm recovery of the MTS. Coordination activities included communication between port partners about weather conditions and the closure of the port, coordination of multiple agencies to support post-storm harbor survey and cleanup activities, and coordination between the public and private sectors to facilitate the resumption of port commerce
  - **Relationships and trust:** Effective coordination was also facilitated by a network of relationships and trust between port partners, which may have been built through the committees as well as other prior experiences working together. Some described the resilience of the port in these terms, emphasizing that it is about people and difficult to measure
  - **Prior experience:** Effective coordination, response, and recovery were facilitated by the prior experiences of participants, and of the port community in general, in dealing with previous storms and other disasters
  - **Expertise and improvisation:** Another key to success was the port partners' ability to improvise before, during, and after the storm, drawing upon the relationships previously described, as well as prior experiences and professional expertise. This was necessary because of the extraordinary size of the storm and the associated surge, which flooded areas and caused damage that for some was unanticipated
  - **The value of maritime assets:** Another success was the way in which maritime resources helped support the recovery of the broader region
- Work with customs and major cargo brokers and shipping lines, at the national level, to develop joint protocols to prioritize ports, should there be widespread disruption
- Examine major incidents to pull out best practices in how maritime and surface transportation and the energy sector all have to be coordinated and work together for recovery
- Use the Maritime Risk Assessment Module to focus on a particular target and predict the consequences of an incident
- Promote cybersecurity lessons learned:
  - Cybersecurity is absolutely key to resilience and recovery. Any cyber system is backed up manually. Cyber is a huge vulnerability. In looking at all the elements of USCG plans through a maritime dimension, one always needs to consider how a cyber event can disrupt the port.

  - It is very easy to jam GPS with a stronger signal. That is a vulnerability to the entire transport system, as well as to other sectors
  - Maritime committees are looking at the many cyber vulnerabilities. There are impacts from disruptions, but systems are usually able to recover in hours and days, although it does cost a significant amount of money. Most incidents are accidental or an amateur event.
  - The USCG is not involved in providing cybersecurity patches. The USCG does not look at the level of intrusions, but it does have security standards for systems and backups. The USCG is looking at incorporating cyber into the risk assessments, but the USCG is still developing the USCG realm of authority
- Collect and disseminate public-private leadership best practices from the committees through the USCG
- Develop the ability to improvise and establish ad hoc processes that draw on prior relationships, shared experiences, and trust in one another's professional expertise

VI. Pipeline Mode

The following overview describes the assets, ownership structure, funding sources, regulation, interdependencies, and resilience status of the mode.

Table G-6. Pipeline Mode Overview

Pipeline Mode
ASSETS AND INFRASTRUCTURE
• **Physical Assets:** Natural gas transmission lines and storage, natural gas distribution lines, hazards liquid pipelines and tanks, and liquefied natural gas (LNG) processing and storage facilities - Natural Gas Transmission Lines and Storage (mostly interstate pipelines): Over 320,200 miles of pipelines and 400+ natural gas storage facilities - Natural Gas Distribution Lines (mostly intrastate pipelines): Local distribution company pipelines transporting gas to residential, commercial, and industrial customers. 2,146,034 pipeline miles - Hazardous Liquid Pipelines and Tanks (mostly interstate pipelines): 192,396 miles of pipeline including 60,911 miles of crude oil pipeline; 63,532 miles of refined petroleum products pipeline delivering gasoline, diesel, jet fuel, and other refined products; and 62,742 miles of natural gas liquid pipeline transporting propane, ethane, and other industrial raw materials - LNG Processing and Storage Facilities: 133 in-service facilities receive LNG from tanks, ships, or trucks, or receive natural gas via pipeline for liquefying it into LNG - More than 1,400+ compressor stations maintaining pressure on the natural gas pipeline network • **System Assets:** Supervisory control and data acquisition (SCADA), process control, and distributed control systems for controlling natural gas distribution systems, flow and pressure, temperature levels, and alerts and alarms
OWNERSHIP AND OPERATION STRUCTURE
• A majority of pipelines are privately owned and operated; however, all pipelines are regulated by public authorities

Pipeline Mode

- Approximately 3,000 companies in the U.S. operate a majority of the pipeline mode assets, including: 182,000 miles of hazardous liquid pipelines; 325,000 miles of natural gas transmission pipelines; and 2.15 million miles of natural gas distribution pipelines
- The companies operating the pipelines typically control, monitor, and maintain the pipeline systems
- Pipeline modal activity is diverse with different pipe components, construction methods, operational strategies, and transported materials, across various companies

FUNDING SOURCES

- Private sector owner and operators bear a large share of the financial responsibility for the development and maintenance of the pipeline system
- Federal funding is available to sustain education, protection, and resilience programs and operations ($120M was enacted to support PHMSA in FY2014)
- White House FY 2015 budget requests $261 million devoted to support PHMSA's operations

REGULATION

- DHS (pipeline security authority); key division is the Transportation Security Administration, particularly the Surface Division Pipeline Security Branch to enhance the security preparedness of the lines
- DOT (focus on safety, standards, coordination of systems, partnerships, and regulation); key division includes the Pipeline and Hazardous Materials Safety Administration, esp. the Office of Pipeline Safety
- DOE—Federal Energy Regulatory Commission regulates, reviews, and ensures reliable energy and pipeline activities

KEY INTERMODAL DEPENDENCIES

The critical Intermodal Dependencies center on the relationship between pipelines and the products they carry which are then disbursed as transportation fuels. Fuel is an essential component to each mode and as such, **each transportation mode** is dependent on the pipeline mode to varying degrees.

CROSS-SECTOR INTERDEPENDENCIES

The pipeline system is vital to the transportation sector—through transportation fuels—and the **energy sector**, and maintains a level of importance to other critical sectors. End users are located within the **commercial facilities, critical manufacturing,** and **government facilities sector**. Typically, pipelines carry natural gas and crude oil; however, pipelines also transport manufacturing chemicals used in fertilizer—an essential component to activities within the **food and agriculture sector**. Pipelines are also dependent on the **information technology sector** due to their reliance on computer control systems, which are susceptible to cyber-attacks.

CYBERSECURITY AND RESILIENCY STATUS

The pipeline system is **composed of hundreds of SCADA systems**, thousands of remote terminal units, and nearly one million controllable devices, all of which could be potential targets for a cyberattack. As SCADA systems become modern, the systems become more efficient yet more vulnerable. Exploitation and infiltration of these systems may result in disrupted service, spills, explosions, or fire—all initiated and controlled from remote locations. **Coordinated cyber intrusions** seem to specifically target U.S. pipeline computer systems.

In terms of accepted industrial control system cybersecurity standards, the **pipeline system is the most advanced**. Multiple regulatory standards addressing cybersecurity exist within the mode and **key players are engaged**, for instance: the American Petroleum Institute developed SCADA standards for owners/operators of oil and gas liquid pipelines (2009), the Interstate Natural Gas Association of America released standards on

Pipeline Mode
control system cybersecurity (2011), and TSA developed cyber asset security measures within the Pipeline Security Guidelines (2011). The standards are an extension of the nature of the mode's strong reliance on control system for operation—the **industry is highly automated and increasingly vulnerable.**

Practices Contributing to Pipeline Resilience

Robustness

- Use the Pipeline System Relative Risk Ranking Tool to rank the most critical systems and assets according to the greatest importance to energy supplies and risk in terms of threat, vulnerability, and consequences
- Conduct on-site security reviews, enabling TSA to understand operator security planning and implementation
- Examine the risks associated with transporting TIH materials through the TIH Materials Transmitted in Pipelines Program
- Identify security gaps and recommend ways to mitigate those gaps through the Pipeline Cross-Border Vulnerability Assessment Program
- Participate in forums, such as the International Pipeline Security Forum, which allows U.S. and Canadian officials to discuss security issues and gaps
- Participate in TSA Pipeline Security Stakeholder Conference Calls, which provide opportunities for periodic information sharing
- Enable coordinated interagency and cross-jurisdictional implementation of security practices through entities such as the Transportation Sector Government Coordinating Council (GCC), Energy Sector GCC, and the Critical Infrastructure Partnership Advisory Council (CIPAC) Joint Sector Committee
- Engage the private sector in security planning and pipeline protection issues through the Oil and Natural Gas/Pipeline Sector Coordinating Council and the CIPAC Joint Sector Committee
- Develop and promote documents, such as the Pipeline Security Smart Practices, to assist the industry in security planning and implementation
- Define encryption methods for supervisory control and data acquisition (SCADA) systems
- Recommend security practices and guidelines to be implemented
- Provide a model for proactive industry actions to improve security through the American Petroleum Institute (API) Pipeline SCADA Security Standard (API Standard 1164)
- Provide a comprehensive review and quantitative assessment of company security programs through the API Information Management and Technology Program
- Develop and promote a risk-based corporate security program. These programs typically include the following measures, which increase "robustness":
    - Appropriate levels of staff, training, and equipment
    - Developed corporate security plan
    - Real-time, 24/7 connection to TSA for security awareness

    - Developed and maintained cyber/SCADA security plan
- Implement a risk-based approach for operators that includes the following assessments:
  - Criticality assessment (determining facility criticality)
  - Threat assessment (identifying known or potential adversaries)
  - Vulnerability assessment (identifying potential weaknesses)
  - Risk assessment (based on threat, vulnerability, and criticality assessments)
  - Risk mitigation (determine and implement appropriate risk-reduction countermeasures)
  - Ongoing risk management (monitor, reassess, and modify)
- Develop hazardous materials incident information programs within local agencies
- Develop a hazardous materials effort, through the Hazardous Materials Cooperative Research Program—a program which is composed of the following elements:
  - Hazardous Materials Commodity Flow Data and Analysis (supports local risk assessments)
  - Hazardous Materials Transportation Incident Data for Root Cause Analysis (develops methods to improve incident data, identify gaps, and understand incident under-reporting)
  - A Guide for Assessing Emergency Response Needs and Capabilities for Hazardous Materials Releases (guidance for conducting emergency response needs assessments)
  - Emerging Technologies Applicable to Hazardous Materials Transportation Safety and Security (technologies to enhance the safety and security of pipeline material transportation)
  - Current Hazardous Materials Transportation Research and Future Needs
  - Improving Local Community Recovery from Disastrous Hazardous Materials Transportation Incidents
  - Hazardous Materials Transportation Risk Assessment: State of the Practice
  - Best Practices in Hazardous Materials Pipeline Emergency Response Plans
  - Methodology for Evaluating the Effectiveness of Hazardous Materials Transportation Training
- Focus on including pipelines in state Hazard Mitigation Plans

Resourcefulness

- Conduct exercises that are relevant to security partners' challenges and risks, and refine programs through evaluation and continuous improvement
- Conduct pipeline I-STEP exercises
- Conduct pipeline security exercises annually
- Develop and distribute the Pipeline Security Awareness for the Pipeline Industry Employee Training CD
- Familiarize the private sector with threats from IEDs through the Pipelines: Countering IEDs Training Program
- Enhance the law enforcement community's understanding of pipelines and their security through the Protecting Pipeline Infrastructure: The Law Enforcement Role Training Program

- Supplement pipeline security practices information through the Pipeline Security Awareness for Employees Brochure
- Develop the Pipeline Emergencies training curriculum to support the response phase of a pipeline incident

Rapid Recovery

- Provide information-sharing programs that allow the government and the private sector to be more vigilant, such as the Homeland Security Advisory System
- Allow for the sharing of security information, threat intelligence, indications, and warnings through systems similar to the Homeland Security Information Network
- Ensure each pipeline operator has a risk-based corporate security program that cuts across multiple types of resilience practices (see the "Robustness" section for additional practices). These programs typically include the following measures, which increase "rapid recovery":
  - Appropriate threat levels are implemented, depending on the type of alert received
  - TSA is notified of all security incidents as soon as possible
- Hold joint-agency emergency responder forums
- Convene the Pipeline & Hazardous Materials Safety Administration's Pipeline Emergency Response Working Group to institutionalize pipeline safety knowledge in the emergency response community
- Develop pipeline safety resources for emergency responders
- Prepare communities for responding and recovering from a hazardous materials incident through the Transportation Community Awareness and Emergency Response program
- Create strategies for emergency response communications and training, and develop an emergency response pipeline incident model that is transferable to other states, such as through the Georgia Pipeline Emergency Response Working Group

Adaptability

- Conduct exercises that are relevant to security partners' challenges and risks

VII. Postal and Shipping Mode

The following overview describes the assets, ownership structure, funding sources, regulation, interdependencies, and resilience status of the mode.

Table G-7. Postal and Shipping Mode Overview

Postal and Shipping Mode
ASSETS AND INFRASTRUCTURE
• **Physical Assets:** wide range of facilities; aircraft, trucks, and other delivery vehicles; cargo terminals; warehouses; mail and other postal/shipping drop boxes • **System Assets:** automated screening technologies; automated sorting and forwarding systems; rigorous cybersecurity systems; robust communications systems

Postal and Shipping Mode

- Postal & Shipping mode is mainly composed of four large, integrated carriers that represent 94% of the mode: United States Postal Service (USPS), the United Parcel Service (UPS), FedEx, and DHL International; P&S moves over 574 million messages, products, and financial transactions each day
- P&S activity is differentiated from general cargo operations by its focus on letter or flat mail, publications, or small- and medium-size packages, and by its wide spectrum of customers: millions of senders to 152 million destinations
- Mailing Industry Job Study (2012) reported that there were more than 8.4 million jobs and more than $1.3 trillion in revenue attributed to the mailing industry
- USPS: handles 40% of the world's mail volume; 32,000 Post Offices, stations, and branches, plus thousands of Contract Postal Units (CPUs), Community Post Offices (CPOs), Village Post Offices (VPOs), and retail establishments that sell postage stamps and other services; mail is delivered six days a week to almost 153 million city, rural, Post Office box, and highway delivery points; fleet of vehicles numbers about 211,654 (one of the largest civilian fleets in the world)
- UPS: HQ Atlanta, GA; global reach extends to more than 220 countries and territories; 2,700 worldwide operating facilities; nearly 400,000 employees across the globe; 1,955 daily flight segments; 103,000 vehicles in fleet; more than 16.9 million packages delivered each day
- FedEx: HQ Memphis, TN; covers every US address and more than 220 countries and territories; provides time-sensitive, air-ground express service through 375 airports worldwide; 3.9 million packages delivered each day; 11 million pounds of freight carried each day; 47,000 surface vehicles; 630 aircraft
- DHL: HQ Bonn, Germany; present in over 220 countries and territories; more than 315,000 employees; approximately 2.7 million customers; more than 250 dedicated aircraft serving 500 airports

OWNERSHIP AND OPERATION STRUCTURE

- USPS assets are owned by the Federal Government; other postal and shipping carriers privately owned
- USPS is an independent agency of the U.S. Government responsible for providing postal service in the United States; UPS, FedEx, and DHL are private sector companies
- The remainder of the mode consists of smaller, privately owned firms providing regional and local courier services, other mail services, mail management for corporations, and chartered air delivery services

FUNDING SOURCES

- USPS: Has not received taxpayer dollars since the 1980s; for the past seven years from 2013, USPS incurred $46 billion of net losses; stamp sales in 2013 totaled about $7.5 billion; earns income from payment for services provided
- UPS, FedEx, and DHL are private sector owned and operated service providers

REGULATION

- Postal Reorganization Act stipulates that USPS is an independent establishment of the Executive Branch of the U.S. Government
- The Postal Accountability and Enhancement Act created the Postal Regulatory Commission (PRC), and gave it regulatory and oversight obligations in regards to the USPS

KEY INTERMODAL DEPENDENCIES

P&S owns and/or **utilizes all transportation modes** (e.g. aviation for air shipment, highways for truck shipments), functioning in integrated domestic and international networks.

Postal and Shipping Mode
CROSS-SECTOR INTERDEPENDENCIES
The sector utilizes the **energy sector** to fuel its operations. To varying degrees, other critical infrastructure sectors use the services of the postal and shipping sector to support the communications component of their business operations.
CYBERSECURITY AND RESILIENCY STATUS
TSA in 2011 **defined cybersecurity goals** for Postal and Shipping as: • Define conceptual environment • Improve and expand voluntary participation • Maintain continuous cybersecurity awareness • Facilitate effective information sharing • Ensure sustainability USPS has collaborated since 2011 with the CERT division at Carnegie Mellon University's Software Engineering Institute in **implementing and improving the CERT Resilience Management Model** (CERT-RMM). The model is used across the domains of security management, business continuity management, and aspects of information technology operations management. **Collaboration** has included projects dealing with incident response, export screening, authentication services, and development of mail-specific resilience management practices for mail induction, transportation, delivery, and revenue assurance.

Practices Contributing to Postal and Shipping Resilience

Robustness

- Establish working groups composed of domestic and international agencies and industry partners to focus on refining procedures and implementing technology to reduce the risk of terrorism and increase system resilience
- Initiate studies to evaluate the security of U.S. mail transported on domestic passenger aircraft
- Conduct security assessment reviews at postal and shipping facilities nationwide
- Implement various programs to enhance the security and resilience of assets across the mode, including the following:
  - Enhancing cybersecurity awareness
  - Targeting high-value cyber crimes
  - Mitigating risks to new postal products and business planning
  - Enhancing frontline employee awareness
  - Identifying cross-sector risks
  - Improving sector resilience
  - Identifying supply chain vulnerabilities
  - Identifying integrated carrier vulnerabilities
  - Strengthening supply chain security awareness
  - Establishing and implementing global security protocols for international mail
  - Participating in tabletop exercises and full-scale exercises at postal and shipping facilities nationwide

- Pursue the following activities to address varied security challenges:
  - Revisit postal and shipping goals for applicability under current threats
  - Review risk mitigation activities to align them with goals and plans for moving forward and the ability to accurately measure progress
  - Engage the analytical community to provide regular threat analyses
  - Engage modal and sector partners to assess threats, vulnerabilities, and consequences
  - Identify a methodology for developing assessments of dependencies and interdependencies
  - Engage other modes and sectors in assessing sector dependencies and interdependencies
  - Continue to engage partners in the international community in strengthening the global supply chains that carry inbound and outbound international mail
  - Complete a study assessing the risks of mail transported on domestic passenger aircraft and implement next steps that emerge from the study
  - Complete a market survey of the mail courier industry
  - Initiate a market study of mailrooms to understand the stakeholders and their characteristics, and develop a plan to engage the industry within the National Infrastructure Protection Plan framework, identifying where security and resilience can be improved
  - Interact with other segments of the industry (e.g., couriers and mailrooms) to assess their needs regarding risk mitigation and the best means for engagement
  - Ensure that timely threat information is effectively disseminated and shared
  - Understand the full scope of cybersecurity issues and vulnerabilities, develop mitigation strategies, and communicate cybersecurity improvement programs to postal and shipping mode stakeholders

Resourcefulness

- Support and participate in the mode's Cities Readiness Initiative (sponsored by the Centers for Disease Control and Prevention) to achieve the following:
  - Enhance emergency preparedness
  - Facilitate the sharing of security information
- Continually consult with port and border authorities, regulatory and law enforcement agencies, customers, and other stakeholders to understand security issues
- Modify vehicles, systems, methods, and training as appropriate to keep customer shipments secure. These efforts cover air and ground fleets, facilities, and IT systems
- Implement new techniques and technologies for safer and more efficient air traffic control as part of the NextGen program at FAA
- Add new training to help drivers and back-office workers identify potential misuse of postal and shipping networks by illegal online pharmacies

- Develop IT applications that apply an advanced algorithm to customize map data to provide delivery drivers with optimized route advice; for example, United Parcel Service (UPS) developed the On-Road Integrated Optimization and Navigation (ORION) system

Rapid Recovery

- Test resilience and recovery capabilities in the event of an incident to ensure that the roles in responding to an incident are clear and effective
- Assist communities in becoming more resilient through foundations and/or associations; this also includes donating in-kind services, transportation, technology, and supply chain solutions using air and ground fleets
- Use networks to facilitate fast, efficient relief operations undertaken by national governments and global relief organizations in times of disaster

Adaptability

- Identify and define modal training and communications requirements that will allow components (e.g., integrated service providers, mailers, couriers, package handlers, mailroom operators, and government mailing operations) to improve the preparedness, resilience, and security of their operations
- Develop and refine changes in technology, processes, and policies to improve the resilience of the mode and the mitigation of threats, and foster communication channels to support the resultant changes, as well as improve alerts and responses

Appendix H: Case Study of Disruption Scenarios – Ports of Los Angeles and Long Beach

As the Study Group was tasked with conducting a case study to inform the Council's Working Group recommendations to the full Council, the Study Group organized a workshop to discuss resilience gaps and examine cross-modal and cross-sector dependencies through five transportation disruption scenarios affecting the Ports of Los Angeles and Long Beach (POLA-POLB). The workshop took place on February 10, 2015, in a two-hour facilitated webinar discussion. Section I of this Appendix summarizes the results of the workshop, Section III describes the analysis of the disruption scenarios in greater detail, and Section III provides an overview of POLA-POLB transportation infrastructure for reference.

Workshop participants included Study Group members and additional subject matter experts with experience in transportation logistics, port security and resilience, emergency management, and other critical infrastructure sectors. To facilitate a robust discussion, participants were given comprehensive background information on the disruption scenarios, and were asked to focus on four key areas:

- Common elements across the five POLA-POLB scenarios (e.g., challenges, impacts)
- Cross-sector dependencies
- Cross-modal transportation impacts
- Resilience gaps

The five disruption scenarios (three studies detailing natural and man-made disruptions and two after-action reports from California port response and recovery capabilities exercises) were selected due to their relevancy to POLA-POLB and applicability to the Study Group's charge.

Table H-1 presents an overview of the five scenarios, organized by natural and manmade events. For each scenario, the following is presented:

- **Scenario Description:** Key scenario information, including disaster type and major themes derived from each scenario
- **Key Failure Points:** Points of failure in processes, communication, or infrastructure contributing to disruption
- **Challenges:** Obstacles uncovered during/after the disruption
- **Public-Private Issues:** Differences experienced between the public and private sector during the disruption
- **Lessons Learned:** Information gained that could improve transportation security and resilience
- **Recommendations:** Actions suggested by experts based on the scenario evidence

Table H-1: Overview of Disruption Scenarios

Scenario Description	Key Failure Points	Challenges	Public-Private Issues	Lessons Learned	Recommendations
Scenario: The ShakeOut **Disaster Type:** Earthquake **Major Themes:** • Interdependency of lifeline sectors, as well as of modes • Prioritization of transportation restoration • Inadequacy in stockpiled supplies and transportation's capacity to absorb disruption	• Transportation corridors (e.g., interstates, mountain passes) • Infrastructure lines (e.g., communications, rail, NG) on fault line • Water delivery system (e.g., aqueducts) • Secondary hazards (e.g., floods, fires) lead to more failures	• Corridor or lifeline repair requires highway/bridge repair first • Severed communications and Internet hamper response/recovery efforts • Incident scope is greater than available resources and personnel • Cargo diversion is not a whole solution	• Freight (private) relies on publicly-maintained roadways and bridges • Public utilities are critical to the private sector • Commuter and freight users compete for restored transportation • Full recovery needs robust public-private coordination, collaboration	• CA mitigation investment increases lifeline resilience • Some losses are well-understood but many failures are unknown or not fully recognized • Aviation is a critical mode during port disruption and underused airports can be used for airfreight	• Establish and encourage contingency plans • Identify transportation infrastructure and lifelines to prioritize for repairs • Create strategies to address commuter vs. freight user conflict • Examine technological solutions to resilience (e.g., automated control system)
Scenario: Alaska Peninsula Offshore Earthquake **Disaster Type:** Tsunami **Major Themes:** • Rippling economic effects can be deep and expansive, despite light port damage • Resilience drastically reduces economic costs from disasters	• POLA-POLB are critical to Southern California economy • Significant trade and business disruption can result from a port shutdown of only a few days	• Evacuations of low-lying areas in Southern California are extremely difficult • Clean-up after a disaster can delay recovery and add greatly to the costs of an event	• Government and private sector cooperation on resilience measures can significantly reduce economic impacts from disasters	• POLA-POLB breakwaters and channels reduce wave impact but during tsunamis their entrances have port-damaging currents • Owner/operator adoption of resilience measures can greatly reduce economic costs from port shutdown	• Include tsunami events as part of CA exercises • Plan holistically for coastal flooding/erosion, tsunamis, sea level rise, earthquake liquefaction • Encourage adoption of resilience measures to mitigate disaster effects

Scenario Description	Key Failure Points	Challenges	Public-Private Issues	Lessons Learned	Recommendations
Scenario: Nuclear Device in Shipping Container **Disaster Type:** Terrorist Attack **Major Themes:** • Long term impacts can be difficult to identify and measure • Impact includes social and economic aftershocks and is understood as not just physical damage	• POLA-POLB play an essential role in the national and global economy; cascading effects from closure can be severe and widespread • Impact on insurance industry and other financial institutions can hamper recovery	• Key challenges (1) keeping the global shipping supply chain operating; (2) restoring orderly economic relations within national, global economies • Destroyed POLB refineries reduce the region's fuel supply • Port personnel may be affected by fallout	• Balancing government and private sector priorities after a major terrorist event (e.g., weighing security vs expediting recovery) • Restoring normal economic relationships and rebuilding infrastructure require public-private cooperation	• Long-term analysis suggests alarming vulnerabilities and a very challenging recovery • Long-term consequences are not well known • Exercises can help decision makers understand issues and help plan for contingencies	• Expand modeling/gaming tools to examine long-term disaster consequences • Identify failure points in social and economic systems and assess policy solutions by Federal, state, port, and business leaders • Understand decisions made post-incident and decision-making challenges
Scenario: 2010 Golden Guardian Exercise **Disaster Type:** Terrorist Attack **Major Themes:** • Pre-event planning, training, resources, can be strained in significant/expansive disasters • Complex interdependencies exist among systems, processes, and supply chains—internationally and throughout the public and private sectors • Timely, accurate information and reinforcing continuity is vital to response/recovery	• Improperly redirecting or closing cargo causes significant business loss leading to long-term and global economic disruption • Unbalanced security, continuity, and recovery needs threaten successful response/recovery	• Simultaneous, multiple disasters require complex response and coordination • While training is received, exercising or applying training in real events may be limited • Ports may have insufficient assets and supplies to address major disasters • Significant disasters may also destroy outside assets and supplies	• Public sector decisions (e.g., closures) affect ports, which then affects other sectors, such as in port closures limit agricultural export volume • Officials balance between reducing anxiety and providing full communications • Long-term recovery issues (waiving requirements) affecting the private sector require government support	• Councils inclusive of industry enable sector coordination, decision-making, collaboration •Communication is essential for situational awareness and recovery • Limited resources need to be prioritized in fast-moving incidents • Port issues are far-reaching and have great impact outside ports • Continuity and recovery needs to be balanced	• Conduct review of resource and information management systems • Provide credible information to the public and private sector • Develop a joint government and port leadership field office • Implement recovery plans in conjunction with response activities • Comprehend supply chain ripple effects and involve the private sector

Scenario Description	Key Failure Points	Challenges	Public-Private Issues	Lessons Learned	Recommendations
Scenario: Cybersecurity Tabletop Exercise **Disaster Type:** Cyber Attack **Major Themes:** • Effective preparedness requires public-private coordination, communication • Exercises and training reveal strengths and vulnerabilities Cybersecurity is ambiguous full preparedness is deficient	• IT personnel depend on timely, relevant information • Lack of standard cybersecurity terminology use • Missing or misidentifying cyber incidents • Lack of cyber threat information	• Standard systems/tools for internally/externally sharing information with stakeholders do not exist • Physical and cyber security is handled by separate departments • Use of unified command and terminology is unclear • Cyber security plans are uncommon	• Port personnel need to work with tenant IT personnel for situational awareness • Relevant, timely information and analysis is not always shared across the public and private sector	• Exercises enable cyber readiness assessment • Current cybersecurity plans are deficient • Without cybersecurity plans, incidents may go unreported • Inter-port communication deficiencies can slow information sharing and response capabilities	• Improve internal/external information sharing • Better coordinate physical/cyber security • Establish policies for cyber incident thresholds and notification • Host training, exercises • Develop formal, coordinated cybersecurity plans

I. Workshop Results

The workshop discussion was focused on: identifying common scenario impacts on POLA/POLB and port response and recovery efforts, as well as contributing observations made on broader transportation issues such as cross-sector dependencies; cross-modal transportation impact; and resilience gaps. This section highlights workshop results, providing insights and perspectives that were used in the Study Group's analyses and deliberations.

Insights and Perspectives

Transportation Risks

- The ports are highly dependent on the Energy Sector for power and fuel sources. Other sector dependencies include Water and Wastewater Systems, Communications, and the entirety of the Transportation Systems Sector. Ports are dependent not only on the infrastructure these sectors provide, such as critical highways and railways, but also their workforce/labor.
- These cross-sector dependencies can become single points of failure for the ports.
    - For POLB, one such point is the disruption of the power supply. The port relies on the operation of approximately 90 large cranes, which require an adequate power supply. While an earthquake may not physically damage the port, it could severely impair the energy infrastructure.
    - Major transportation hubs, such as in POLB, may be located below sea level. In the event of a tsunami or subsequent flooding incident, wastewater and storm water must be pumped out, requiring both power and fuel. Without these energy resources, pumps will shut down and the workforce will not be able to work due to hazardous working conditions.
- Labor issues present a potential single point of failure for POLA-POLB and other major West Coast ports.
    - If labor unions go on strike, if management locks personnel out of facilities, or if the workers are unable to report to their jobs due to safety and environmental concerns, then the ports will shut down.
    - The port workforce—especially those involved in transloading cargo from ships to rail and trucks—are in many cases highly trained and specialized. They cannot be easily replaced; however, mutual assistance from other ports or compatible transportation modes can assist in securing an able workforce to operate the port.
    - Moreover, cargo owners will likely divert cargo to the same ports you would be calling upon for aid in the supply of port workers and thus, may be unable to provide the needed aid to continue or recover POLA-POLB operations.
- Ports are heavily dependent on waterborne salvage equipment to recover from a major disaster. If this equipment is unavailable, full port operations will be unable to resume until the wreckage is cleared.
- POLB and Southern California's pipeline infrastructure is critical not only to the region but also to adjacent states. While these pipelines allow fuel to flow out of the ports and region, there are

fewer pipelines that allow fuel to flow into the ports and region. Therefore, a disaster destroying the pipeline infrastructure will affect the entire region, inclusive of adjacent States.

  - An adequate fuel supply is needed for search and rescue, infrastructure repair, utility provision, and recovery activities.
  - Fuel transport is further complicated by modal capacity issues. Tanker trucks and manpower capacity may be insufficient, leaving freight rail as the only option. Freight rail dependence freight rail is precarious, as the tracks and infrastructure are likely to be debilitated during a major disaster.

- Due to the construct of the landlord/lease port structure, port cybersecurity information sharing is limited. For example, leased terminal operators often do not share their cybersecurity issues with port management. Requirements such as tariff modifications are necessary to mandate this type of sharing.

Infrastructure Investment and Funding

- The Transportation Systems Sector is complex and operates as a system full of dependencies. There is a need to better allocate resources dedicated to understanding these dependencies in order to prevent or mitigate disruptions.

Making the Business Case

- The economic consequences of a major disaster are not well understood. In the event of a chemical, biological, radiological, nuclear or explosive attack, costly impacts manifest beyond the disruption's point of origin. People may not want to invest in recovery and lenders may not offer construction loans if there is a risk for a second attack. Further, such economic impacts may affect local businesses.
- POLB is conducting a thorough review of the substantial energy requirements of the port to identify specific needs in the event of an electricity supply disruption. The study includes determining terminal energy requirements and alternative power sources, which will facilitate the identification and application of resources needed to sustain the port in a disruption.
- The amount of coordination and information sharing between ports and terminals varies considerably, depending upon the type of business model employed. In POLA-POLB's landlord/lease port structure, terminal operators are independent of port authorities and have little incentive to share information with the port. Whether an attempt to protect private sector information or maintain a competitive edge over other terminals, this lack of information sharing severely restricts risk management cooperation between the public and private stakeholders at the ports.
- In the case of major transportation hubs such as POLA-POLB, examining the connections between ports and their various transportation modes will aid in understanding system disruption impacts.

Policies and Practices

- Current transportation disruption scenarios and tabletop exercises are limited and unable to capture the sector' complexity. They may be mode-specific, or focused solely on the response phase and/or the capabilities of specific localities. Federal resources could greatly aid in the

improvement of exercises and understanding of disruption impacts. The following highlights suggestions to resolve this issue:

  - Regional and/or national-level exercises should be developed to comprehensively examine the transportation system and its dependencies and interdependencies, both within and across modes and jurisdictions.
  - Exercises should not only test response capabilities, but they should also test recovery phase capabilities. The Federal Government can support this by specifying the inclusion of a recovery component in exercises funded through Federal grants and by incorporating recovery into Federal exercises.
  - Exercises are an ideal way to understand dependencies across and within modes and sectors. A dependencies checklist/framework could be developed and the exercise scenario could be designed to test each of these dependencies. This would be particularly suited for local exercises, because the rules and dependencies vary geographically.
  - Ports can serve as one model for structuring recovery exercises, due to the prevalence of interdependencies including energy (including fuel issues and emergency fuel restriction), as well as a varied workforce (including labor unions and emergency access credentials), and legislation and regulations governing recovery.

- The design of training and exercises to focus on both response and recovery incorporates the cross-jurisdictional element as successful recovery requires much outside help. Disaster planning should include coordinated response and recovery efforts that should advance concurrently.
- The private sector should become more involved response and recovery planning by participating in both the development of emergency management plans and in public sector exercises.
- Ports such as POLB could prevent or mitigate cyber attacks by coordinating cybersecurity assessments across ports and conducting exercises on denial of service (DoS), spamming, and malware attacks. In addition, the development of mitigation mechanisms may help minimize the spread of impacts following a cyber attack. For example, POLB is focused on the ability to quickly replicate how the breach occurred in order to decrease the vulnerability of its cyber infrastructure.
- Regulations can impede response and recovery efforts. While the necessary infrastructure equipment such as generators may be readily available, their use may be restricted by regulations.
- However, there is an opportunity to coordinate with regulatory authorities to secure pre-approved waivers in advance of certain types of disruptions. These pre-incident efforts would considerably shorten response and recovery time.

Leadership and Coordination

- In the event of a POLA-POLB closure, the movement of goods and services to and from other ports becomes a national priority. The disruption of such a major transportation node would

alter the flow of activity throughout the entire transportation system. Public and private sector agencies need to work to mitigate the disruption impacts of such a closure.

- The key to successful use of alternative resources in the event of a disruption is logistical coordination among providers, customers, and response/recovery personnel.
- In order to successfully navigate a port disruption, communication and coordination needs to take place not only within the port structure itself, including terminals, but also across the modes operating within the ports. Coordination occurs in a time-compressed and complex environment during disruptions, so it is critical to establish a common operating procedure, outlining consistent communication mechanisms for ports and first responders. For example:
    - During emergencies, communication is required to ensure unnecessary vehicles are not entering the region and causing additional gridlock, which will inevitably extend the disruption. POLB works with the California Highway Patrol and California Department of Transportation (Caltrans) to communicate with trucking and shipping companies for this purpose.
- Freight transportation requires cross-modal coordination. If a prolonged disruption occurs, the backlog resulting from halted or slowed operations would need to be cleared. For example, cargo congestion proliferates during West Coast port slowdowns. Major freight railroad companies connecting to POLA-POLB for intermodal transfer of cargo would need to first clear the cargo congestion before resuming operations.
- The prioritization of cargo movement and infrastructure restoration may be ambiguous and prioritization needs vary by region. The following illustrates select prioritization challenges with potential paths forward:
    - Fuel and emergency supplies should be prioritized first for both life safety and property preservation. The challenge lies in knowing the location of specific cargo containers and what containers need to be removed first in order to make room for prioritized containers.
    - The prioritization of goods is dependent on the disaster type and region. Following an earthquake in Southern California, fuel may be a vital resource due to the potential destruction of the region's energy infrastructure. However, following a major snowstorm in the Northeast, salt may be an important resource for roadway application.
    - Guidelines for prioritizing cargo and Establishing prioritization cargo guidelines and personnel allowances immediately after a disaster are larger issues affecting ports across the nation. While general guidelines can be established, definitive needs are dictated by each incident. Setting priorities requires national, regional, or state decision making.
- In California, ambiguity surrounds who maintains responsibility for deploying energy during and after a disaster and as such there lacks a convening authority to take up this charge. At the distribution level, the utility companies themselves are the single points of responsibility.

II. Disruption Scenario Analysis

The Study Group was tasked with conducting a case study scenario focused on intermodal and cross-sector interdependencies. In support of this tasking, an assessment was conducted on available transportation disruption scenarios, which was followed by the selection based on the strongest relevance to POLA-POLB and applicability to the Study Group's charge. The analysis below comprises the five disruption scenarios that best meet the criteria of both relevancy and applicability.

POLA and POLB Disruption Context

Hazard analysis and mitigation plans from California state, Los Angeles, and Long Beach ranked earthquakes among the top highest-risk hazards. Terrorist attacks, fire, flooding, and critical infrastructure losses were also consistently ranked as high risk hazards. While tsunamis pose a low risk to POLA-POLB, they would have devastating effects. This necessitates their consideration as a significant threat.

Section A includes a synthesis of the analysis conducted on each of the five selected disruption scenarios. The subsequent sections include summaries organized by six criteria for analysis: major themes, key points of failure, challenges, public-private issues, lessons learned, and recommendations. The analytic summaries in Section B focus on the transportation disruption impacts for each of the six disruption scenarios. Section C exclusively focuses on the six disruption aspects of two port exercises (one cyber incident, one terrorism incident) designed to test California port response and recovery capabilities.

Synthesis of Analytic Summaries

This section represents consistent transportation-related themes traversing five disruption scenarios.

Major Resilience Themes across Scenarios

- Although physical damage may be minor in many instances, resuming normal operations can require **significant time and resources** while **business interruption endures and losses proliferate**.
- **Interdependencies** exist among and in the lifeline sectors, transportation system, and supply chain.
- **Preparedness activities**—such as plans, training, and exercises—mitigate disruption consequences in addition to illuminating strengths and vulnerabilities that otherwise may not have been noticed.
- **Timely, accurate information sharing** accompanied by **reinforced coordination and communication** among port personnel and the public and private sectors enable a complete response and recovery.
- **Prioritization** is key in recovery, specifically in a resource deficient environment or expansive disruption. This includes prioritizing infrastructure for restoration and stakeholder and user needs.

Key Points of Failure

- Resilience mitigates cascading effects and prevents business losses.
- Debilitated lifeline sectors and damaged transportation corridors exacerbates port disruptions.
- How port officials manage disaster response, redirect cargo, balance port continuity and recovery, and identify possible cascading effects affects an event's consequences and recovery time.
- Extensive interdependencies among POLA-POLB, transportation, and other sectors leads to varying degrees of disruption in regional, State, and national supply chains and economies.

Challenges

- Secondary disruptions strain already overtaxed resources and delay the return of port personnel.
- Limited access to transportation and the incapacity of alternate ports to process the influx of redirected cargo constricts the supply chain.
- Officials must coordinate between intersecting port and lifeline physical/cyber infrastructures to endure disruptions.

Public-Private Issues

- Public sector decisions, infrastructure ownership, and asset maintenance impact port operations, transportation systems, and supply chains.
- Successful response, recovery, and business restoration requires public-private coordination.
- Public and private sectors must balance security and continuity, as well as commuter and freight needs.

Lessons Learned

- Internal/external port information sharing enables ports to monitor widespread disruption effects.
- While some losses are easily apparent, many vulnerabilities, failures, and long-term effects remain unknown.
- Plans and exercises aid ports in decision-making and readiness assessment, especially for emerging threats such as cyber.
- Smart restoration involves: prioritizing, balancing, coordinating, and considering stakeholder needs.

Recommendations

- Identify critical infrastructure, economic failure points, and supply chain cascading effects before an incident occurs.
- Increase assessments and exercises and socialize results through relationships, plans, and training.
- Encourage the development of common resilience measures and detailed contingency plans in both the public and private sectors.
- Advance multi-hazard planning and implement recovery mechanisms in conjunction with response activities.

- Improve public and private sector internal and external coordination and information sharing.

Summaries of Selected Disruption Scenarios

The ShakeOut Scenario[73]

A magnitude 7.8 earthquake occurs on the southernmost portion of the San Andreas Fault, with secondary hazards (e.g., landslides, tsunamis) occurring. Long duration and damaging shaking occurs at key transportation chokepoints and LA is significantly impacted. The earthquake occurs far enough from POLA-POLB that physical port damage is minimal; however, transportation lines connecting to the ports will be severely damaged. POLA-POLB will not return to full capacity until railroads and highways are reopened—anywhere from 2 weeks to 2 months. 15 percent of the business lost at the ports will never be recovered and the earthquake causes a total of 1,800 deaths and $213 billion in economic losses.

OVERVIEW OF DISRUPTION IMPACTS

Infrastructure

- I-10, I-15 and major transportation passes critically damaged
- Many instances of damaged lifelines across fault: railroads (21), aqueducts (32), natural gas pipelines (39), power transmission lines (141), fiber optic cables (90)
- Rail tracks destroyed and offset
- Large cargo equipment (e.g., cranes) is damaged
- Major building, warehouse losses region-wide but less in damage LA

Economic

- Businesses unable to function due to lifeline loss (e.g., water, energy)
- Lack of water conveyance is the largest factor in business disruption—$50B lost
- Most port business recaptured, but 15% permanently lost
- Repair costs are nominal, when compared to costs from business disruption (e.g., highway damage repairs $400M, but their disruption has economic impacts of $4.6B)

Human and Environmental

- Many port personnel cannot resume operations due to transportation inaccessibility or attending to their families
- Evacuations due to secondary hazards (e.g., floods, fires)
- Major secondary hazards: flooding, aftershocks, 10,000–100,000 landslides, 1,200 uncontrollable fires
- 50–100 sewage spills contaminate water supplies

MAJOR CRITICAL INFRASTRUCTURE SECTOR IMPACTS

Transportation

- Roads impassable for 3 days due to debris, downed traffic signals; full repairs take 1 yr.
- Short term: Corridor repair is difficult due to access road loss/fires/floods
- Ports non-operational 3 days post-incident; at 2wks operating at 10%
- Many lifelines are rebuilt, not repaired

Energy

- Electricity immediately lost; within 3 days LA electricity is restored
- Affected counties fully back online in 1–4 months

[73] U.S. Geological Survey and California Geological Survey, *The ShakeOut Scenario* (May 2008).

The ShakeOut Scenario[73]

- Generation plants taken offline, some for many weeks
- Mutual aid invoked with aid arrival in 1–7 days; but with process snags

Water

- Piped water is disrupted for >1wk, but worst areas have no water for 6 mos.
- 30 dams within 15 miles of the fault are majorly damaged—evacuations occur
- Reservoirs and aqueducts burst, affecting many industrial users
- Water/sewer lines need to be rebuilt

Emergency Services

- Responding personnel overwhelmed by scope of disaster
- Lack of lifeline sectors supplies complicate response ability—only hardened communications (radios) are available
- Supporting infrastructure damaged—60% of hospitals nonfunctional

Communications

- Major infrastructure damage and heightened demand post-event
- 100,000–200,000 addresses lose phone and Internet service for 2–5days
- Assets are widely damaged, but companies quickly recover due to experience and plans in place

The ShakeOut Scenario – Criteria for Analyzing Disruption

Major Themes

The interdependency of lifeline sectors, as well as transportation modes, is accentuated in such a disaster. The restoration and use of transportation requires some degree of prioritization. Physical damage may be easily overcome but returning to normal operations requires more time and resources. Stockpiled supplies and the transportation system's capacity to absorb disruptions may be inadequate.

Key Points of Failure

Critical transportation corridors (Tejon, Soledad, Cajon, San Gorgonio, Coachella Valley passes) and major routes used to get into the Greater Los Angeles area—I-10 and I-15—are impassable. Natural gas, railroads, aqueducts, and communications lines connecting to LA and POLA-POLB and running through the corridors are displaced and severed. Damaged bridges render roadways impassable.

Examples of Cascading Failures

- Damaged transportation roadways to critical corridors inhibits restoration of these passes, which then delays inspection and restoration of freight rail and trucking infrastructure in these corridors.
- Power loss affects 4,000 LA traffic signals and cable connections to traffic centers are severed. Intersections have strained emergency services directing traffic until cables are repaired.
- Ruptured pipelines affect natural gas supplies. Natural-gas powered public transit stops until lines are repaired, limiting transit options and contributing to passenger congestion on restored roads.
- Bridge damage also damages communications cables (due to co-location), which impacts the communications used by response and utility restoration personnel.

The ShakeOut Scenario – Criteria for Analyzing Disruption
• Inaccessible or strained water and energy supplies affect the cool down of electronic and communications equipment and supporting generators.
Challenges Lifelines are co-located and without coordination repairs interfere with other lifelines. Regional ports lack the rail capacity to distribute additional freight and cargo diversion is not a whole solution. Limited transportation means the Ports operate at 10% capacity for two weeks post-incident. Disconnected Internet and communications affect rapid restoration, while resources are overwhelmed.
Public-Private Issues Public utility disruptions greatly impact business operations and the community. Freight from the Ports relies on the restoration of publicly-maintained roadways and bridges. Both commuters and freight will compete for restored transportation access. For disaster response, the public sector first mobilizes, but the disaster's magnitude requires a multi-level public and private sector engagement for full recovery.
Lessons Learned • Pre-event mitigation efforts proved successful but more can be done to further reduce vulnerability. • Reduced transportation system availability creates conflict between commuter and freight needs. • Some losses are well-understood but many types of failures are less obvious or not fully recognized. • Aviation is a critical mode post-disaster and underused airports can be used for airfreight purposes.
Recommendations • Establish and encourage contingency plans in communities and public and private sector. • Identify and define critical intersections, highways, and brides to prioritize for repairs. • Create strategies to address conflicts between commuter and freight use of restored transportation. • Publicize the scenario to all decision makers and use it for planning, training, and alliance-building. • Examine technological resiliency solutions (e.g., automated control system or reverse power supply).

Alaska Offshore Earthquake and Tsunami[74]

A magnitude 9.1 earthquake occurs offshore the Alaska Peninsula. The first tsunami waves arrive at POLA-POLB 6 hours after the earthquake and continue for several hours. Northern California would be subject to higher waves, but Southern California is more vulnerable to inundation because of low-lying topography, a larger coastal population, and concentration of maritime assets. POLA-POLB is hit by 5-10 foot waves, damaging some vessels, docks, and cargo. Most disruption occurs because of strong currents. The ports would be shut down for a minimum of 2 days.

OVERVIEW OF DISRUPTION IMPACTS

Infrastructure

- Along CA coast, 1/3 of boats are sunk and 1/2 of docks are damaged or destroyed
- Many small craft, commercial fishing, and large port vessels damaged to varying degrees
- POLA-POLB marinas have 90 damaged and 5 sunken boats
- Crane power supply structures are flooded and non-functional
- Port containers, cargo vehicles, and cargo system support is damaged
- Harbors, marinas, and coastal fishers are damaged; agriculture fields, onshore facilities flooded

Economic

- Damages, port shutdowns result in major losses: $6B for all CA, including $3.2B for Southern CA
- Adoption of resilience strategies can reduce total losses by 80–90%
- Greatest damage is to buildings and properties at $2.6B, compared to $100M in damages to POLA-POLB
- Port damages and downtime results in $1.2B from lost port trade value, and associated business interruption losses triples that value

Human and Environmental

- Southern LA and Long Beach populations greatly impacted
- 175,000 residents evacuated; 8,500 residents need shelter due to damaged homes
- Low-lying islands in ports have evacuation issues due to limited exits and short warning periods
- The tsunami pushes debris from many sources (e.g., power plants, industrial facilities, petroleum ships and terminals, wastewater treatment plants) to coastal and onshore areas
- Strong currents spread debris/ contaminants more for 2 days

MAJOR CRITICAL INFRASTRUCTURE SECTOR IMPACTS

Transportation

- Large vessels damaged because lack of time to execute port dispersal plan
- Harbor/marina damage takes 1–2 months; but if all docks are destroyed, then repairs take 1–3 years
- Maritime transportation will take the longest to restore due to debris in navigation channels or lengthy cleanup from oil spills in port waters
- Flooding damages electrical rail signal parts
- Functional UP/BNSF lines near LA serve as regional detour routes

Energy

- Disaster results in a 1-month long reduced marine oil terminal capacity, which can be mitigated if there is off-site storage access

[74] U.S. Geological Survey, *The SAFRR (Science Application for Risk Reduction) Tsunami Scenario – Executive Summary and Introduction* (2013).

Alaska Offshore Earthquake and Tsunami[74]

- Long-lasting reduced capacity disruptions run through limited inventories and result in fuel shortages for Southern CA
- If port substations are correctly powered down, equipment drying only takes 2 days–1 week

Water

- Wastewater treatment systems are inundated and contribute to the disbursement of containments in human, agricultural, and ecological supplies
- Limited water supplies impact the ability to run port operations

Commercial Facilities

- Fishing vessels cannot return to work for >1 month due to damaged harbors and processing plants
- Commercial/industrial inundation causes fires if electricity is not properly shut off

Alaska Offshore Earthquake and Tsunami – Criteria for Analyzing Disruption

Major Themes

Damage at POLA-POLB is relatively minor at $100 million; but losses from port trade could exceed $1.2 billion. California's total economic loss is about $10 billion, including $6 billion due to business interruption. Resilience strategies could reduce the loss from the tsunami by approximately 80–90%.

Key Points of Failure

POLA-POLB is critical to Southern California's economy. A shutdown of only a few days can result in major trade and business disruption. The level of resilience implementation is a key variable in losses.

Examples of Cascading Failures

- West Coast ports that POLA-POLB would normally divert cargo to are damaged, complicating cargo re-direction in the region and increasing regional and State economic losses to business disruption.
- The location, construction, and contents of container holds in the ports make them susceptible to fire. Closely located port infrastructure spreads the fire and fireboats are unable to effectively extinguish fires due to strong current.
- Flooded and damaged terminal operating systems mean several marine oil terminals operate at 50% capacity for 1 month, limiting regional supplies for response/recovery. Ports cannot export typical fuel supplies and draining alternate fuel inventories is a short term solution, ultimately resulting in long term disruption to Southern California's economy.

Challenges

Evacuation of areas in Newport Beach (CA) and the entire Balboa Peninsula (CA) would be complicated, even with a 6-hour warning of a possible tsunami. Enforcing the Merchant Vessels Dispersal Plan for larger vessels in POLA and POLB would be essential to limit port damage. Cleanup of debris, damaged buildings, and hazardous materials could be long and costly, adding to business interruption and loss.

Public-Private Issues

Government and private sector cooperation and coordination can improve preparedness, mitigation, and continuity planning, thus reducing economic impacts and enhancing recovery efforts.

Alaska Offshore Earthquake and Tsunami – Criteria for Analyzing Disruption

Lessons Learned

- Breakwaters and channels at POLA and POLB can lessen wave impact, but during tsunamis their entrances have strong currents capable of damaging structures and breaking vessel mooring lines.
- Resilience strategies, such as using existing inventories and working extra shifts after the event, can significantly reduce business losses from port disruption.

Recommendations

- Develop a coordinated, robust policy framework for tsunami hazard assessment and mitigation planning for California's coastal communities, ports, and harbors.
- Advance multi-hazard mitigation planning along California's coast and bays to more holistically address issues of future tsunami risk, sea level rise, coastal flooding and erosion, and earthquake-induced liquefaction.
- Encourage responders and government managers at all levels to conduct self-assessments, devise exercises, and utilize tsunami evacuation playbooks and maritime mapping and guidelines being developed by the State of California.
- Expand the annual California ShakeOut earthquake exercise to include tsunamis.
- Encourage the adoption of resilience practices to minimize damage to the state economy, including conservation, utilizing excess capacity, ship rerouting, export diversion, inventory utilization, and recapturing lost production by working overtime or extra shifts once operations are restored.

Nuclear Device in Shipping Container Explodes in POLB[75]

A 10-kiloton nuclear bomb, hidden in a container, is shipped to the POLB. After being unloaded onto a pier, it explodes and devastates a vast portion of the LA metropolitan area, with much of the destruction caused by radioactive fallout. In addition to large scale death and injury, 6 million people try to evacuate the LA region. POLA and POLB infrastructure is destroyed, including the POLB refineries, resulting in critically short gasoline supplies across the region. Nationwide, ports are closed and rail and truck container shipments are moved outside large metropolitan areas for inspection. Early costs exceed $1 trillion for medical care, insurance claims, workers' compensation, construction, and evacuation. The political and economic effects would be felt across the region, nation, and world.

OVERVIEW OF DISRUPTION IMPACTS

Infrastructure

- All ships in POLB and the adjoining POLA are destroyed by the blast and subsequent fires
- The hull of cargo ships rupture, including crude oil tankers, dispersing contents
- Buildings within a .6mile blast radius are destroyed
- Light physical damage occurs to City of Long Beach but affected area is a main business quarter

Economic

- $1 trillion in total costs, for: homes lost, insurance claims, ports and surrounding infrastructure damage, evacuated populations for 3 years, and commercial facility losses
- Disaster has large economic implications for all U.S. domestic business operations and severe disruptions in the availability of basic goods and petroleum in the U.S.

Human and Environmental

- 60,000 dead (primarily POLB/POLA personnel) from the blast and major radiation poisoning; 150,000 exposed to hazardous radioactive port water and sediment
- 6 million try to evacuate LA
- Radioactive fallout prohibits residence for 10–20 years, requiring 2–3 million re-located residents
- Crude oil from destroyed tankers flows into the harbor

MAJOR CRITICAL INFRASTRUCTURE SECTOR IMPACTS

Transportation

- Large-scale exodus of port city populations fearing further attacks results in an extended port closure due to security concerns and lack of personnel
- Within 10 miles of the blast site, drivers are temporarily blinded, causing accidents and shutting down highways
- 3 days-post incident, major highways cleared but secondary routes impassable. Several bridges near the ports are displaced, needing repair.

Energy

- Loss of POLB refineries causes critically short regional fuel supplies—POLB supplies 1/3 of gas west of the Rockies
- 5 out of 10 LA refineries are contaminated, removing 40% of refining capacity for months or even years
- Major fuel distribution issues for CA, NV, AZ
- Destroyed power grid nodes near the Ports' cause widespread LA power outages

Emergency Services

[75] Charles Meade and Roger C. Molander, *Considering the Effects of a Catastrophic Terrorist Attack* (2006).

Nuclear Device in Shipping Container Explodes in POLB[75]

- Responders have difficulty in getting to the site due to traffic congestion
- Combustibles up to 2 miles from the blast are ignited, starting uncontrollable fires; responders cannot take immediate action due to radiation fallout
- Medical facilities and supplies are overwhelmed

Information Technology

- Electronic equipment within 1 mile of the blast are destroyed due to the blast's electromagnetic pulse
- Power blackout affects most traffic signals and highways move slow, which severely complicates necessary evacuations

Nuclear Device in Shipping Container Explodes in POLB – Criteria for Analyzing Disruption

Major Themes

Although the short-term effects of such a disaster can be calculated, there is great uncertainty for longer term effects and additional study is needed to develop scenarios for testing catastrophic events. There are social and economic aftershocks that occur beyond the immediate physical damage.

Key Points of Failure

POLA and POLB have essential roles in the national and global economies. If the ports should be destroyed, the cascading consequences could be severe in both the near- and long-term. One key point of failure is the inability of the insurance industry to absorb such massive losses. Bankruptcies, loan/ mortgage defaults, and failures to meet contract obligations would likely delay re-opening the ports.

Examples of Cascading Failures

- Half of the refineries in the LA basin are contaminated, removing 40% of LA's refinery capacity for months/years. An acute regional fuel shortage ensues for Southern California, Nevada, and Arizona and pipelines cease flows into the region. Shortages are exacerbated by fire-ravaged storage tanks.
- Destroyed businesses in POLA-POLB and the vicinity find extreme shortages in insurance availability. Ports may find it difficult to operate, because creditors demand insurance coverage for physical assets yet coverage is unavailable, further complicating business recovery efforts.
- Most of the West Coast cargo traffic is handled by POLA-POLB. Diverted cargo to other West Coast ports only makes up 80 percent of the West Coast capacity loss. Major alterations to the region's and Nation's transportation network takes place as a result of the POLA-POLB closure.

Challenges

Two key challenges would face decision makers after the initial 72-hour emergency response: (1) keeping the global shipping supply chain operating, and (2) restoring orderly economic relationships. The destroyed POLB refineries reduce fuel supplies and complicate response and recovery efforts. Radioactive fallout causes evacuations and relocations that may affect personnel operating the Ports.

Nuclear Device in Shipping Container Explodes in POLB – Criteria for Analyzing Disruption

Public-Private Issues

After such an event, different stakeholders would have differing interests and preferred decisions. Policymakers in both government and the private sector would be challenged in balancing the political aim to prevent a future attack by carefully checking all containers arriving at U.S. ports, and the business interest in re-opening the global shipping supply chain as quickly as possible through expedited cargo transfers. Both capital and labor might flee the areas affected, further complicating the recovery. Restoring normal economic relationships would require close public-private cooperation and coordination. Cleanup and rebuilding the infrastructure would also require coordinated efforts.

Lessons Learned

- Exact outcomes are difficult to predict but event consequences suggest alarming vulnerabilities.
- The consequences of a major failure of existing economic systems are not well known, nor are the potential benefits of alternative potential policies known.
- Exercises based on catastrophic events can help policymakers anticipate the types of decisions they might be forced to make and enable them to plan in advance for such contingencies.

Recommendations

- Increase modeling/gaming to investigate long-term economic consequences of catastrophic events.
- Identify failure points in current social and economic systems and assess benefits of new policies.
- Gain insights into the policy and economic decisions likely to be made following such events.

Summaries of Selected Port Disruption Exercise Scenarios

Cyber Incident at a Key Critical Infrastructure Site[76]

In 2014, the POLA conducted the Cybersecurity Tabletop Exercise (TTX), simulating a cyber incident at a key critical infrastructure site and multiple locations. The TTX assessed the ability of stakeholders to effectively coordinate and collaborate to manage and investigate a cyber incident. It included a component focused on cyber incident information sharing and response collaboration and tested 3 of the 5 National Preparedness Goal mission areas: prevention, protection, and response. 210 personnel from the private sector and Federal, state, local, and nongovernmental agencies participated.

Major Themes

Cyber incident preparedness requires strong coordination and communication among government, port personnel, and the private sector. Exercises and training uncover cybersecurity strengths and vulnerabilities. Cybersecurity is essentially ambiguous and further complicated by the lack of robust cybersecurity plans, attack tactic knowledge, and internal/external information-sharing mechanisms.

Key Points of Failure

Action taken by IT personnel is dependent on timely, relevant information shared. The identification of cyber incidents is dependent on established relationships and compatible public and private cyber terminology. Ensuring the identification of emerging or imminent cyber threats is crucial to prevention.

Challenges

There is no standard system or tool to share information either internally or externally with stakeholders and participants. Cybersecurity plans outlining specific processes, protocols, roles, and responsibilities are uncommon and ambiguity surrounds cybersecurity incident response. Physical and cyber security are intimately linked, yet are disconnectedly handled by separate departments.

Public-Private Issues

During a cyber incident, port personnel need to collaboratively work with tenant IT personnel to gain incident situational awareness. In addition, relevant, timely, and actionable information and analysis needs to be shared across state, local, and Federal agencies, law enforcement, and the private sector.

Lessons Learned

- Exercises provide an opportunity for participants to assess current cyber incident readiness.
- Participants had difficulty effectively communicating and sharing information internally/externally.
- Current cybersecurity plans are deficient in outlining processes, protocols, roles, and responsibilities.
- Without formal cybersecurity policies in place, cyber incidents may go unreported until it is too late.
- Deficiencies in inter-port communication can slow information sharing and response capabilities.

Recommendations

- Improve partnerships among port components and better coordinate physical and cyber security.
- Develop inter-port communication protocols and improve information sharing with stakeholders.
- Establish policies to assist IT organizations in determining when an incident should be escalated out of the department, who should be notified, and what information needs to be shared and acted on.
- Host cybersecurity exercises and training to develop trusted relationships and assess readiness.
- Develop formal, coordinated cybersecurity plans and cyber incident reporting requirements.

[76] Port of Los Angeles, *Cybersecurity Tabletop Exercise After-action Report/Improvement Plan* (2014). Redacted.

Golden Guardian 2010 Exercise: Terrorist Attacks at Ports[77]

In 2010, an exercise challenging local, State, regional, and Federal response and recovery capabilities was conducted. The scenario entailed multiple terrorist attacks, with varied attack styles, on California ports over the course of a two-day period, including the POLA and POLB. The POLA-POLB complex was subjected to a "Mumbai" style attack with hostages taken on a charter ferry. Additional scenarios included, but are not limited, an improvised explosive attack (IED) on a rail car and a water-borne IED targeting a ship. The exercise uncovered many successes and challenges in response and recovery.

Major Themes

Pre-event planning, training, and resources in place for response and situational awareness are crucial to success; however, these resources can quickly be strained should multiple incidents occur statewide.

Complexly interdependent systems, processes, and supply chains in the public and private sectors exacerbate consequences and challenge the restoration of port business. Effective response is enabled by timely, accurate information and reinforced continuity induces recovery momentum.

Key Points of Failure

Improperly redirecting or closing cargo causes significant business loss leading to global and long-term economic disruption. Unbalanced security, continuity, and recovery needs threaten response/recovery.

Challenges

Simultaneous, multiple terrorist attacks entail a complex response and require coordination. Although personnel may receive incident command and emergency operations training, exercising or applying this training may be limited. Ports may have insufficient resources to maintain an elevated security level for an extended time and outside assets may not be available due to the incident's scope.

Public-Private Issues

Public sector decisions impact port closures which then affect a broad range of other sectors. Incident communication decisions are complicated, as officials want to reduce anxiety in low trust situations yet also disseminate information. Effective communication between the public and private sector is critical to response/recovery. Many long-term recovery issues (e.g., waivers) will need government assistance.

Lessons Learned

- Maritime security councils gather industry to cogently coordinate, collaborate, and make decisions.
- Communication is essential in developing a common operating procedure and situation control.
- Decisions need to be made to prioritize limited resources in a complex fast-moving environment.
- Issues involving major port decisions, supply chain, or economic situations are complex and far-reaching and thus, need to be publicly communicated outside the ports.
- Finding a balance between continuity and recovery is a priority for port officials.

[77] California Emergency Management Agency, *Golden Guardian 2010 After Action Report* (2010).

Golden Guardian 2010 Exercise: Terrorist Attacks at Ports[77]

Recommendations

- Conduct a review of the information management and resources systems used during emergencies.
- Government must provide credible and trusted information to the public and private sector.
- Improve the understanding of the U.S. Coast Guard's MARSEC (MARitime SECurity) system.
- Develop a joint government and corresponding port leadership field office for better coordination.
- Establish recovery plans implemented in conjunction with response activities as a best practice.
- Examine and plan for supply chain cascading effects. At all process points, involve the private sector.

III. Overview of Transportation Infrastructure at POLA and POLB

Freight Rail Mode

There are two principal Class I railroads connecting to the POLA-POLB region, Union Pacific (UP) and Burlington Northern Santa Fe (BNSF); these rail systems then connect to other Class I railroads serving the eastern half of the nation. A Class III railway, the Pacific Harbor Line (PHL), provides transportation, maintenance, and dispatch services to both the POLA and POLB rail facilities. Freight rail activity within the POLA-POLB region is primarily concentrated in the Alameda Corridor. The corridor is the first link in the Los Angeles rail system, which then branches into three main routes that lead into and out of the POLA-POLB area.[78] Freight rail from the POLA-POLB region is primarily destined for four major gateways—St. Louis, Missouri; Chicago, Illinois; Memphis, Tennessee; and New Orleans, Louisiana.[79]

- **POLA:** Possesses the Nation's largest on-dock rail assets, and provides the highest frequency of intermodal access to 14 major freight hubs across the United States.[80] POLA is served by UP and BNSF, and POLA houses four on-dock rail complexes with loading rail tracks complemented by storage rail tracks.[81] The four on-dock rail complexes are the following:
    - APL On-Dock Railyard: A 262-acre container terminal, with eight loading tracks and eight storage tracks.
    - Maersk On-Dock Railyard: The largest on-dock railyard at POLA, located within POLA's largest terminal. A 484-acre container terminal; 12 loading tracks with the capacity for 96 railcars, and 6 storage tracks.

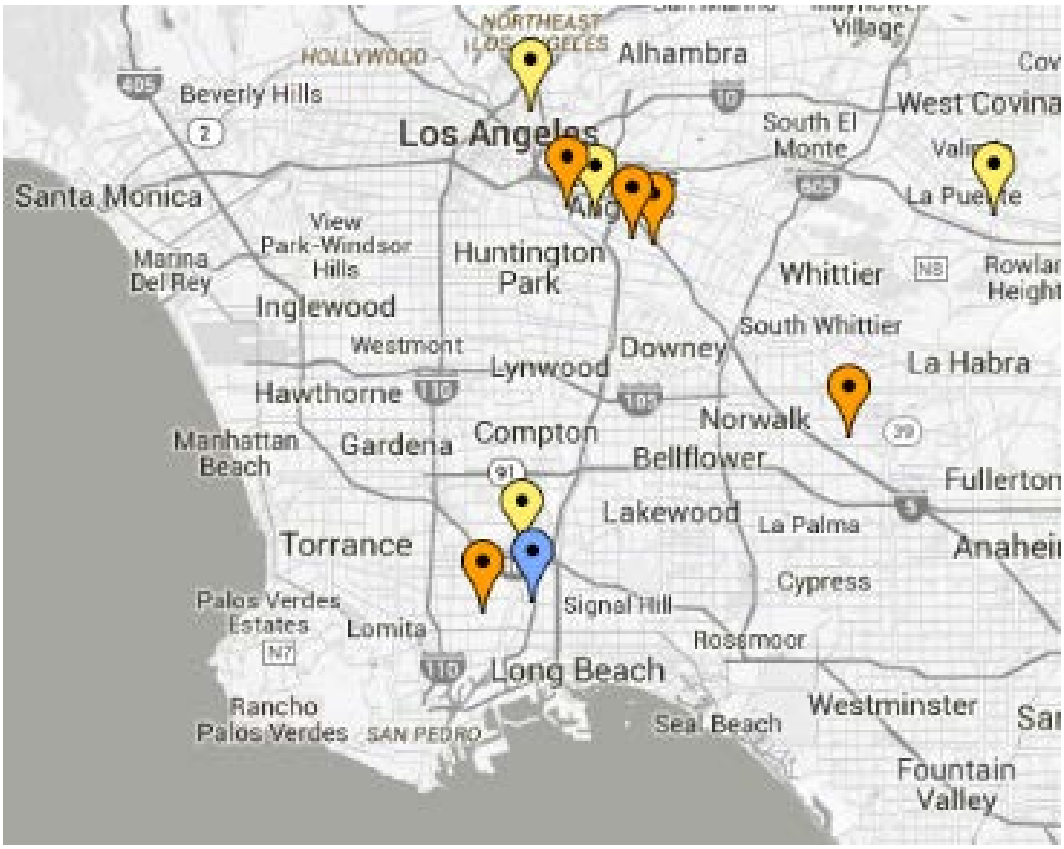
[78] Alameda Corridor Transportation Authority, *Trade Impact Study Report* (2009).
[79] California Department of Transportation, *Caltrans Freight Rail Fact Sheet.*
[80] POLA, *A Profile of the Port of Los Angeles*.
[81] POLA, *Rail & Intermodal Yards* and *Goods Movement.*

- Terminal Island Container Transfer Facility On-Dock Railyard: Composed of two terminals (162 acre and 185 acre) located on Terminal Island, with four loading tracks and five storage tracks.
- Yang Ming/China Shipping On-Dock Railyard: A 130-acre container terminal, with three loading tracks and three storage tracks.

- **POLB:** Nearly half of the cargo arriving at POLB is moved by rail to the rest of the country, and roughly 25 percent of all POLB cargo moves to and from the waterfront via the Alameda Corridor freight rail expressway.[82] Five of the six POLB terminals are served by on-dock rail, with an average of 60 trains departing from on-dock rail facilities every week and taking approximately 72 hours to reach Chicago, Illinois, by freight rail. POLB uses the same two railways as POLA.[83]

Figure H-1. Railyards for Class I Railroads Map

(BNSF railyards denoted in orange, UP railyards in yellow, and the Port Intermodal Container Transfer Facility in blue)



[82] Port of Long Beach (POLB), *Trade/Commerce* and *FAQs*.
[83] POLB, *Rail Guide*.

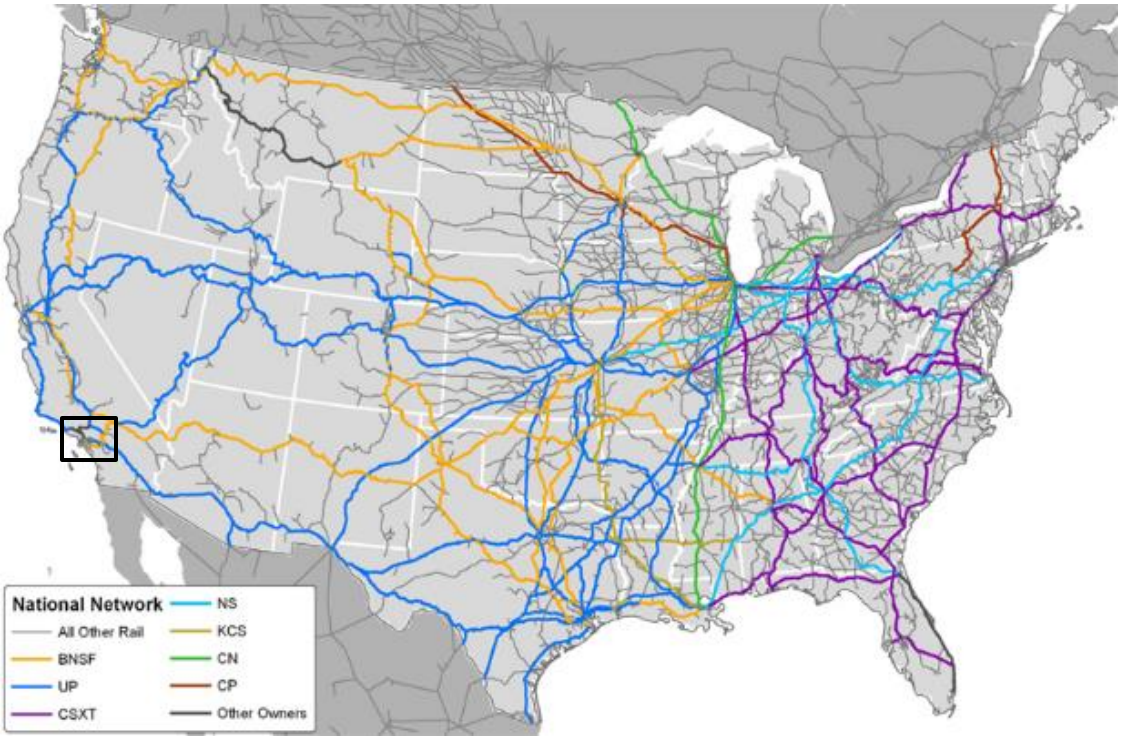
Freight Rail – Critical Assets and Corridors

- **Alameda Corridor:** This 20-mile corridor is located within the southern half of Los Angeles County and was built in 2002 under a public-private partnership between POLA, POLB, UP, and BNSF.[84] The corridor consolidates rail traffic from both POLA and POLB, and all harbor-related UP and BNSF trains use the Alameda Corridor.[85] In 2013, more than 16,500 trains utilized the corridor, with an average of 45 trains running per day.[86]
- **Intermodal Container Transfer Facility (ICTF):** Operated by UP, this near-dock railyard is located approximately 5 miles from POLA-POLB and is composed of 146 acres of primary terminal and 87.4 acres of storage terminal. It is used as a relay point between the ports and major railyards near downtown Los Angeles) for intermodal container transfer. 15 percent of containers entering POLA-POLB go through ICTF.[87] There are 16 entrance/exit lanes for trucks through the main gate, which is open 24/7 and able to process an average of 1,800 transactions per day.[88]
- **Centralized Traffic Control (CTC) System:** Operated by PHL for the POLA-POLB region, the CTC System manages all inbound and outbound train movements. UP, BNSF, and on-dock railyards are linked into the CTC System.[89]
- **Henry Ford/Badger Avenue Bridge:** Provides the only railroad link to Terminal Island from the mainland and feeds directly into the Alameda Corridor. It runs parallel to the Commodore Schuyler F. Heim Lift Bridge, which carries trucks and automobiles into/from the ports.[90]
- **Cajon Pass:** This corridor is a major artery of transportation into Southern California. UP and BNSF have main rail lines running through the corridor in close proximity to each other.[91]
    - UP: Cajon Pass is one of two access points for UP trains running into the Greater Los Angeles area. It also enables UP trains to travel along the West Coast and through the interior and southern United States.
    - BNSF: The pass is an access point for BNSF trains running into the Greater Los Angeles area, along the West Coast, and through the interior United States.
- **San Gorgonio Pass:** This corridor is the second access point for UP trains running into the Greater Los Angeles area. It enables travel through the southern United States and provides a connection to interior lines.

---

[84] POLA, *Goods Movement.* The Alameda Corridor Transportation Authority estimates that 2 million twenty-foot equivalent units (TEUs) per year travel from POLA/POLB to the Inland Empire (Colton, Ontario, Mira Loma, etc.). The Inland Empire is home to more than 350 million square feet of warehousing. Most of the port-related containers are carried on the heavily traveled I-710, I-10, and I-60 freeways.
[85] Railway-technology.com, *The Alameda Corridor Route Map*.
[86] Alameda Corridor Transportation Authority, *Corridor Stats.*
[87] Intermodal Container Transfer Facility-Joint Powers Authority, *Fast Facts.*
[88] POLA, "Intermodal Container Transfer Facility (ICTF) (Near-dock)," in Rail *& Intermodal Yards.*
[89] POLA, "Intermodal Traffic Control," in *Rail & Intermodal Yards*.
[90] POLA, *CA-103 Commodore Schuyler F. Heim/Henry Ford Bridge*.
[91] DHS, FEMA, *Inventory of Lifelines in the Cajon Pass, California* (1992).

Figure H-2. U.S. National Railway System Map (POLA-POLB region outlined in black)
National Surface Transportation Policy and Revenue Study Commission, Transportation for Tomorrow Final Report—Volume III: Section 6, Submissions Sponsored by Commissioners (2007).



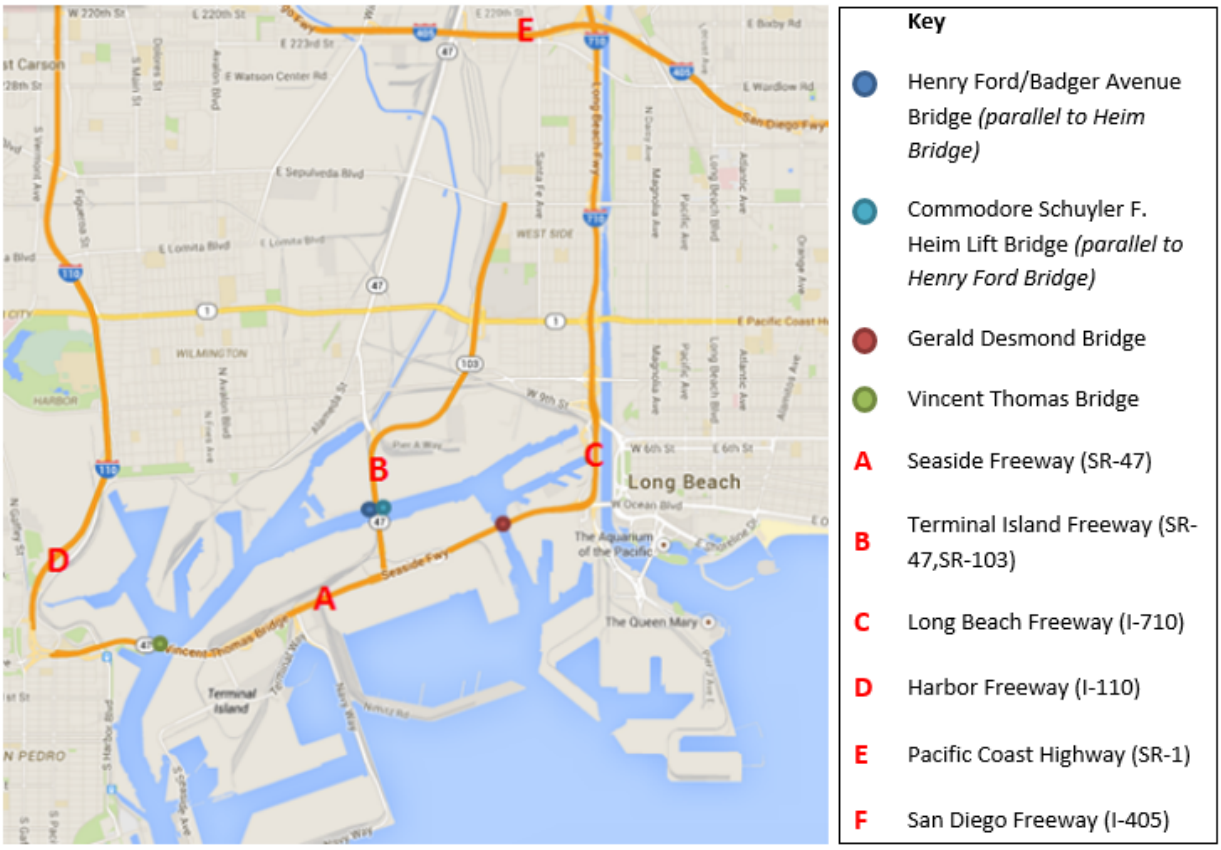
Highway and Motor Carrier Mode

Access to and from the POLA-POLB region is primarily served through a network of freeways and arterial street routes. There are three major freeway arteries running north from the region that feed into a major freeway traversing region. Farther north is a major freeway (I-405) that cuts across two of the three major freeway arteries running north from the POLA-POLB region. Major freeways include the following:

- **Seaside Freeway** (SR-47, and locally referred to as Ocean Boulevard/Seaside Avenue) is a 4–6 lane roadway running east-west with a capacity of 4,000 vehicles and a steady flow of volume throughout the day.
- **Terminal Island Freeway** (SR-103, SR-47) runs north-south. It maintains six lanes nearest the POLA-POLB region and narrows to four lanes on its northern segment. It is the main artery for freight trucking to and from the harbor region, with a capacity of 6,000 vehicles and a steady flow of volume throughout the day.
- **Long Beach Freeway** (I-710) runs north-south extending from the POLB area, maintains six general purpose lanes within the harbor region, and has a capacity of 8,000 vehicles.
- **Harbor Freeway** (I-110) runs north-south, has six general purpose lanes within the harbor region, and has a capacity of 8,000 vehicles. In terms of volume, traffic leaving the port region is highest in the morning hours, and traffic into the region is highest in the afternoon hours.

- **Pacific Coast Highway** (SR-1) extends east-west north of the POLA-POLB region, crosses all three major freeways emanating from the port region, and maintains 4–6 lanes.
- **San Diego Freeway** (I-405) runs north-south and has eight general purpose lanes. Between I-110 and I-710 it has the capacity to handle 10,000 vehicles.[92]

Figure H-3. Overview of Major Freeways and Bridges within the POLA-POLB Region



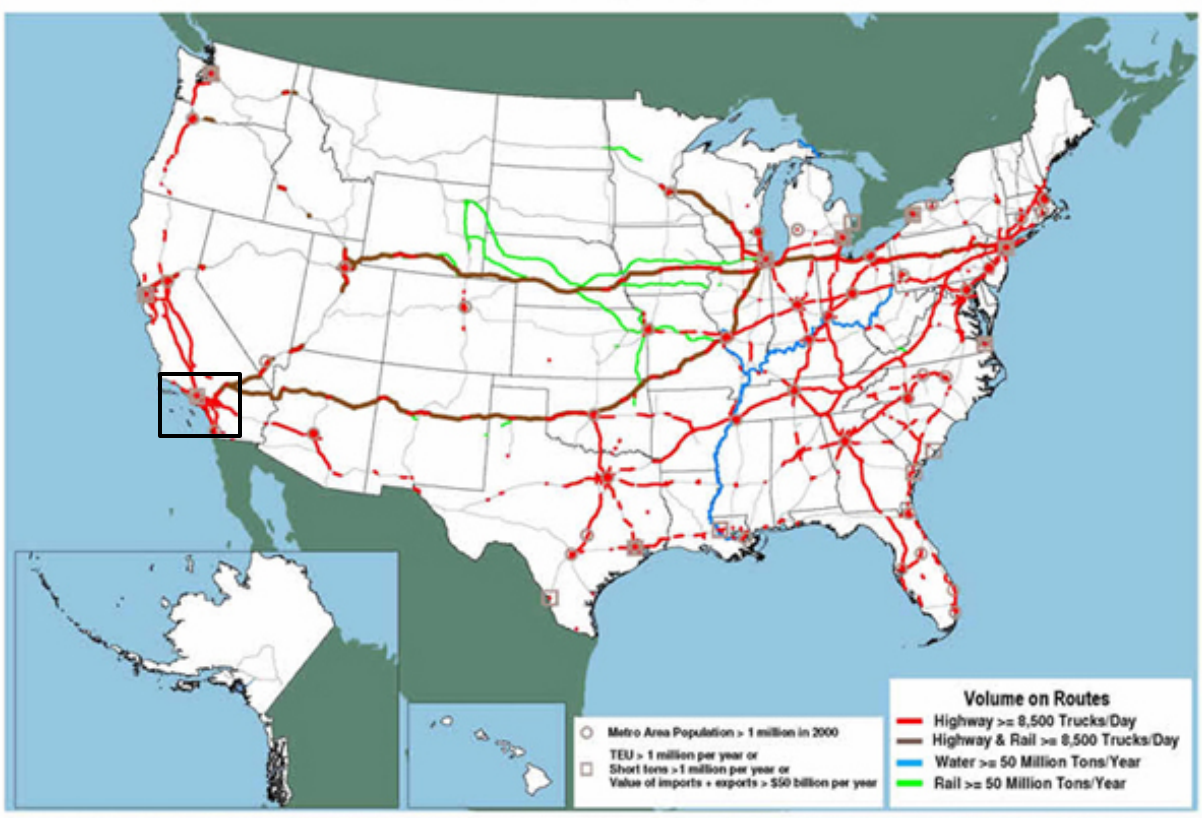
Freight Trucking

Nearly all cargo moving to or from the POLA-POLB region involves some trucking, with most freight trucking movement connecting freight rail terminals to the ports or to the final destination. Both the POLA and POLB experience major drayage activity—transporting containerized cargo between the ports or between docks and rail terminals. In May 2014, the number of heavy-duty trucks listed in the Long Beach Port-owned Drayage Truck Register with access to either POLB or POLA was 12,893, and the total number of full and empty truck moves during that month within POLB was 296,988.[93] Approximately 80 percent of the trucks were frequent and semi-frequent trucks, and 20 percent were non-frequent trucks; all three types typically completed short-to-moderate hauls.[94] Freight trucking is concentrated

[92] Los Angeles Harbor Department, "Chapter 3.10 Transportation/Circulation," in *Southern California International Gateway Project Final Environmental Impact Report (EIR)*, Draft (n.d.).
[93] POLB, Clean *Trucks Program: Report of May 2014* (2015).
[94] POLA, *San Pedro Bay Ports Clean Truck Program* (2008).

within California and the western United States; however, the reach of the freight trucking extends across the central United States and to the East Coast. As illustrated in Figure H-4, the POLA-POLB region is a major freight corridor, with more than 8,500 trucks per day operating routes within the region. In addition, the region is also considered a major freight corridor due to the combined volume in freight trucking and freight rail.[95]

Figure H-4. Major Freight Corridors (POLA-POLB region outlined in black)
Source: DOT, FHWA, "Major Freight Corridors Map."



Freight Trucking – Critical Assets and Corridors

- **Bridges:** Three major highway bridges connect Terminal Island to the mainland—the Vincent Thomas Bridge (four lanes processing 32,000 vehicles each weekday), Gerald Desmond Bridge (two lanes, expanding to six lanes), and Commodore Schuyler F. Heim Lift Bridge (six lanes).[96]
- **Major interstate highway corridors:** The Southern California region, containing the POLA-POLB region, is accessed through four major interstate highway corridors:
    - **I-5:** Runs north-south and links the West Coast, Canada, and Mexico. This corridor includes the Tejon Pass and is the westernmost major roadway artery to San Diego. SR-14/Antelope Valley Freeway, containing the Soledad Pass, connects to I-5 and links to the various state routes between I-5 and I-15.

[95] DOT, FHWA, *Major Freight Corridors.*
[96] POLA, *Transportation.*

  - **I-15:** Runs north-south and links Southern California to the interior United States. Cajon Pass, a critical transportation access point to Greater Los Angeles, is located along I-15.
  - **I-40:** Runs east-west, begins in the west at I-15, and links Southern California to the interior United States.
  - **I-10:** Runs east-west, links Southern California to the southern United States, and contains the San Gorgonio Pass—a critical route for UP freight rail trains.[97]
- **Major container transport corridors:** Containers coming from the POLA-POLB region are primarily transported through I-110, I-710, and SR-47/103, which later connect to major roadway linkages up the West Coast, to ICTF, and to roadway linkages through the interior and southern United States.[98]

Mass Transit Mode

Within the POLA-POLB region, four transit agencies provide service to the harbor region: Los Angeles County Metro (LACM), Long Beach Transit, Torrance Transit, and the Los Angeles Department of Transportation (LADOT). These transit agencies operate 13 transportation routes that connect to the harbor region. Various modes of mass transit are either connected to or service the harbor region.[99]

- **Metro rail:** Only one Metro rail line connects to the port region. The Metro Blue Line serves the Downtown Long Beach area.
- **Public bus service:** The POLA-POLB region is primarily served by county and municipal bus routes:
  - LACM operates the following bus services to the POLA-POLB region: four Metro Bus (local and limited service) lines; two Metro Express lines, concentrated nearest to POLA; and one Metro Rapid line, concentrated nearest to POLB. The Metro Bus services both the POLA and POLB sides of the port region.[100]
  - LADOT operates the DASH San Pedro Line, connecting to the POLA side of the region, as well as the Commuter Express Line 142, which connects to both the POLA and POLB sides of the region.[101]
  - Long Beach Transit operates bus routes that connect to the cruise terminal for POLB.
  - Torrance Transit operates various bus routes that serve the city of Torrance, which is approximately 8 miles from the POLA-POLB region, as well as the Metro rail line connecting to the Downtown Long Beach area.
- **Amtrak:** Provides services to cruise line port areas, with one station servicing the Catalina Terminal at POLA and another station approximately 4 miles from POLB.[102]

---

[97] DOT, FHWA, "Interstate Multimodal Corridors," *in Southern California Regional Freight Study* (2013).
[98] California Department of Transportation, "Appendix B-4-5: Port of Los Angeles," in *California Freight Mobility (n.d.).*
[99] Sanpedro.com, *San Pedro and LA Harbor Area Local Transit* (2014).
[100] Los Angeles County Metro, *System Maps.*
[101] Los Angeles Department of Transportation Transit Services, *Dash* and *Commuter Express.*
[102] Amtrak, *California Stations.*

- **Santa Barbara Airbus:** Serves the POLA and POLB cruise line terminals primarily through the Los Angeles International Airport (LAX); however, three city starting locations are available.
- **Waterfront Red Car Line:** POLA runs a 1.5-mile waterfront electric trolley line—holding approximately 50 people per trip—that connects the World Cruise Center and points along the San Pedro Waterfront.[103]

Figure H-5. Public Mass Transit Serving the POLA-POLB Region
Source: Metro System Map

Aviation Mode

There are several airports located within a five-county radius surrounding the POLA-POLB region. The closest major airports are LAX, which is 20 miles from POLA, and the Long Beach Airport (LGB), which is 11 miles from POLB. Within 115 miles of the POLA-POLB region, there are six additional commercial service airports at various distances from the ports.

- **LAX:** The third-busiest airport in the United States, the foremost international gateway to the Asia/Pacific region, and served by nearly 90 passenger and cargo airlines. In 2013, LAX served

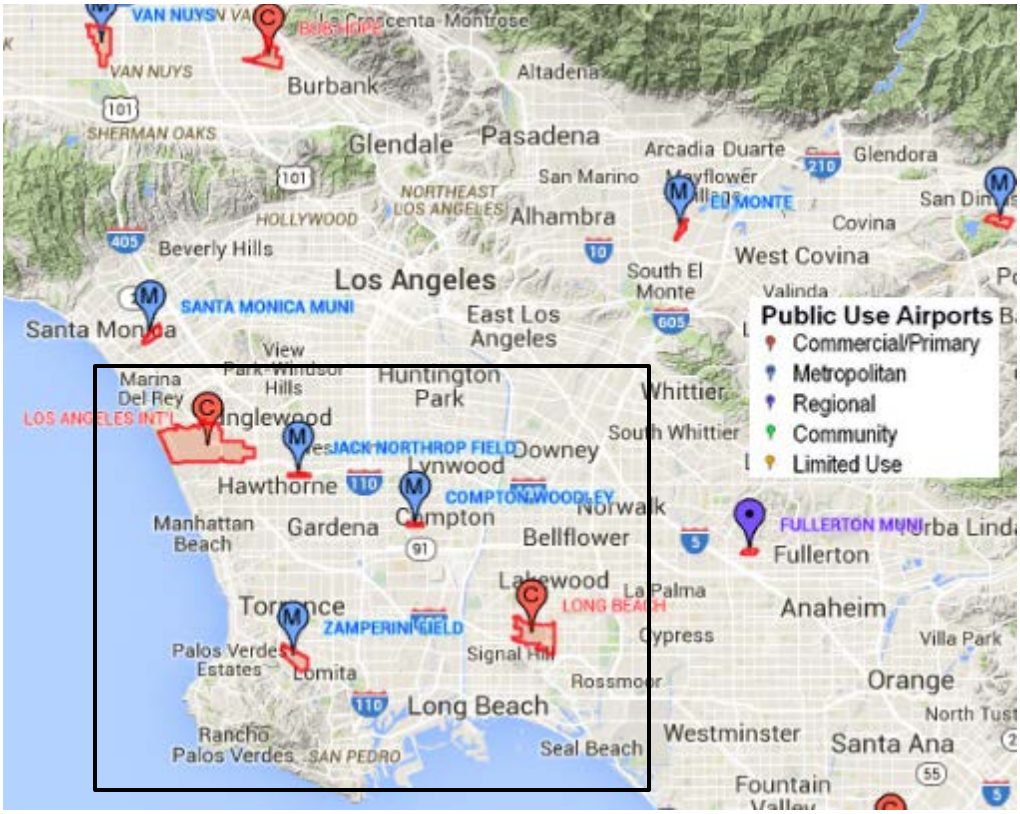
[103] POLA, Waterfront *Red Car Line.*

66.7 million passengers and processed more than 1.9 million tons of air cargo, worth more than $91.6 billion.[104]

- **LGB:** The closest airport to the POLA-POLB region. It is served by five passenger airlines and is one of the five-busiest general aviation airports in the United States, with 365,000 operations annually. These operations include donor organ and critical care delivery, search/rescue, and law enforcement flights. In 2013, LGB transported 26,858 tons of cargo and recorded 251,957 operations.[105]

Figure H-6. Public Use Airports

POLA-POLB region outlined in black



Pipeline Mode

Within the POLA-POLB region, there is a complex system of pipelines transporting natural gas and hazardous material. As indicated in Figure H-7 below, the POLA-POLB region contains a concentration of both natural gas transmission lines and hazardous liquid (e.g., petroleum/oil) pipelines. The region primarily serves the Los Angeles area and San Diego. Most of the crude oil refineries in the Los Angeles area are located 2–5 miles north of POLA. POLA and POLB are the major ports for marine import of

[104] Los Angeles World Airports, "News and Facts," in *General Description*.

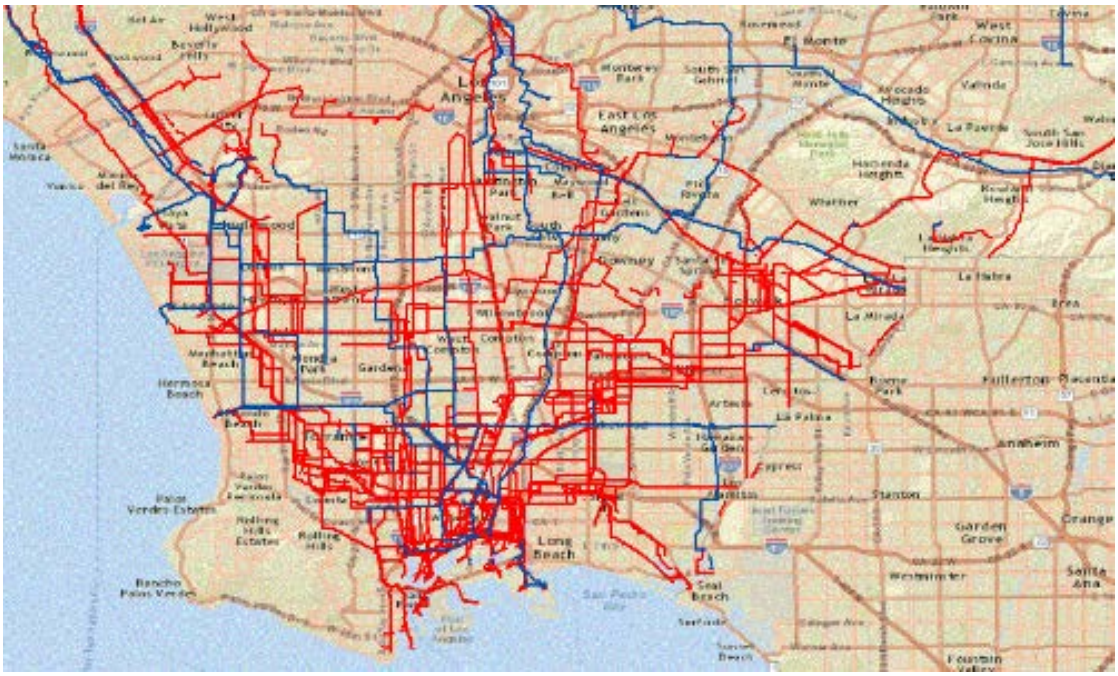
[105] California Department of Transportation, "Appendix B-3-6: Long Beach Airport," in *California Freight Mobility Plan (n.d.)*.

crude oil into Southern California.[106] Additionally, California accounts for more than one-tenth of the total U.S. capacity for petroleum, and the ports process large volumes of Alaskan and foreign crude oil.[107]

- **POLA:** Seven companies operate seven liquid bulk facilities featuring tankers, barges, bulk carriers, and storage tanks that are conveniently located alongside rail access.[108]
- **POLB:** Five companies operate six piers that receive and transport crude oil, gasoline, and miscellaneous chemicals.[109]

Figure H-7. Pipelines in the POLA-POLB Region

Gas transmission lines denoted in blue and hazardous liquid pipelines in red



Postal and Shipping Mode

Postal shipping is typically handled by transportation modes that do not directly involve the ports. There are no U.S. Postal Service facilities located directly on the campus of POLA or POLB; however, there are U.S. Post Offices nearby, and Los Angeles is home to a major FedEx distribution hub.[110]

---

[106] POLA, "Appendix D3: Southern California Petroleum Market Assessment," in *Pacific L.A. Marine Terminal LLC Crude Oil Terminal Draft SEIS/SEIR* (2008).

[107] U.S. Energy Information Administration, "Petroleum," in *California State Profile and Energy Estimates: Profile Analysis* (2014).

[108] POLA, *Liquid Bulk.*

[109] POLB, Liquid *Bulk.*

[110] FedEx, Fedex *Hub Network Map.*

Appendix I: Compendium of Prior NIAC Recommendations Related to Resilience

The purpose of this appendix is to provide a listing of past NIAC recommendations related to resilience in the transportation sector to leverage knowledge and findings already acquired in past studies for the current study. The recommendations are organized into six categories:

I. Cross-Sector Interdependencies
II. Strategically Improving Transportation Infrastructure
III. Complementary Public and Private Resilience Building
IV. Emergency Planning and Response
V. Information Sharing
VI. Emerging Issues

I. Cross-Sector Interdependencies

NIAC recommendations in this category focus on sector interdependencies—how events impacting one sector can cascade across other sectors, often in unexpected ways. It is essential to understand these interdependencies in order to prepare for large-scale events. Cross-sector partnerships build understanding and work to address these interdependencies.

Identifying Interdependencies

- The President should task the NIAC to identify the highest-priority cross-sector risks affecting national security and resilience and produce a written report to the President within 18 months recommending potential executive-level, cross-sector action. (Recommendation 1.3. Regional Resilience, 2013, p. 5)
- Emphasize cross-sector interdependencies and collaboration through the Sector Partnership Model:
    - The U.S. Department of Homeland Security (DHS) and other Federal organizations should increase resources to conduct cross-sector studies and analysis, guided by private-sector knowledge of infrastructure operations.
    - Increase understanding of cross-sector interdependencies and capabilities, led by the sectors that have a well-established partnership and a strong security posture. (Recommendation 6 [with selected bullet point]. CI Partnership Strategic Assessment, 2008, p. 11)
- The national laboratories should focus their interdependency modeling and research on the regions and sectors whose failure would have the highest impact on the economy and national security. The Study Group suggests starting with modeling the telecommunications and energy sectors and the interdependencies among them and other critical infrastructure. In addition, existing research and development (R&D) studies need to be indexed and cross-referenced so

that these materials are accessible to appropriate parties. (Recommendation 9. Cross Sector Interdependencies, 2004, p. 11)

- The DHS Office of Infrastructure Protection (DHS-IP) should expand the provision of scalable, low-cost tools and techniques for community-level identification and assessment of infrastructure interdependencies. (Recommendation 3. Optimization of Resources, 2010, p. 21)
- The NIAC should prepare a follow-up report to the July 2009 *Framework for Dealing with Disasters and Related Interdependencies* to determine the implementation status of recommendations to remove cross-jurisdictional and other impediments to the transportation and use of outside assets during an emergency. (Recommendation 6. Optimization of Resources, 2010, p. 22)

Cross-Sector Partnerships

- The Secretary of Homeland Security should facilitate the development of cross-sector partnerships within selected regions to improve the regions' resilience to very large-scale events that could impact national security, resilience, and economic stability. (Recommendation 2.1. Regional Resilience, 2013, p. 5)

II. Strategically Improving Transportation Infrastructure

This section highlights recommendations related to strategic development, organized by several focus areas: existing frameworks for resilience, regulatory policies affecting recovery, regional needs, and infrastructure investments and incentives.

Adopting Existing Frameworks for Resilience

- Promote the use of the NIAC-developed framework for setting resilience goals in the critical infrastructure and key resources (CIKR) sectors and for providing a common way to organize resilience strategies within Federal and state governments and CIKR sectors. (Recommendation 5. Establishing Resilience Goals, 2010, p. 52)
- Fortify government policy framework to strengthen critical infrastructure resilience:
    - The President should adopt the NIAC definition for resilience for development of resilience policy.
    - Government should establish a collaborative dialogue with CIKR owners and operators in each sector to develop a commonly agreed-upon set of outcomes-focused goals for each sector.
    - The President should issue a Homeland Security Presidential Directive (HSPD)-level authority to develop a national policy on resilience in a manner similar to and consistent with the HSPD-7 policy for protection, but also ensure the authorities under this guidance and public-private infrastructure protection partnership is retained. (Recommendation 1 [with selected bullet points]. Critical Infrastructure Resilience, 2009, pp. 16–18)
- All critical infrastructure sectors should consider adopting the industry self-governance model exemplified by the Institute of Nuclear Power Operations and the North American Transmission

Forum to enable the private sector to collaborate on industry-wide resilience and security issues outside the regulatory compliance process. (Recommendation 4. Establishing Resilience Goals, 2010, p. 52)

Addressing Regulatory Policies Affecting Recovery

- A process for identifying and addressing statutory, regulatory, and policy impediments to recovery:
    - DHS should institutionalize processes and provide funding as needed to systematically develop and maintain at the Federal, state, and local (especially major metropolitan) government levels, catalogs of specific laws and regulations that may need to be suspended or modified during different disaster scenarios to improve CIKR recovery efforts.
    - The Executive Branch should work with Congress and state legislatures to pass legislation with provisions that allow the executive branches in government, at the Federal and state levels, to grant blanket waivers for statutes and regulations identified as impeding recovery efforts during an emergency or disaster-type event. (Recommendation 1 [with selected bullet points]. Framework for Dealing with Disasters and Related Interdependencies, 2009, pp. 20–21)
- Potential Federal, state, and local action to address statutory, regulatory, and policy impediments to disaster recovery/preparedness:
    - To address the lengthy waiver process for Environmental Impact statements (EIS), DHS should ask Congress to validate the "Alternative Arrangements" rule the Council on Environmental Quality has used to expedite EIS requirements during emergencies.
    - DHS should work with the relevant Sector-Specific Agencies (SSAs) and regulators to identify a process for emergency waivers for document filing deadlines with regulatory agencies on processes that need to be expedited during a disaster.
    - DHS should collaborate with the Transportation Systems and Energy Sectors, as well as with all other relevant sectors to identify actions that assist in expediting vehicle restrictions—including driver-hour limitations, road size and weight restrictions, and port access restrictions, among others—during CIKR emergency recovery efforts.
    - DHS should ask Congress to consider legislation authorizing the waiver of Federal and state restrictions on the interstate movement of motor vehicles responding to a disaster.
    - The DHS Federal Emergency Management Agency (FEMA) and DHS-IP should collaborate to develop a structured, commonly applicable best practices decision-making process for authorities to use for credentialing CIKR workers and granting access to a disaster area during an emergency (Recommendation 2 [with selected bullet points]. Framework for Dealing with Disasters and Related Interdependencies, 2009, pp. 21–23)

- Determine the role of policies, regulation, and consolidation within industries and its impact on resilience, security, innovation, and resilience. (Recommendation 1.3, CISR R&D Plan, 2014, p. 25)

Focusing on Regional Needs

- The President should require that Federal agencies: (a) explicitly consider and address the differences among regions when promulgating security and resilience rules, programs, or guidance; and (b) expressly state how they have customized implementation to each region if there is not generic applicability. (Recommendation 3.3. Regional Resilience, 2013, p. 6)
- The President should designate the Energy, Communications, Water and Wastewater Systems, and Transportation Systems Sectors as lifeline sectors and direct SSAs to examine their policies, procedures, and programs to determine the extent to which they recognize the priority of the lifeline sectors and the individuality of regions, amending or revising those that do not. (Recommendation 3. Regional Resilience, 2013, p. 6)
- The Secretary of Homeland Security should initiate a pilot program with state and local governments in select regions to conduct regional joint exercises, develop risk maps of critical sector interdependencies, and extract lessons learned on regional needs and gaps for government and sector partners. (Recommendation 2.2. Regional Resilience, 2013, p. 5)

Facilitating Infrastructure Investments and Incentives

- Explore the potential for creating tax incentives or other instruments to incentivize the private sector to enhance the resiliency of critical infrastructure. (Recommendation 8. Cross Sector Interdependencies, 2004, p. 11)
- The President should direct the Council of Economic Advisors and the Office of Science and Technology Policy to work with Federal agencies to create a strong and enduring value proposition for investment in resilient lifeline infrastructure—and its underlying physical and cyber systems, functions, and assets—and accelerate the adoption of innovative technologies in major infrastructure projects. (Recommendation 6. Regional Resilience, 2013, p. 7)
- Within one year, DOE, in conjunction with the Council of Economic Advisors and the White House Office of Science and Technology Policy, should complete a pilot analysis of the value proposition for investment in infrastructure grid modernization and recommend any incentives or alternative mechanisms for cost recovery that may be needed to encourage long-term investment in the modernization of lifeline infrastructure. Using the Energy Sector as the vanguard, all lifeline-sector SSAs should work with their sector partners to establish the value proposition for investment and financing in other critical sectors. (Recommendation 6.1. Regional Resilience, 2013, p. 8)
- DHS should work through Federal research organizations, academic institutions, and the national laboratories to develop Applied Centers of Excellence for Infrastructure Resilience to provide an operating environment to test and validate innovative technologies and processes that build resilience into new large-scale infrastructure projects, integrate next-generation R&D, and share results with other designers in other regions. By partnering with lifeline sector owners

and operators, these centers will leverage opportunities for real-world testing, raise awareness of new capabilities, and speed commercialization of emerging technologies. (Recommendation 6.3. Regional Resilience, 2013, p. 8)

- Encourage resilience using appropriate market incentives:
  - Government should partner with CIKR owners and operators to leverage their understanding of market forces, incentives, and disincentives in order to apply appropriate action that will strengthen infrastructure resilience. (Recommendation 5 [with selected bullet point]. Critical Infrastructure Resilience, 2009, pp. 26–27)
- Research and analyze the labyrinth of regulations and policies across all levels of government that impede and dis-incent investments in security and resilience. (Recommendation 1.1, CISR R&D Plan, 2014, p. 24)
- Identify essential elements of enabling policies and regulations that would encourage and facilitate owner and operator investment and gain public acceptance of such investments, particularly for many of the lifeline sectors, for which rates and return on investment are determined through state and Federal commissions. (Recommendation 1.2, CISR R&D Plan, 2014, p. 25)
- Identify and establish the elements for business and public justification for investments from lessons learned. (Recommendation 2.1, CISR R&D Plan, 2014, p. 25)
- Develop an effective model of shared industry funding. (Recommendation 2.2, CISR R&D Plan, 2014, p. 26)

III. Complementary Public and Private Resilience Building

Critical infrastructure security and resilience require close collaboration between the public and private sectors. On its own, neither sector can understand, prepare for, or manage the complexities inherent in securing and making our Nation's interdependent and complex infrastructure more resilient. The NIAC has been at the forefront of advocating close public-private partnerships as a practical way to address the need for resilience on a massive scale.

Improving Public-Private Partnerships

- Clarify roles and responsibilities of critical infrastructure partners:
  - Review current incident management documents including the National Response Framework and the National Incident Management System and identify opportunities to expand training and outreach activities to CIKR owners and operators. Such activities provide Federal, state, and local entities a better understanding of the components of resiliency during an event and allow for increased information sharing.
  - CIKR owners and operators and DHS should identify a mechanism to monitor and measure resilience at the CIKR sector level. This process should include establishment and support of a feedback mechanism to address CIKR owner and operator concerns in all critical infrastructure sectors and should specifically assess the adequacy of the supply chain to meet response and recovery needs. This process should be analogous to

and in coordination with the National Infrastructure Protection Plan annual reporting process.
    - Government should develop a better understanding of the role that repair and maintenance funding can have on CIKR and prioritize funding for these activities, both as a component of its resiliency activities and part of its broader funding support of public infrastructure. (Recommendation 3 [with selected bullet points]. Critical Infrastructure Resilience, 2009, pp. 19–21)
- Strengthen and leverage public-private partnership:
    - Government should collaborate with CIKR executive decision makers throughout the resilience policy development process. Development must be an iterative process featuring bidirectional communication and a clear understanding of how to reach consensus.
    - Government should use the existing Sector Partnership Model to plan and implement resilience efforts in coordination with, and addition to, current protection activities.
    - DHS should implement the NIAC's recommendations contained within the *Framework for Dealing with Disasters and Related Interdependencies* that support needed changes for CIKR operator regulatory relief during a national crisis or incident, CIKR worker credentialing and access to a disaster area, and clarification of disaster recovery priorities and roles. This improved coordination among CIKR sectors and government will provide faster recovery times and more focus on restoring operations, order, and public safety.
    - Government should endeavor to better understand the role of design and construction in infrastructure resilience. Application of this understanding will help to shape the policy, R&D funding, and incentives that can spur technological innovation as well as the robust design and construction of critical infrastructure needed for resilience. (Recommendation 4 [with selected bullet points]. Critical Infrastructure Resilience, 2009, pp. 21–26)
- Increase flexibility in the sector partnership to better accommodate diverse sector needs:
    - DHS should encourage Sector Coordinating Councils (SCCs) to develop strategic roadmaps to enable sectors to articulate a variety of sector needs, identify sector priorities, and implement protection and resilience strategies. (Recommendation 5 [with selected bullet point]. CI Partnership Strategic Assessment, 2008, pp. 10–11)
- The Secretary of Homeland Security should facilitate efforts with governors, mayors, and local government officials to identify or develop regional, public-private, cross-sector partnerships, led by senior executives, to coordinate lifeline sector resilience efforts within a given region. (Recommendation 2. Regional Resilience, 2013, p. 5)
- DHS-IP should lead a national effort to improve the understanding of resilient activities and how they are implemented in support of combined infrastructure and community resilience. (Recommendation 1. Optimization of Resources, 2010, p. 19)

Fostering Senior Executive-Level Partnerships

- The President should direct the heads of the appropriate SSAs to form partnerships with senior executives from lifeline sectors, using a process modeled after the government's successful executive engagement with the Electricity subsector. (Recommendation 1. Regional Resilience, 2013, p. 4)
- Within six months, the President should direct the heads of appropriate SSAs to convene a meeting with CEOs or other owner/operator leadership with equivalent decision making authority from each lifeline sector to explore the formation of a partnership to address high-priority risks to the sector's infrastructure. (Recommendation 1.1. Regional Resilience, 2013, p. 5)

IV. Emergency Planning and Response

When a disaster occurs, effective emergency planning and response can mean the difference between life and catastrophic loss. While the NIAC framework for resilience emphasizes a spectrum of activities, including planning, preparation, recovery and adaptability, the Council has frequently made recommendations focused specifically on improving emergency planning exercises and operations to support Federal, state, local, and private sector efforts in these areas.

Conducting Cross-Sector Emergency Planning Exercises

- Implement government enabling activities and programs in concert with critical infrastructure owners and operators:
    - Engage CIKR owners and operators to conduct more cross-sector emergency planning exercises to identify interdependencies, improve preparedness, and establish relationships between sectors, local government, state government, and the Federal Government. Results of these exercises should be accessible to all related sectors and facets of government, regardless of whether or not they participated in the exercise, so that the full benefits of resilience and business continuity planning can be realized. (Recommendation 6 [with selected bullet point]. Critical Infrastructure Resilience, 2009, p. 27)

Coordinating Emergency Operations

- DHS should examine how the Federal Government, state governments, and regional entities currently coordinate action with and provide support to the lifeline sectors in event response. (Recommendation 3.1. Regional Resilience, 2013, p. 6)
- The FEMA National Response Coordination Center, Federal agencies, and state and local governments should modify their processes and plans for emergency operations to include the co-location of representatives of lifeline sectors in their emergency operation centers during major disasters. (Recommendation 3.2. Regional Resilience, 2013, p. 6)
- Chemical event recommendations:

  - Improve controls over hazardous material transportation. Work with the private sector to ensure controls are consistent with risk assessment results.
  - Evaluate the efficacy of border control measures (e.g., Customs-Trade Partnership Against Terrorism [C-TPAT]) and ensure a robust customs and border control program.
  - Ensure all agencies follow the DHS lead on facility, navigable waters, transportation and supply chain security, and disaster planning and response initiatives. Provide training for both the public and private sectors, especially local governments and responders, on implementation of National Incident Management System and the new National Response Plan Framework. (Chemical Event Recommendations. CBR and CI Workforce, 2008, pp. 8–9)
- Preparing for a pandemic event: "The Transportation sector recommends the best way for it to prepare for a pandemic is for the government experts to first identify and prioritize what goods and services are most critical to the Nation's interests. Once identified, the Transportation sector and its sub-sectors will be in a good position to develop a prioritized list of the sector's most critical goods, services, and workers necessary to ensure the Nation's transportation needs." (Transportation Sector Profile, in Prioritization of CI in Pandemic Outbreak, 2007, p. 113. Note: the Transportation Sector Profile [pp. 110–117] contains a list of sector critical workers and their numbers for each mode.)

V. Information Sharing

In its studies, the NIAC has consistently found that information sharing is an essential part of public-private partnerships across the entire spectrum of preparedness. Without sufficient information sharing, collaboration between various levels of government and critical infrastructure owners and operators would not work. This is a complex issue, however, and the NIAC has spent considerable time assessing the various means and effectiveness of public-private information sharing. The following recommendations are a sampling of the NIAC's work in this area.

Improving Information Sharing

- Direct that DHS and the Office of the Director of National Intelligence (ODNI), in collaboration with other members of the U.S. Intelligence Community and the SSAs, prepare a quadrennial report on the state of intelligence information sharing for infrastructure protection and resilience. (Recommendation 4.1.c. Intelligence Information Sharing, 2012, p. 44)
- DHS, with the guidance and aid of ODNI, should establish core teams of 3–4 intelligence specialists for each sector, as well as a team that focuses on cross-sector information issues. These specialists should (1) be drawn from the members of the Federal Intelligence Community, (2) have expertise in both intelligence processes and sector business and risk-management processes, and (3) be responsible for fusing varied intelligence information streams into products useful for owner and operator planning and decision making. (Recommendation 4.2.c. Intelligence Information Sharing, 2012, p. 46)

- Senior executive information-sharing mechanism: Develop a voluntary executive-level information-sharing mechanism between critical infrastructure CEOs and senior intelligence officers. (Recommendation 1. Public-Private Sector Intelligence Coordination, 2006, p. 22)
- The Federal Government should ensure the availability of qualified, vetted security professionals. (Recommendation 4. Implementation of EO 13636 and PPD-21, 2013, p. 18)

Understanding Infrastructure Intelligence Needs

- Direct the Federal Intelligence Community to consider infrastructure protection and resilience as a national priority; collect infrastructure intelligence needs; and prepare a National Intelligence Estimate to evaluate terrorist targets in the 18 critical infrastructure sectors and assess vulnerability to such attacks, including cross-sector interdependencies and risks. (Recommendation 4.1.b. Intelligence Information Sharing, 2012, p. 44)
- The NIAC recommends that DHS work with each SSA to implement, for all 18 critical infrastructure sectors, a robust intelligence requirements process that (1) meets the information needs of owners and operators, (2) delivers these requirements to appropriate elements of the Intelligence Community, (3) is consistent with existing Intelligence Community processes, and (4) supports advocacy for critical infrastructure priority within the Intelligence Community. (Recommendation 4.3. Intelligence Information Sharing, 2012, pp. 46–47)
- Staffing: Within key intelligence agencies throughout the Intelligence Community, create "sector specialist" positions at both the executive and operational levels, as applicable. (Recommendation 5. Public-Private Sector Intelligence Coordination, 2006, p. 25)

Developing Access Credentialing Solutions

- The Secretary of Homeland Security, working with heads of appropriate Federal agencies, should launch a cross-agency team within 60 days to develop solutions to site access, waiver, and permit barriers during disaster response and begin implementing solutions within one year. (Recommendation 5. Regional Resilience, 2013, p. 7)
- DHS-IP and FEMA should collaborate with state, local, tribal, and territorial governments and owners and operators to develop a commonly applied process or system to credential lifeline sector owners and operators and grant them access to disaster areas more effectively. (Recommendation 5.1. Regional Resilience, 2013, p. 7)
- DHS should work with state and local government and infrastructure owners and operators to catalog the waivers and permits commonly required during a variety of disaster scenarios and develop a streamlined process for rapidly issuing those permits and waivers at the Federal, state, and local level. (Recommendation 5.2. Regional Resilience, 2013, p. 7)
- DHS should work with regulators from the Transportation Systems and Energy Sectors, as well as from other lifeline sectors, to identify actions that will expedite waivers and remove impediments to fleet movement, including driver-hour limitations, road and weight restriction, port access restrictions, and toll crossing processes. (Recommendation 5.3. Regional Resilience, 2013, p. 7)

VI. Emerging Issues

Resilience occurs in a dynamic environment—the Nation enhances resilience through a continual process of implementation, review, and improvement. Emerging areas of resilience studied by the NIAC in recent years include social media capabilities, cybersecurity, simulation and modeling tools, and design standards and best practices.

Examining Social Media Capabilities

- FEMA and the Federal Communications Commission should convene a task force of senior emergency managers from lifeline sector SSAs and representatives of leading private-sector social media and technology firms—such as Twitter, Facebook, and Google—to examine how new and emerging social media apps, platforms, and capabilities can be used to support emergency notification and response and provide greater value to the public. The task force should publish its findings in a report on best practices. (Recommendation 4.1. Regional Resilience, 2013, p. 6)

Addressing Cybersecurity Issues

- Use the Federal Government's procurement power to encourage information technology suppliers to develop cybersecurity framework–compliant hardware and software. (Recommendation 3. Implementation of EO 13636 and PPD-21, 2013, p. 17)
- The Federal Government should leverage its purchasing power to incentivize enhanced security and resilience in core cybersecurity systems and programs (e.g., Information Technology, Industrial Automation, and Telecommunications Sectors). (Recommendation 7.2. Implementation of EO 13636 and PPD-21, 2013, p. 19)
- The Federal Government should develop policies and apply resources to pursue and discourage global cyber criminals from attacking critical infrastructure facilities. (Recommendation 7.4. Implementation of EO 13636 and PPD-21, 2013, p. 19)
- Recommendations for security as an enabler:
    - The President should establish a goal for all critical infrastructure sectors that no later than 2015, control systems for critical applications will be designed, installed, operated, and maintained to survive an intentional cyber assault with no loss of critical function.
    - DHS should promote uniform acceptance across all sectors that investment in control systems cybersecurity is a priority. For sectors with regulatory oversight of earnings and investments, DHS should promote inclusion of the costs of control systems cybersecurity as legitimate investments and expenses that deserve approval by their regulatory bodies. (Recommendations for Security as an Enabler [with selected bullet points]. Convergence of Physical and Cyber Security, 2007, p. 18)
- Recommendation for market drivers:
    - DHS and the SSAs should encourage the application of existing security and security-relevant standards and criteria in the development and implementation of secure

control systems. (Recommendations for Market Drivers [with selected bullet point]. Convergence of Physical and Cyber Security, 2007, p. 20)

- Recommendation for executive leadership awareness:
  - To improve executive leadership awareness of the cyber risk to control systems, the NIAC recommends that DHS work with SSAs to implement a program for control systems cybersecurity executive awareness outreach. (Recommendations for Executive Leadership Awareness [with selected bullet point]. Convergence of Physical and Cyber Security, 2007, p. 22)
- Recommendation for information sharing:
  - DHS should enhance existing program activities to create the ability to integrate and track understanding of the cyber risk for critical infrastructure control systems using all available sources.
    - This collaborative program should collect, correlate, integrate, and track information on the following:
      - Threats, including adversaries, toolsets, motivations, methods/mechanisms, incidents/actions, and resources.
      - Consequences, including potential consequences of compromise to sector, industry, and facility-specific control systems.
      - Vulnerabilities in control systems or their implementations in the information technology infrastructure that adversaries could exploit to gain access to critical infrastructure control systems.
    - This capability is a DHS operations function, and it will include input and expertise from the following: critical infrastructure owners and operators and other relevant parties in the private sector regarding consequences and vulnerabilities, the Intelligence Community regarding threats, Carnegie Mellon's Computer Emergency Response Team Coordination Center and other sources regarding incidents, and DHS (including the United States Computer Emergency Readiness Team) regarding cyber vulnerabilities.
    - DHS will communicate resulting warning information to control systems owners and operators to ensure protection of U.S. critical infrastructure. (Recommendations for Information Sharing, Recommendation 6. Convergence of Physical and Cyber Security, 2007, p. 27)
- Direct lead agencies to work with each of the critical sectors to more closely examine the risks and vulnerabilities of providing critical services over network-based systems. (Recommendation 1. Prioritizing Cyber Vulnerabilities, 2004, p. 10)
- Direct DHS to sponsor cross-sector activities to promote a better understanding of the cross-sector vulnerability impacts of a cyber attack. (Recommendation 4. Prioritizing Cyber Vulnerabilities, 2004, p. 10)
- Direct Federal agencies to include cyber attack scenarios and protective measures in their disaster recovery planning. Encourage sector coordinating groups to include cyber attack

scenarios and protective measures in their disaster recovery planning. (Recommendation 5. Prioritizing Cyber Vulnerabilities, 2004, p. 11)

- Security should be designed to be built in to systems, rather than layered on top of systems. (Recommendation 7.1. Implementation of EO 13636 and PPD-21, 2013, p. 19)
- Develop real-time cybersecurity risk analysis and management tools. (Recommendation 3.1, CISR R&D Plan, 2014, p. 27)
- Establish new architectures to "bake in" self-healing and self-protected cyber systems. (Recommendation 3.2, CISR R&D Plan, 2014, p. 27)
- Develop automated security analysis and data collection tools and methods. (Recommendation 3.3, CISR R&D Plan, 2014, p. 28)
- Understand cross-sector connections that could cause cascading effects. (Recommendation 3.4, CISR R&D Plan, 2014, p. 28)
- Measure the effectiveness of security. (Recommendation 3.5, CISR R&D Plan, 2014, p. 28)

Developing Simulation and Modeling Tools

- Scale risk assessment and, management decision support tools for local communities and individual institutions. (Recommendation 4.1, CISR R&D Plan, 2014, p. 28)
- Develop, scale and integrate interdependency and consequence modeling, and simulations to support operational decisions to predict and prevent cascading failures. (Recommendation 4.2, CISR R&D Plan, 2014, pp. 28-29)
- Continue research and development for managing "big data." (Recommendation 4.3, CISR R&D Plan, 2014, p. 29)

Design Standards and Best Practices

- Determine design standards and best practices for the replacement, upgrading, and maintenance of critical infrastructure systems. (Recommendation 2.3, CISR R&D Plan, 2014, p. 26)
- Identify innovative, cost-efficient, and accelerated approaches to "People Readiness" in developing a skilled workforce. (Recommendation 2.4, CISR R&D Plan, 2014, p. 26)
- Determine factors and approaches to accelerate recovery following a disaster. (Recommendation 2.5, CISR R&D Plan, 2014, pp. 26-27)
- Establish resilience metrics. (Recommendation 2.6, CISR R&D Plan, 2014, p. 27)

Appendix J: Compendium of Prior Recommendations from Other Sources

Resilience themes have emerged as common threads across previous NIAC studies on critical infrastructure. The sources listed below are among the many identified as having potentially significant insights for the current NIAC study on resilience in the Transportation Systems Sector. The text included under each source is an example of the source's recommendations or key observations that relate to individual themes. Resilience themes include:

I. Aging Infrastructure
II. Cyber-Physical Dependencies
III. Sector Dependencies
IV. Intermodal Coordination
V. Policy and Strategy
VI. Funding and Programs
VII. Impact and Cost: Short-Term vs. Long-Term
VIII. Climate Change
IX. Criticality of Transportation
X. Adopting Resilience Lens
XI. Measurements and Standards
XII. "Stovepiping" of Federal Programs

I. Aging Infrastructure

Source: American Society of Civil Engineers (ASCE), *2013 Report Card for America's Infrastructure*

- America's infrastructure must meet the ongoing needs for natural resources, industrial products, energy, food, transportation, shelter, and effective waste management, and at the same time protect and improve environmental quality.
- Sustainability, resilience, and ongoing maintenance must be an integral part of improving the Nation's infrastructure.
- Today's transportation systems, water treatment systems, and flood control systems must be able to withstand both current and future challenges.
- As infrastructure is built or rehabilitated, life cycle cost analysis should be performed for all infrastructure systems to account for initial construction, operations, maintenance, environmental, safety, and other costs reasonably anticipated during the life of the project, such as recovery after disruption by natural or man-made hazards.
- Both structural and non-structural methods must be applied to meet challenges. Infrastructure systems must be designed to protect the natural environment and withstand both natural and man-made hazards, using sustainable practices, to ensure that future generations can use and enjoy what we build today, as we have benefited from past generations.
- In addition, research and development should be funded at the Federal level to develop new, more efficient methods and materials for building and maintaining the Nation's infrastructure.
- Leadership at the Federal, state, and local levels of government, and by businesses, is needed to communicate the importance of the Nation's infrastructure, craft innovative solutions that reflect the diverse needs of the nation, and make the investments the system needs.

Source: National Freight Advisory Committee, *Recommendations to U.S. Department of Transportation for the Development of the National Freight Strategic Plan* (2014)

- Security and resilience factors need to be considered and built into transportation infrastructure design and investment decisions.
- Address aging infrastructure, bridge weight limitations, excepted rail track; generally poor road pavement conditions within heavy-haul corridors, etc. with a priority toward state of Good Repair and Asset Management.

II. Cyber-Physical Dependencies

Source: National Freight Advisory Committee, *Recommendations to U.S. Department of Transportation for the Development of the National Freight Strategic Plan* (2014)

- Increase efficiencies along the supply chain by promoting electronic communications among all logistics supply chain business segments.
- Expand the use of Intelligent Transportation Systems, technology, and innovation to improve the flow of freight that minimizes community impacts and improves environmental and safety conditions while fostering economic productivity and efficiency.

Source: National Institute of Standards and Technology (NIST), *Framework for Improving Critical Infrastructure Cybersecurity* (2014)

- The national and economic security of the United States depends on the reliable functioning of critical infrastructure. Cybersecurity threats exploit the increased complexity and connectivity of critical infrastructure systems, placing the Nation's security, economy, and public safety and health at risk. Similar to financial and reputational risk, cybersecurity risk affects a company's bottom line. It can drive up costs and impact revenue. It can harm an organization's ability to innovate and to gain and maintain customers.

Source: DHS, *Roadmap to Secure Control Systems in the Transportation Sector* (2012)

- Careful evaluation and analysis of all risk factors—including physical, cyber, and human—need to be considered when designing, operating, and maintaining transportation facilities, processes, and equipment. While attacks on a cyber system may involve only the cyber components and their operation, those impacts can extend into the physical, business, human, and environmental systems to which they are connected. A cyber event, whether caused by an external adversary, an insider, or inadequate policies and procedures, can initiate a loss of system control, resulting in negative consequences.
- Each organization and mode should use the Goals, Objective, Milestones, and Metrics model to identify the cybersecurity features currently in place and determine the remaining activities necessary for improving cybersecurity performance.

III. Sector Dependencies

Source: City of New York, *A Stronger, More Resilient New York* (2013)

- Improve all levels of communications about the restoration of transportation services.

Source: Volpe, *Final Report: Beyond Bouncing Back* (2013)

- Our infrastructure is becoming increasingly dependent on information technology and networks, and the interdependencies among transportation, the power grid, our communications systems, and other infrastructures are complex.

Source: Volpe, *Infrastructure Resiliency: A Risk-Based Framework* (2013)

- The confluence of the greater frequency of high-impact events spurred on by climate change and population growth, coupled with the cascading effects of interconnected technology systems, has made us increasingly vulnerable to catastrophic disruptions. A resiliency approach to designing, building, and protecting our critical infrastructure and managing its risks is needed to address these risks at the systemic level.

Source: Idaho National Laboratory, *Critical Infrastructure Interdependency Modeling: A Survey of U.S. and International Research* (2006)

- This Idaho National Laboratory report surveys U.S. and international research (as of 2006) on sector interdependencies and how they can be modeled and better understood.
- Be it through direct connectivity, policies and procedures, or geospatial proximity, most critical infrastructure systems interact. These interactions often create complex relationships, dependencies, and interdependencies that cross infrastructure boundaries. The modeling and analysis of interdependencies between critical infrastructure elements is a relatively new and very important field of study.

IV. Intermodal Coordination

Source: New York State 2100 Commission, *Recommendations to Improve the Strength and Resilience of the Empire State's Infrastructure* (2013)

- Expand networks to create redundancies.

Source: Transportation Research Board (TRB), *Potential Impacts of Climate Change on U.S. Transportation* (2008)

- Federal, state, and local governments, in collaboration with owners and operators of infrastructure, such as ports and airports and private railroad and pipeline companies, should inventory critical transportation infrastructure in light of climate change projections to determine whether, when, and where projected climate changes in their regions might be consequential.

Source: Gulf Coast Research Center for Evacuation and Transportation Resiliency, *Resilient Transportation Systems in a Post-Disaster Environment: A Case Study of Opportunities Realized and Missed in the Greater New Orleans Region* (2010)

- The transportation network as a whole lacks communication and coordination across modes in the Greater New Orleans Region.

Source: National Freight Advisory Committee, *Recommendations to U.S. Department of Transportation for the Development of the National Freight Strategic Plan* (2014)

- DOT in conjunction with the private sector should provide education and training programs for MPO and state DOT planning staff to expand their understanding of supply chain issues,

modeling freight movements, the dynamics of multi-state corridors and the economics of mega regions and international trading patterns, among other issues.

- The Nation's freight transportation system depends on multi-modal networks (rail, air, highway, waterways) and both the public and private sectors. All levels of government serve a vital role in freight and goods movement, from regulation of interstate commerce at the Federal level to provision of truck-loading zones at the local level. The complexity of players and stakeholders, as well as the interdependencies involved in modern supply chains, calls for better and more effective coordination.
- Cross-modal security programs, policies, and regulations must be harmonized, including areas such as credentialing, to ensure consistency in the system and the seamless unimpeded movement of freight between modes.

V. Policy and Strategy

Source: New York State 2100 Commission, *Recommendations to Improve the Strength and Resilience of the Empire State's Infrastructure* (2013)

- Integrate resilience planning, protection, and development approaches.
- Develop criteria for integrated decision making.
- Build for resilience with enhanced guidelines, standards, policies, and procedures.
- Create shared equipment and reserves, promote integrated planning and decision making for capital investments, and enhance institutional coordination.

Source: Volpe, *Final Report: Beyond Bouncing Back* (2013)

- In the Transportation Systems Sector, resilience has two distinct aspects. Supply-side resilience focuses on robustness, adaptive capacity, and post-event mitigation. Demand-side resilience can be enhanced through strategies such as resource prioritization, flexible usage patterns, and incentive-based pricing mechanisms.

Source: Stephen E. Flynn and Sean P. Burke, *Critical Transportation Infrastructure and Societal Resilience* (2012)

- Resilience generates a different assessment of risk than security, and it broadens the range of solutions.

Source: World Economic Forum, *Building Resilience in Supply Chains* (2013)

- Business and government approaches to building supply chain resilience must be complementary.
- Three "must-have" requirements: establish common risk vocabulary, improve data/information sharing, and build greater agility and flexibility into resilience strategies.
- A blueprint for resilient supply chains requires four components: partnerships, policy, strategy, and information technology.

Source: National Academies, *Disaster Resilience: A National Imperative* (2012)

- Federal Government agencies should incorporate national resilience as an organizing principle to inform and guide the mission and actions of the Federal Government and the programs it supports at all levels.

- All Federal agencies should ensure they are promoting and coordinating national resilience in their programs and policies.

Source: National Freight Advisory Committee, *Recommendations to U.S. Department of Transportation for the Development of the National Freight Strategic Plan* (2014)

- Include intermodal emphasis in project Delivery Policy Declaration.
- DOT should develop a comprehensive national freight transportation plan to improve network performance that minimizes community impacts and improves environmental and safety conditions while fostering economic productivity and efficiency.

Source: Dane S. Egli, *Beyond the Storms: Strengthening Preparedness, Response, & Resilience in the 21st Century* (2013)

- This study emphasizes the importance of collective action in addressing national-level preparedness through expanded interagency coordination and increased private-sector participation. Building upon functional continuity, preparedness, and disaster management principles, there is a need to better understand resilience as an organizing principle to address national preparedness and critical infrastructure and key resource imperatives. Further research is needed to generate new data and models for understanding highly complex and uncertain environments. A systematic mapping of local, regional, state, and national capabilities-based requirements, based on a "functional" decomposition of all infrastructure dependencies and interdependencies, is needed. As this study highlights, such research should be a high Federal priority and be pursued aggressively with an all-hazards, intergovernmental, holistic approach to advance national preparedness and resilience objectives.

VI. Funding and Programs

Source: ASCE, *2013 Report Card for America's Infrastructure*

- While infrastructure investment must be increased at all levels, it must also be prioritized and executed according to well-conceived plans that both complement the national vision and focus on system-wide outputs. The goals should center on freight and passenger mobility, intermodality, water use, and environmental stewardship, while encouraging resilience and sustainability. The plans must reflect a better defined set of Federal, state, local, and private-sector roles and responsibilities and instill better discipline for setting priorities and focusing funding to solve the most pressing problems. The plans should also complement our broad national goals of economic growth and leadership, public safety, resource conservation, energy independence, and environmental stewardship. Infrastructure plans should be synchronized with regional land use planning and related regulation and incentives to promote non-structural as well as structural solutions to mitigate the growing demand for increased infrastructure capacity.

Source: TRB, *Potential Impacts of Climate Change on U.S. Transportation* (2008)

- Federal and academic research programs should encourage the development and implementation of monitoring technologies that could provide advance warning of pending failures due to the effects of weather and climate extremes on major transportation facilities.

Source: National Freight Advisory Committee, *Recommendations to U.S. Department of Transportation for the Development of the National Freight Strategic Plan* (2014)

- Security and resilience factors need to be considered and built into transportation infrastructure design and investment decisions.
- The U.S. DOT should invest in a robust, multimodal Federal research program that covers the range of research from basic (long range high risk) to research development (short range) to deployment or implementation.
- Encourage intermodal freight activity through streamlined investment.
- Create a dedicated fund for multi-modal freight projects.
- DOT should encourage integrated freight and passenger transport planning, as well as encourage investment and operational solutions that maximize safety and effectively utilize resources while minimizing environmental, energy, and local impacts.

VII. Impact and Cost—Short Term versus Long Term

Source: New York State 2100 Commission, *Recommendations to Improve the Strength and Resilience of the Empire State's Infrastructure* (2013)

- Transition from short-term solutions to long-term resilience measures.
- Identify projects with climate resilience and other significant economic and quality-of-life benefits.

Source: ASCE, *2013 Report Card for America's Infrastructure*

- Investment is faltering; it is not keeping pace with needs.
- Require transit systems to adopt comprehensive asset management systems to maximize investments.

Source: TRB, *Potential Impacts of Climate Change on U.S. Transportation* (2008)

- Transportation planners and engineers should use more probabilistic investment analyses and design approaches that incorporate techniques for trading off the costs of making the infrastructure more robust against the economic costs of failure. At a more general level, these techniques could also be used to communicate these trade-offs to policy makers who make investment decisions and authorize funding.
- State and local governments and private infrastructure providers should incorporate climate change into their long-term capital improvement plans, facility designs, maintenance practices, operations, and emergency response plans.
- Federal planning regulations should require that climate change be included as a factor in the development of public-sector long-range transportation plans; eliminate any perception that such plans should be limited to 20–30 years; and require collaboration in plan development with agencies responsible for land use, environmental protection, and natural resource management to foster more integrated transportation–land use decision making.

Source: National Academies, *Disaster Resilience: A National Imperative* (2012)

- In the short term, state and Federally funded transportation infrastructure rehabilitation projects in highly vulnerable locations should be rebuilt to higher standards, and greater

attention should be paid to the provision of redundant power and communications systems to ensure rapid restoration of transportation services in the event of failure.

VIII. Climate Change

Source: City of New York, *A Stronger, More Resilient New York* (2013)

- Integrate climate resilience features into future capital projects.

Source: TRB, *Potential Impacts of Climate Change on U.S. Transportation* (2008)

- DOT should take a leadership role, along with those professional organizations at the forefront of civil engineering practices across all modes, to initiate immediately a Federally funded, multiagency research program for ongoing reevaluation of existing design standards and development of new design standards as progress is made in understanding future climate conditions and the options available for addressing them.

Source: National Freight Advisory Committee, *Recommendations to U.S. Department of Transportation for the Development of the National Freight Strategic Plan* (2014)

- Air quality and climate impacts should be considered up front in planning new transportation infrastructure.
- In order to address the environmental sustainability challenge, DOT should incentivize holistic, multi-modal freight planning and operational strategies, risk assessment, and collaborative problem solving that involves multiple stakeholders.

Source: Martin T. Schultz, *The Quantification and Evolution of Resilience in Integrated Coastal Systems* (2012)

- Resilience is the ability of a system to maintain and/or recover its functional performance following a disturbance. This property of resilience may evolve as environmental and other boundary conditions change over time. Interest in the characterization and management of resilience in coastal systems has increased in recent years, having been prompted by the occurrence of several severe storm events that have had notable impacts on the functionality of coastal systems and the safety of coastal residents. Interest has been further heightened by projections of global sea-level rise that presently range between 0.4 and 4.9 feet per century. Changes in sea level may affect the resilience of coastal systems, but there is limited understanding of how significant these impacts might be and how they might be evaluated.

IX. Criticality of Transportation

Source: Gulf Coast Research Center for Evacuation and Transportation Resiliency, *Resilient Transportation Systems in a Post-Disaster Environment: A Case Study of Opportunities Realized and Missed in the Greater New Orleans Region* (2010).

- Transportation systems play a crucial role in responding to a region's pre-disaster evacuation and post-disaster recovery. Their ability to perform under adverse conditions in times of disaster depends upon the resilience of their fixed and moveable assets as well as their operational procedures before, during, and after the event. In addition, planning and coordination between the individual modes and various state and Federal agencies is now recognized as a critical factor during all phases of a disaster.

X. Adopting Resilience Lens

Source: Volpe, *Final Report: Beyond Bouncing Back* (2013)

- Community resourcefulness, combined with advanced data collection and problem solving and adaptive agency responses, can significantly contribute to the resilience of a city in the face of a natural or man-made hazard.
- Resilience means moving away from a threat-based orientation. Terrorist attacks are rare events and we do not have enough data to build scenarios on every possible type. We should move toward using data about the systems themselves, their vulnerabilities, and the consequences, regardless of the type of disruption.
- We cannot eliminate uncertainty or damage: we must learn to deal with them. Balancing preventive protection and adaptive resilience enables us to be error-tolerant, by learning from each failure to improve performance.

Source: Stephen E. Flynn and Sean P. Burke, *Critical Transportation Infrastructure and Societal Resilience* (2012)

- Those who have been looking through a security lens have been largely seeing transportation as something a terrorist might exploit so as to endanger the lives of people. But when we shift to adopting a resilience lens, our focus ends up centering on the fact that transportation is a critical infrastructure whose continuity must be ensured in the face of potential disruptive threats.

Source: Julie Dean Rosati, *Method to Assess Resilience of the Marine Transportation System* (2014), PowerPoint presentation provided to the NIAC

- Presentation explains differences between engineering, ecological, and community resilience in the context of the USACE'S responsibility to ensure the Marine Transportation System is able to functionally perform under the stress of disturbances.

XI. Measurements and Standards

Source: Martin T. Schultz, *The Quantification and Evolution of Resilience in Integrated Coastal Systems* (2012)

- (Provides possible model for measuring and assessing critical infrastructure resilience.) Study outlines procedures for analyzing the engineering resilience of integrated coastal systems (ICSs):
  - Identify one or more functional performance objective for each ICS.
  - Decompose each subsystem by identifying the components and processes that support each functional performance objective.
  - Establish performance measures for the function of each component and process.
  - Establish performance objectives for each component and process function in terms of selected performance metrics considering each possible level of event severity.
  - Develop a fragility curve for each component and process function.
  - Transform the fragility curve to characterize uncertainty in functional performance given the level of environmental force acting on the component or process.
  - Develop an interoperability matrix, and update the probabilities of functional performance.

- Establish recovery objectives for each component or process.
- For each component or process, characterize uncertainty in the time that would be required to restore the pre-disturbance performance level of that component or process given the severity of the disturbance event.
- Using a suitable performance function, simulate performance for each level of event severity, accounting for uncertainty in the response and rapidity of the component or process function.
- Calculate the probability of maintaining an acceptable level of functional performance and/or recovering pre-disturbance performance levels within an acceptable time period given the magnitude of an event for each component or process from the performance trajectory for that component or process using Monte Carlo simulation.
- Calculate a measure of resilience for the subsystem as a whole and aggregate subsystem resilience measures to obtain a measure of resilience for the ICS.

Source: NIST, *Framework for Improving Critical Infrastructure Cybersecurity* (2014)

- The Framework focuses on using business drivers to guide cybersecurity activities and on considering cybersecurity risks as part of the organization's risk management processes. The Framework consists of three parts: the Framework Core, the Framework Profile, and the Framework Implementation Tiers. The Framework Core is a set of cybersecurity activities, outcomes, and informative references that are common across critical infrastructure sectors, providing the detailed guidance for developing individual organizational profiles. Through use of the profiles, the Framework will help the organization align its cybersecurity activities with its business requirements, risk tolerances, and resources. Framework Information Tiers provide a mechanism for organizations to view and understand the characteristics of their approach to managing cybersecurity risk.
- The Framework enables organizations—regardless of size, degree of cybersecurity risk, or cybersecurity sophistication—to apply the principles and best practices of risk management to improving the security and resilience of critical infrastructure. The Framework provides organization and structure to today's multiple approaches to cybersecurity by assembling standards, guidelines, and practices that are working effectively in industry today. Moreover, because it references globally recognized standards for cybersecurity, the Framework can also be used by organizations located outside the United States and can serve as a model for international cooperation on strengthening critical infrastructure cybersecurity.

Source: NIST, *Developing Guidelines and Standards for Disaster Resilience of the Built Environment* (2013)

- Codes and standards for transportation systems need to be reviewed to determine gaps in performance.
- Metrics are needed to support risk management decisions and evaluate the impact of damage on the resilience of transportation systems and the community. Intermodal transportation dependencies, such as ship-to-rail or ship-to-truck transport of goods, also need to be considered.

Source: Volpe, *Infrastructure Resiliency: A Risk-Based Framework* (2013)

- Argues that approaching infrastructure asset management in accordance with a systematic process of engineering system resilience will likely result in a safe, efficient, survivable, and sustainable infrastructure system. The outcome of instituting a resilience process is that the infrastructure systems that are engineered in accordance with these principles are likely to meet three high-level performance criteria: efficiency, sustainability, and survivability:
    - Efficiency. This criterion requires that an infrastructure system perform its functions in order to meet its specified functional requirements (technical efficacy) at lowest cost (cost effectiveness). Metrics for efficiency include the costs of building and maintaining a complex infrastructure system within the constraints of its technical performance, reliability, and service continuity.
    - Sustainability. This performance criterion evaluates the extent to which the system uses resources—natural, human, and manufactured—in a sustainable manner. Sustainability is defined as a resource-use pattern that "meets today's needs while protecting resources for future use." To be sustainable, critical infrastructure must be designed and operated within the context of its impacts on the surrounding ecosystems, now and in the future. The metrics for assessing infrastructure's sustainability include the extent to which transportation construction and operating inputs and resources are used in accordance with the long-term economic and environmental standards developed for the system.
    - Survivability. A third key performance criterion for resilient infrastructure is the ultimate test of the safety, security, and survival of the people, infrastructure assets, and ecosystem. In accordance with this criterion, infrastructure meets the resilience standards if it is capable of withstanding damages with minimal adverse impacts—lost lives, ecological impacts, structural damage—on the people, transportation operations, economy, and environment.

XII. "Stovepiping" of Government Programs

Source: Volpe, *Final Report: Beyond Bouncing Back* (2013)

- Resiliency requires a change in focus from near-perfect efficiency to planned redundancy, flexibility, fault tolerance, and resourcefulness.
- The Federal Government's role may need to change—such as moving away from its twentieth-century silos and clustering around challenges instead of departments—because many solutions are going to be local and decentralized.

Source: TRB, *A Guide to Emergency Response Planning at State Transportation Agencies* (2010)

- State transportation agency executives should become familiar with the changing context and challenges facing emergency response, in addition to the challenges of multiple agency communication, cooperation, coordination, and consensus.

Appendix K: Consolidated Interview Information Collected by the Working Group

This appendix presents a synopsis of information consolidated from Working Group interviews. It is organized into five sections:

I. Transportation Risks
II. Infrastructure Investment and Funding
III. Making the Business Case
IV. Policies and Practices
V. Leadership and Coordination

I. Transportation Risks

System-wide transportation risks are not well understood, and there is only limited visibility of risks across modes and sectors. Better understanding of systemic risks is needed for planning and risk management in the transportation sector in order to understand the extent of key dependencies and confront emerging risks such as cyber threats.

System-level visibility should be primarily a government activity, and the public sector needs to drive sponsorship.

- There is often an element of moral hazard on the part of the private sector: why should individual communities invest in resilience if Washington will pay for repairs after a natural disaster?
- A partnership with the public sector would be more appealing to the private sector if it is framed in the focus of continuity/rapid restoration.
- As such, the government faces a few key investment challenges. First, to gain acceptance from private entities, the government should frame funding as a partnership, rather than highlighting the vulnerabilities of private systems. The government must also turn feedback from diverse stakeholders into a common operating vision. It must also balance the necessity of funding after disasters with the importance of communities investing in resilience.
    - Superstorm Sandy serves as an example of the importance of visibility. Stakeholders, including the Department of Energy (DOE), had limited visibility into how the liquid fuel supply worked before Sandy, and did not realize that infrastructure was almost entirely private. This contributed to the collapse of the liquid fuel supply distribution system after the disaster.

Localized, rational action can cause a globalized disruption due to a lack of visibility.

- Actors working independently and dealing with events in real-time may cause cascading effects that work against recovery, further exacerbating what may have been the initial disrupting force.

  - For example, schools are used as a place to house displaced people as a short-term measure, but this may prevent children from returning to school in a timely manner. Informal relationships are also relied on too often.
- Past experiences can provide useful information for future incorporation of resilience, and current investment does not reflect the potential value of modeling and simulation. "What if" modeling, for example, can simulate cascading effects on transportation modes. Successful modeling includes stress-testing systems, spotting vulnerabilities, and mitigating them, which includes working with suppliers and other critical supply chain providers. Such activity is fundamental for preserving the continuity of critical function, and is essential for both security and recovery.
- Recommendation: DHS' Science and Technology Directorate (S&T) can create a geographically accurate infrastructure that is functionally active but fictional, which would allow stakeholders to work through 'what if' scenarios. This would not only stimulate dialogue, but also help foster the visibility needed to examine critical connections that would otherwise have not been apparent.

There is a disconnect between incident management teams and long-range communication planners, which can prove detrimental to coordinating response following an incident.

- It is often a challenge for transportation officials to connect with others who have important information, and often there is a lack of understanding over the type of coordination required after a disaster. Incident management officials may not be communicating regularly with long-range communication planners. Similarly, in the emergency management world, there is often disconnect between the emergency operations and long-range mitigation planners.
  - For example, in most cases, emergency managers are not reaching out to transit agencies in advance to ask, "How can we effectively respond to people who need help and transport mobility?"
- Mr. Craig Fugate, head of the Federal Emergency Management Agency (FEMA), emphasized planning has to be for the whole community. There should be transport access for everyone.
- The Emergency Planning cycle consists of planning and preparedness, response and recovery, and mitigation.
- In many local communities, the emergency manager might wear many hats, for instance orchestrating transportation and public health. It is important to make sure transportation officials are involved in emergency management. However, emergency managers might not welcome the participation of transportation officials initially, as their involvement may affect the way exercises are normally conducted.

Intermodal and cross-sector planning and preparedness are crucial to responding and recovering quickly.

- While executive leadership is key, a robust program of drills, plans, and exercises is necessary to prepare for events. There needs to be both a formal and informal network of responders engaging before a crisis in order to form fruitful relationships.
  - The Federal Aviation Administration (FAA)'s handling of the sabotage in the Chicago air traffic control center serves as a recent positive example. The skilled workforce shared

the necessary information across systems and demonstrated the ability to deal with unexpected events quickly.

- How do we make sure ongoing activities do a better job of identifying vulnerabilities and building in resilience? More innovative, integrated, and interconnected projects are needed, in addition to more coherent planning processes.

Incorporating resilience and risk mitigation into the transportation sector requires network redundancy, command and control operations centers in place, and information dissemination.

- At the systems level, resiliency involves redundancy, command and control, and information dissemination elements.
- At the asset or project level—such as a specific road in a particular location—there is a need to incorporate design elements that can withstand impacts and bounce back quickly after a disaster. Such elements should focus on contingency factors, taking into account uncertainty regarding future stressors.
- People often don't understand the meaning of resilience. Transportation officials rarely talk about sectors beyond transportation, beyond land use and development. However, the electricity sector plays a prominent role in cross-sector cascading effects. Officials need to increase their understanding of not only the connectivity between transportation system operations and performance, but also what happens across sectors when events occur.

One of the major gaps in incorporating resilience in the transportation sector is the lack of coordinated responses among the jurisdictions that are responsible for the individual parts of the system, especially regarding operations.

- Jurisdictions have their own idea of what they should do—the lack of jurisdictional coordination is often an obstacle to encouraging resiliency.
- There is a lack of understanding of how to assign benefits to resilience across jurisdictions.
- What often drives decisions on whether or not to incorporate resilience are cost-benefit analysis and least-cost solutions, which often results in omitting resilience investments. From an engineering perspective, the gaps are the tools, methods, definitions, and quantifications.
- For example, one Southern state attempted to mitigate the long term effects of climate change by redesigning a coastal road to prevent future inundation from flooding. However, because their job was to find the least-cost solution, they removed the potential improvements.

Coastal flooding is a both a security and economic threat to our transportation system.

- There are at least 12 international airports subject to coastal flooding and several chokepoints in the northeast corridor where flooding would simultaneously disrupt multiple modes of transportation. Additionally, up to 60 percent of our population lives in coastal communities, and 95 percent of the goods we use come through the coast.
- Coastal resilience is often tied to socioeconomics:
    - Insurance companies have interesting data for poor and middle class communities. The losses with first-wave incidents are major, and there are also devastating losses in the second-wave incident. If coastal properties are abandoned, this will also affect payments on school systems for other communities.

  - Superstorm Sandy serves as an example: the poorest areas in New York City and middle class communities along New Jersey's coast lost homes and businesses and did not recover.

Our infrastructure was built to safeguard against high risk, low probability events, but these have become high risk, inevitable events.

- We are facing events that have not occurred together before, such as rising sea levels, extreme storms, and aging infrastructure. We do not have past experience to guide us in making resilience decisions.
- We are more likely to focus on repairing old infrastructure than investing in new infrastructure.
- Investing in gray infrastructure could be a potential solution:
  - For example, the surge barrier on the Thames River in London has been used 150 times since it was built, and 40 of those times were in the last two years. New York City could benefit from a similar surge barrier; this would cost at least $20 billion.

From an intermodal perspective, there are areas that should be prioritized due to their vulnerability and their urban proximity.

- We need a resilience plan that is focused on urban areas of critical national concern, and does not solely focus on high-income areas.
- There are areas that should be addressed first, such as the Northeast corridor, as well as major sea ports and airports.

Cascading effects are widely seen in the reliance of the transportation sector on the energy sector, but resilience is being built into current and future projects, such as high-speed rail.

- Officials are acutely aware of the risks the dependence on the electrical grid poses for high-speed rail, as the sector provides energy and maintenance of the transmission lines for delivering energy. Redundancy and safeguards need to be built in to mitigate disruptions. For example, redundancy on the lines, on-site solar energy generation, and multiple system providers.
- The high-speed rail authority in one State has a safety and security task force that regularly meets to identify and work through any issues. The task force seeks to verify that all of the relevant agencies understand the challenges and what their specific role will be in responding to them. This serves as an example of advanced planning, as well as incorporating resilience into the design of the project.
- The task force has regional meetings with local authorities and statewide officials. Subjects include early engagement on planning and construction, stress prevention through design, and risk-based approaches. In addition, the task force periodically hosts workshops with agencies to examine risk from multiple perspectives. While the agencies each have different perspectives, they collaborate to determine what is best for the rail system.

While the transportation sector is aware of the need to bolster cybersecurity, much of the issue is still new territory with regard to building in resilience.

- The fire at the Chicago air traffic control center serves as an example of the need to address cybersecurity concerns. Every plane movement is being controlled and monitored, so if someone gained control of the system, it could cause serious disruptions.
- As a Federal regulatory requirement, railroads are installing a positive control systems, especially where hazardous materials are transported.
- All management systems of public/private entities use cyber assets to manage and pay personnel. As a means of precaution, while Memphis is discontinuing paper manifestos, they will make sure electronic manifestos are available to first responders.
- Uncertainty remains as to who is in charge and what the specific cyber threat is. There are ongoing hostile, complex threats (e.g., bugs can have a major impact through the entire system).
- With mission creep and responsibilities, the Department of Transportation (DOT) stepped in and took ownership of some key systems, including new computers and software. The Federal Government also built a management network for Y2K response with a control center, but OMB decided to dismantle the system and the control center.

The government needs to leverage resources and expertise more effectively to mitigate cyber risk; currently cybersecurity is not a core competency of a typical transportation agency.

- Many organizations do not have the information technology (IT) capability necessary to maintain cyber resilience.
- For example, high-speed rail will be electric with trains traveling at 200mph. This brings significant concerns over an attack on its inner workings and infrastructure. The safety and security committee for the system needs to consult external experts for guidance.
- Transportation agencies often have a bootstrap responsibility that looks to leverage expertise as much as possible to get expert advice.
- One way to leverage expertise is to utilize university research, such as the work the Mineta Transportation Institute has done in this area.

The U.S. Coast Guard (USCG) recognizes cyber threats as a growing area of concern for maritime transportation, especially due to the number of systems that are interconnected and computer dependent.

- Cyber is a unique threat: the number of potential attacks is unlimited. Malware can be used to launch an attack, and it does not require in-depth technical experience. Malicious actors can also purchase viruses and hackers.
- Cyber also has a dynamic nature—new threats and vulnerabilities are developed and located every day through computer updates, app downloads, etc. Tools, such as cameras, that would have been considered an asset are now vulnerabilities because they can be hacked.
- The USCG encourages the maritime industry to look to the National Institute of Standards and Technology (NIST) Cybersecurity Framework.

The greatest challenge to building resilience into our ports is integrating modes of transport, such as truck and rail, with maritime facilities.

- These entities have different business models—trucks use thousands of individual contractors; rail has large, consolidated operations; and maritime is in-between.
- Getting all the parties around the table to produce cooperative dialogue is a challenge, and real-time needs are even more difficult.
- Strong infrastructure starts at the local level; port authorities are usually connected to state networks and local chambers of commerce.

The complexity of interdependencies make it essential to understand the cascading effects associated with the disruption of any lifeline sector.

- Key intermodal facilities are considered lifeline facilities—the effects of disruptions on them will cascade to other modes of transportation. The earthquake in San Francisco that disrupted the Bay Bridge serves as an example. Tunnels in Boston Harbor and the Port of Miami are examples of critical, potentially vulnerable facilities that will cause major disruptions if they experience failures.
- In addition, research conducted on the economic costs of disruptions to freight systems has shown that the severity of the cascading effects was dependent on the length of the disruption.
- Infrastructure that has shared geographic reach and interdependencies has to be prepared for multiple hazards. This creates a challenge for local, State, and Federal jurisdictions. A regional approach is best for understanding systems across networks.
- One of the findings that came out of Superstorm Sandy is that lifeline infrastructure often refers to regional infrastructure. There is no such thing as national infrastructure; rather, there is local, regional, continental, and global. National plans need to be built around plans that focus on regional systems. Officials also need to coordinate with continental partners, such as Canada and Mexico; our markets depend on a north-south access, not just east-west.
- Any type of CEO roundtable needs to consider interdependencies. The discussion will be most fruitful with participation from a sampling of CEOs from a range of lifeline sectors.

There have been numerous examples of cascading impacts across modes of transportation, and these are most visible in single points of failure.

- Shared freight and passenger train corridors provide efficiency, but do not have a margin for errors or outages. If a line gets flooded or a bridge goes out, often there is no parallel structure to take on this load.
- Many inter-city passenger facilities are home to several different modes of transportation. For example, Union Station in Washington, DC provides service for the MARC, VRE, and Amtrak trains, as well as the underground Metro and multiple bus lines. If a facility like Union Station is debilitated, the effects would cascade across multiple modes of transportation. Fulton Street Station in New York City was out of service for years after 9/11.
- Protecting intermodal facilities is a challenge. For instance, ports, which are vulnerable to storm surges, may be owned by private or state operators—freight is often private, and there are many operators with different types of investments in the port's infrastructure.

II. Infrastructure Investment and Funding

Chronic underinvestment in transportation systems has led to inadequate and decaying infrastructure. Decision makers often do not include resilience in infrastructure investment planning, and lack understanding of resilience and why it is critical. In addition, the structure of public funding provides little incentive to invest in resilience. Public funding emphasizes emergency response at the expense of planning and building resilient infrastructure. Limited public funds are focused on the immediate needs of today, at the expense of investing in the future.

Resiliency is not encouraged or reinforced through funding and organizational structures.

- Instead of incentivizing building resilience into infrastructure, Federal funding focuses on disaster response.
- Sandy showed that rising sea levels could jeopardize concerns about aging and coastal infrastructure, in addition to a growing awareness of terrorism.
- We are in a better place than 5 or 10 years ago regarding awareness, but how do we manage response and build expertise? Can DHS assist transportation agencies by providing technical assistance and expertise?
- Recommendation: Use a portion of the emergency relief funds at DOT to provide pro-active training for prevention and preparedness purposes.

Resilience is viewed as a trend in risk mitigation, so many agencies are using resiliency funds for administrative costs that keep personnel they would otherwise lose if there was a shift in focus.

- The public sector provides capital funds, but not operating and maintenance funds. It has a defensive posture, and it is difficult to get people to make long-term investments. Framing long-term investment as "putting in a billion dollars to save four billion dollars" could change this perspective. We need to create cost benefit ratios far greater than "minus a billion" to "save four billion," and we need to foster the political will for these investment changes.
- "Spot-on repair" doesn't accomplish anything systemically, as there are no plans to upgrade it if it breaks. We need an inter-state, systemic plan for infrastructure development. The post-mortem on Superstorm Sandy will be that no one invested systemically in infrastructure, but no one is planning to update what is being built post-Sandy. Officials need to understand vulnerabilities and monetize the risk of acting and failing to act.
- The National Institute for Coastal and Harbor Infrastructure (NICHI) is developing a coastal alliance to act as an advocate, and should be developed as an academy with campuses.

Federal money is needed to entice states to participate, with the eventual goal of an integrated, interstate, coastal infrastructure system.

- About 60 percent of the U.S. population lives along coasts, and 95 percent of all goods arrives from the coasts.
- While other countries have plans to build integrated infrastructure systems, it is easier for them because they are smaller and more homogenous.

- More money is needed, and not all of it can come from the Federal Government. Federal funds can be used as a carrot to entice other levels of government to participate, including State, regional, and local governments. Officials should not exclude solutions just because they were not in the original frame of a monetary vision.
- Infrastructure funding has to be a shared responsibility between the private and public sector. For example, Pennsylvania is transferring the ownership of 500 bridges to the private sector, and it will be useful to examine the impact of this decision.
- The Metropolitan Transportation Authority (MTA) in New York is taking out parametric insurance, aiming to protect again catastrophic loss due to storm surge, and provides an interesting example for the Federal, state, utility commissions, and the private sector.
- Coordination of these entities is essential–currently, Federal and state agencies are disconnected, as are the public and private sector.

California has expanded the sub-allocation of Federal funds, giving state metropolitan planning organizations a unique amount of responsibility and resources.

- The Metropolitan Transportation Commission is under Federal law as a metropolitan planning organization (MPO).
- There should be strong Federal control of planning responsibility, and this should be required to adopt a long-range plan every four years.
- For example, the State of California owns seven toll bridges, but the actual revenue stream, totaling about $700 million a year, is owned by a state agency. Revenue is used to improve transportation assets; financial resource matters a lot. The agency has specific authority under State law to withhold funds from transit operators if they do not coordinate their affairs and activities with neighboring transit operators.

Governments should frame infrastructure investments as economic and community developments, as this framing structure will make it more likely for investments to be made.

- The Holland Superstorm in the 1950s demonstrated how infrastructure investments benefit communities. Surge barriers erected by the Waterworks Commission became a highway and created tremendous economic development.
- In the Boston Harbor, a new sewage treatment plant installed for $3.6 billion during the 1980s recession resulted in hundreds of billions of dollars in other harbor investment.
- Without this reframing, investments will continue to be delayed and some could never be made.
- NICHI is fostering coastal alignment to advocate for a unified resiliency agenda. The Institute set up a coastal leadership academy to educate public officials on resilience and implement recommendations made on climate preparedness and resilience. This academy needs grassroots support.
- NICHI is also focused on building alliances with communities and public officials who have working relationships with Congress, the Administration, and governors in order to generate political will.

Resilience is being incorporated on a limited basis in transportation planning, but each successfully adopted resilience plan presents a model for future resilience incorporation.

- Some areas are implementing more efficient systems by using simple techniques such as sustainable pavement, LED lighting, and old tires.
- Sales tax and bridge toll collection can generate transportation funds. In the past, these measures would raise capital, not operating costs. Today, they raise both.

III. Making the Business Case

It is difficult to show the value of investing in resilient infrastructure and practices. This is due in part to a lack of cost-benefit data and resilience metrics, funding constraints, and a poor understanding of emerging risks. Better data, tools, methods, and practices are needed that factor in lifecycle costs of transportation infrastructure. This will confront emerging risks such as aging infrastructure, cyber threats, and extreme weather. Near-term investment to protect against possible future risks is a hard sell, even with good data. Yet, rebuilding aging or damaged infrastructure to standards that address only historical risks is short sighted and costly. Resilience must be built into transportation infrastructure to address the "new normal" of risks.

Resilience needs to be incorporated across the entire lifecycle of infrastructure.

- We are at peril if we cannot ensure system functionality during an emergency and throughout recovery. Because resilience is an emerging field, there are coordination and capacity issues for the government when planning infrastructure projects.
- Resilience needs to become a design element in construction projects and maintenance, which requires an understanding of what a resilient design is before rebuilding begins.
- During the aftermath of a disaster, people are rebuilding in a hurry. All of these projects need to be approved, and many have multiple funding sources. This leads to design problems that have to be retrofitted afterwards. Many agencies do not have past experience and materials to draw from when planning resilient projects, so they are unsure of how to even approach resilience as a design element. We need to invest in a workforce that is aware of resilience principles.
- One way companies can develop a comprehensive understanding of resilience is to publish a resilience impact statement (similar to an environmental impact statement) for each project.

In taking a comprehensive lifecycle approach to transportation infrastructure resilience, choosing projects that benefit multiple stakeholders is the best way for the government to manage public response to resilience.

- The government needs to demonstrate how projects such as highway risk mitigation, solar power development, rain gardens, and 'green' surfaces can benefit multiple stakeholders by showing the positive impacts. Projects such as building barriers along coastal tunnels and transit stations can boost business continuity. In addition, developing microgrids or off-grid power sources could provide regional resiliency.
    - For example, after Sandy, the development of micro-grids and green power sources increased resiliency. Transit projects in Hoboken, NJ reduced recurrent flooding through zoning and identifying what would have the highest returns.

- Many agencies, as well as millennials and baby boomers, have a vested interest in resilience. Making significant investments in transportation would reduce deficits and the burden young people will face in the future.
- Usually terms are set up at the beginning of a contract–the investor is responsible for operations and maintenance. How do you factor this into a cost-benefit analysis? Pre-placed contracts worked for some companies, and transit agencies and others have used umbrella contracts in the past.
- It would be helpful to have streamlining mechanisms following a disaster. For example, if a bridge or rail line sustained major damage, and there was a need to expand the piers, it could trigger environmental assessment or environmental impact statement and greatly affect the project's time and cost.

Officials should look at incorporating resilience into the lifecycle of infrastructure from a regulatory perspective, and should focus on building investment.

- Describing the costs and benefits of investing in resilience poses a communications challenge.
- Private sector investors look at the full lifecycle of a project, for example, money is invested in toll roads and supports resilience. It is important to understand and recognize the benefits of investment. For instance, by analyzing the amount of people traveling on a structure compared to previous travel patterns, spanning a period of 10 years. The value should be estimated according to the local economy, local transportation, and the freight industry.
- The organization making the investment gets the long-term returns, and usually is responsible for operations and maintenance. This guarantees resilience remains in its interest.

In the Transportation Systems Sector, resilience measures have been incorporated more often by accident than design. However, they are slowly becoming more commonplace as companies examine transportation projects through lifecycle costs.

- Projects such as high-speed rail are examining risk management and building it into project development. Too often, construction is separated from maintenance and repair, and they are treated separately.
- Recommendation: Consider lifecycle costs in project planning, including what it takes to maintain a project over its lifespan and how design standards can mitigate potential issues in the future:
    - For instance, dealing with a collapsed freeway requires diverting traffic to alternative roads. How do we manage and communicate that diversion? The vast majority of commuters only know one way to get to work; if something happens, their daily routine is disrupted and they panic.

The effects of extreme weather and climate change need to be factored into cost-benefit analysis of transportation infrastructure. Since it is costly to retrofit enhancements, resilience must be incorporated into the lifecycle of transportation infrastructure.

- Extreme weather can have a range of effects on infrastructure. For example, droughts can affect agriculture, which can have an impact on the freight industry, and wildfires can cause pavement to buckle, which can have a significant impact on the transport of goods across the country.

- While railroads have their own funding and generate revenue, highway and public transit systems are suffering from delayed investments and have decayed from deferred maintenance.
- For a bridge to last 100 years, you need to analyze the lifecycle costs, including lane repair (having enough width to accommodate growing traffic needs) and piers that accommodate for flooding.
- Resilience is often phased out of project design because of cost concerns. However, it is more expensive repeatedly repair infrastructure later on. An emphasis on long-term planning is key, because over the next 50 years, at least one major event will likely occur.

The Transportation Systems Sector needs to be able to implement resilience, such as by securing opportunities for executive level engagement and supporting cost benefit analysis for infrastructure projects through modeling.

- Harvard was able to convene CEOs, but just one meeting is not enough. A broader impact can only arise when there is a capacity for implementation.
- In the long-term, we need representation across the country, not just in Washington, DC.
- This includes motivating CEOs and government officials to sustain interest in resilience, such as by raising private sector rewards (e.g., changing general accounting principles) and deciding who (or what agency) will implement resilience across administrations.
- Comprehensive, national data for matrices/models is lacking. However, the insurance industry has a lot of impact data. The issue is also sharing the data and making it available.
- Local and regional governments have acted as first responders, and have served as hotspots where people have built matrices/models to focus on cost benefit models. Louisiana is the most advanced because of Katrina, and is working closely with the RAND Corporation to develop models, and work on cost benefit issues.

Modeling can be an effective tool for examining resilience at the macro level, but tends to fall short at examining resilience at the micro level.

- There are good models of network flows of imports and exports in the U.S, which incorporate changing input variables into the future. However, the models have trouble capturing supply chain logistics at the local level for metropolitan areas such as Boston, Chicago, and Atlanta. How do you model local delivery, including warehousing distribution centers?
- Models need to incorporate the scale of the application and the length of the disruption:
    - For example, after Katrina, liquid fuel distribution was severely disrupted. Oil deliveries were delayed by days, maybe weeks, to Atlanta because of destruction in the Gulf. Input-output models should what goes into the transportation system to make it work (e.g., fuel, human resources), what comes out, and how that flow impacts the economy.
- Land use scenarios are common across the country, and scenario analysis and flexible design incorporate resilience into infrastructure. Contingency and buffer factors protect assets and promote resiliency.

IV. Policies and Practices

Government structures, processes, funding practices, and regulations can act as a barrier to implementing resilience in the transportation sector, and the structure of Federal programs do not foster cross-modal resilience. In addition, Federal managers may lack a clear and coherent definition of resilience and the program tools to encourage resilience, which may lead to disjointed action in building resilient transportation infrastructure.

Government regulations and jurisdictional responsibilities lack a resilience framework, and do not adapt adequately to crises.

- While regulations serve important purposes, they can confound response and recovery to extreme events.
    - For example, during Hurricane Irene's outages, utility trucks were stopped at state borders because they did not have the proper authority to bring in generators.
- It is important to remember that regulations can become a level of governance issue, in that they often involve small and large players, highly and loosely regulated players at the local, county, State, and Federal level.
- We also have to remember that we are dealing with systems that are not only national, but also are cross-border and involve international entities.
    - For example, Superstorm Sandy occurred during the "Christmas rush" for containerized cargo movement, and had particularly negative economic impacts. No one mapped out national cargo movement at a Federal level. Some traffic went to Halifax, Canada, while the Canadian National Railway doubled its capacity, and some cargo made it back down to New York.
    - Norfolk was heavily congested with some of the cargo, and the Jones Act prevented movement, and no waiver was issued.
- There are specific action items governments can take on, such as gaining an understanding of disruptive risk beyond individual systems at the regional level. Officials should also consider moving from a stationary risk perspective to a non-stationary one that accelerates the analysis of unfolding risks. Analytic tools could project these risks against real infrastructure so owners and operators can make informed decisions.

Many guidelines and standards can inhibit resilience development in the Transportation Systems Sector, and the Federal Government needs to provide coherent guidance on how to mitigate risks.

- It's difficult for local transit agencies to tackle global issues such as climate change and sea level rise. The Federal Government should step in and provide guidelines, directions, and funding.
- Training in risk management is key. While many people claim to practice risk management, there is a rigorous science to it, and it's still not practiced by many officials.
- State law requires some areas to use a risk register. This is a scientific approach to assessing risks, which includes identifying what the risks are, and what steps can be taken to manage them. Standard requirements for organizational risk management would be useful and could have positive results.

Insurance could incorporate resilience, because it focuses on real, not political or societal, risks.

- The MTA had a substantial amount of insurance before Sandy, but getting the policy renewed and expanded after the disaster was challenging. Insurance bonds would pay out immediately, and are not built around assessment.
- They have adopted a form of parametric trigger insurance, which means that at a certain storm surge (8 feet at Battery Park), the insurance catastrophe bond pays out immediately. Essentially, the MTA is mitigating up to that threshold.
- Insurers help shift the focus to real risk by compelling mitigation measures and making resources available quickly to support recovery.
- Recommendation: The current formula under the Stafford Act is most likely not sustainable, and Congress is moving against that level of support. Congress could slightly change legislation after the next large event. Rather than providing 80 percent of funding reimbursement, they could reduce it to a lower level (50-60 percent) unless a community performs asset inventory, develops a price, and takes out insurance on a portion of the assets. Essentially, this is devising a policy tool that drives a market tool to change behavior.

Asset management mechanisms, such as the requirement in MAP-21, facilitate system resiliency in the metropolitan planning process.

- Resilience is not just a design, operations, and construction issue, it's very much a planning issue.
- Since every State DOT is required to have an asset management system, a performance-based system is an excellent platform for introducing resiliency into the system. It minimizes change and allows states to practice risk mitigation through examining, updating, and monitoring assets.
- However, the concept of asset management for transit agencies is very different. Most State DOT decisions, such as adding a traffic lane to ease congestion, are based on cost analysis rather than asset management.
- State DOTs rarely consider resiliency in project-level decisions, and this is a real resiliency gap.

While the Federal Government has successfully collaborated with State governments on issues such as climate change, the government can have a more active role in command and control centers and transportation policy and funding regulations.

- The government has funded many demonstration pilots. For example, the Federal Highway Administration (FHWA) had about 22-24 pilots showing MPOs and State DOTs how to examine climate change and presented strategies to minimize disruption. Often State DOTs will not implement changes unless another agency does it first.
- The Transportation Equity Act for the 21st Century (TEA-21) helped locate system bottlenecks. This aided in identifying critical areas of concern for system resiliency—whether for hurricane evacuations or assessing port access vulnerabilities. Federal funding can take an analogous approach.
- For years when something went down, under FEMA, you could only replace it to its pre-existing condition, and couldn't make any design changes. Now the policy statement says design

improvements are allowed for replacement assets. This should be how Federal emergency response works—allowing transit agencies to improve.

- Cybersecurity is a big issue for command and control centers. System resiliency is not just having assets in place, but also includes management of those assets. If people can hack systems such as air traffic control and navigation, it would create havoc.
- As such, control centers are essential—the first one in New York City sparked the rise throughout the country. They show from an operational perspective how resiliency can be integrated into actual system operations.

The transportation industry has the ability to respond to disasters and emergencies, but regional coordination is needed, because control over the system is fractured.

- Primarily, this involves local and regional transportation.
- Could a regional trip planner tie multiple systems together? A metropolitan planning organization kind of function could examine how to manage transportation on a regional basis
- Transportation needs more recognition from the Administration. It involves the economic and overall well-being of regions and cities.

While the state of California has made significant advances in reducing greenhouse gas (GHG) emissions, the state is lacking in adaptation measures, where resiliency is key.

- California has a statewide statutory framework to mitigate GHG emissions. It includes requirements in the transportation sector and meets numerical reductions. This is crucial for infrastructure and residential development to reduce vehicle miles of travel and GHG emissions. However, it has not advanced as much on the adaptation side. This is where resilience for sea level rise is going to play a big role.
- The San Francisco Bay has been rising for many years. The Bay Conservation Development Commission has mapped out the possible severe consequences of sea level rise for the Bay Area. A 48-inch rise in sea level would inundate all three of the national airports, some sections of the BART system, and major highways. The South Bay is very shallow; Google, Facebook, Apple would all be underwater.
- We need to figure out how we can protect those facilities with levees, wetland restoration, and other strategies in the event of sea level rise.

V. Leadership and Coordination

Coordinated national leadership is essential for nurturing and accelerating a culture of resilience in transportation and aligning the actions of government and industry. This requires a clear vision, policies, and plans. The Federal Government's ability to build cross-modal relationships is crucial for creating communication and coordination planning mechanisms throughout the public sector. Top executive engagement and effective collaboration plays a key role in incorporating resiliency into transportation infrastructure.

Resilience should be a key criteria in the design of transportation infrastructure, and the Department of Transportation should lead resilience incorporation in the sector.

- Transportation systems are interconnected, and often weak links are not clear until they are broken. Vulnerabilities need to be incorporated into resilience, but mitigating actions are influenced by other priorities and resource availability.
- DOT should have a designated group to tackle long-term resilience issues, providing immediate responses to provide focus for all agencies within the department.
- Planners and engineers need to design to appropriate standards and anticipate all hazards. There needs to be a planning framework that incorporates the age and condition of assets and the options for managing these assets during and after disruptions.

We need a major change in national policy for the Transportation Systems Sector, starting with a focus on government leadership.

- A leader needs to tackle this problem and coordinate with different transportation modes and other sectors. Additionally, the sector needs to be better coordinated with Federal, state, and municipal resources.
- We need to develop the political will that's necessary for change by looking to past experiences engrained in our cultural institutions. President Carter's "malaise" speech and Reagan's "Morning in America" speech serve as two examples of leadership rhetoric.
- Our policies need to evolve from disaster relief to response and repair.
- There are no plans to invest in coastal resiliency, or resiliency in general. The macro solution is to change policy and government organization.
- Recommendation: We need a method for implementing recommendations, including a specific structure for resilience.

The U.S. Committee on the Marine Transportation System (CMTS) can serve as a model for bridging the gap among multiple government agencies overseeing one complex system.

- There are over 30 Federal agencies and offices engaged with the marine transportation system, including the United States Coast Guard (USCG), the United States Army Corp of Engineers (USACE), the National Oceanic and Atmospheric Administration (NOAA), the United States Maritime Administration (MARAD), the Departments of Energy, Agriculture, and Defense, as well as the Office of Management and Budget (OMB) and the National Security Staff.
- The Coordinating Board of the Committee rotates at the Cabinet level between DHS (USCG), DOD (USACE), DOC (NOAA), and DOT (MARAD). This ensures that a broader perspective is always presented as well as balance, which guarantees that the focus remains on what is in the best interest of the Nation's marine transportation system.
- The Committee has developed a handbook of Federal funding sources for MTS-related infrastructure, featuring sections for each program including points of contact, criteria, funding, etc.
- The handbook provides a Port Developer/Port Authority/State transportation officer with an understanding of what specific funding sources are so that they can leverage their resources with private, State, and local funds to begin their project.

CEO-level engagement plays a major role in gaining support for resiliency.

- The effort needs top-level leadership that includes daily interaction and debriefs after disasters.
- We need to consider what drives private sector decision making. This includes integrating resilience into annual reports. A responsible CEO is already thinking about company resilience. For example, they are aware of supply chain weaknesses and response mechanisms. However, they may overlook long-term vulnerabilities.
- Surface transportation needs a long-term investment commitment. It also needs a timely re-authorization package, and has been suffering from underinvestment since 2009.
- Long-term capital investments take money, commitment, time, and require certainty. Letting existing assets deteriorate (such as seen on the U.S. Army Corps of Engineers Report Cards), not taking action on future demands and requirements (such as that freight movement could double), and not getting asset structure in fundamental order creates significant risks.
- Recommendation: Federal leadership is needed. Transportation assets, such as rail, have an effective process for planning, but do not always use it.

Building working relationships across modes would create common communication and coordination planning mechanisms, and non-profits are particularly suited for bringing together the public and private sectors for this purpose.

- Transportation officials should work with their emergency management counterparts involved in a disruption.
    - For example, officials in charge with coordinating a special event need to work with traffic planning officials, perform modeling to test plans, and strategic development.
- Emergency planning and exercises officials should develop working relationships, as workers who have experienced past events can inform resilience incorporation for the future.
- Non-profits such as the All Hazards Consortium and Pacific Northwest Economic Region effectively bring together the private sector and government stakeholders, spearheading plans for disasters such as power outages to special events such as the Olympics.

Private sector engagement needs to be accomplished in a way that does not isolate the business community or appear as regulatory overreach.

- For example, the San Francisco Bay Conservation Development Commission was set up to restrict fill of the bay, and has land use authority about 100 feet around the bay. They attempted to adopt climate change policies relating to sea level rise, but the business community rose up and eliminated it. They were concerned the commission would overstep the 100-foot zone, and that there would be a regional "land use czar" regulating activity.
- The private sector's strong reaction to the policies serves as a reminder that potential resilience policies need to be discussed with the whole community, including local business owners.

Public-private partnerships can be a valuable tool to incorporate resilience, but there is concern from the private sector that the more requirements that are integrated into project design, the less the businesses will profit.

- Convincing both public and private entities to work together to achieve a common goal for the public that is not necessarily in the private sector's interest will be a significant challenge – how do you encourage private investment in public facilities?
- Designing new facilities in areas prone to natural disruptions, require the incorporation of resilience into contractual arrangements. This has become an important current financial strategy.

Appendix L: Consolidated Information from Study Group Subject Matter Expert Discussions

This appendix identifies key information examined by the Study Group during its discussions with transportation and critical infrastructure resilience subject matter experts (SMEs). This material aligns with the seven roundtable discussions conducted by the Study Group with relevant SMEs. They are:

I. Port Operations – Port of Los Angeles and Port of Long Beach
II. Pipeline and Surface Transportation Planning and Policy
III. Port Operations and Intermodal Transportation
IV. Resilience in Aviation and General Transportation
V. Transportation Resilience and Cybersecurity Policy Perspectives
VI. Supply Chain Perspectives
VII. Freight Rail Transportation Resilience

The information below includes important themes discussed during the course of each discussion and selected discussion excerpts to provide context.

I. Port Operations—Port of Los Angeles and Port of Long Beach

Port resilience is best understood through the lens of business continuity and economic importance.

- The resilience perspective is understood within the concept of economics, such as in ensuring a functioning port economy and examining how the port contributes to the national economy.
- Modifying large vessels and ports to make them more resilient (e.g. cold ironing) in California can be used as a national resiliency model for other ports.
- Funding for business continuity, such as for training and equipment to rapidly recover, is a major concern for the port industry because "business continuity" is a relatively new term for government agencies.
- Getting the right people in the room and enabling stakeholders to exercise together and build relationships is an important piece to the resilience puzzle.

Port business is inextricably tied to the movement of goods, and port disruptions can generate wide-reaching cascading effects.

- The impact of a disruption at a port expands beyond the initial incident and can have lasting impacts that transcend time and place. This ultimately affects trust between the port and businesses using its services. Cargo that is lost during the incident may never be regained.
- The Port of Long Beach examined logistics chains and the movement of goods at both the international and local level. This began with contacting businesses connecting to the port, examining what moved the goods, and holding meetings to develop synergy.
- Major disruptions require the port to be restored, as well as infrastructure (e.g. bridges, rail lines) that connects to it or is used for the movement of goods.

The single-most important factor for maintaining port operations during a disruption is maintaining the energy supply.

- A single point of failure exists in the electricity supply. In order to mitigate the impact of a power disruption on port operations, the port must look to alternative sources. However, alternative supplies may not be sufficient in sustaining a fully functioning port or may not completely address the energy disruption.
- Power and fuel are a top priority during transportation disruptions. During a disruption, ports need to secure and disperse fuel to affected locations.
- Power is critical to port operations, and there is a need to understand the synergy of ports and power generation. Power operates the cranes, fuel pumps, and pipelines. Without it, goods cannot be moved.

The basic nature of ports and other lifeline dependencies creates a vulnerability-rich environment.

- The nature of port locations can make them vulnerable to disasters outside a port's campus. Transportation paths (e.g. bridges) can be severed; creating major complications for moving goods.
- Water is an issue, due to the single point of failure present in the local water system, especially when ports rely on only one water system. Water disruptions or shortages will upset port operations from a labor perspective, as personnel must have certain levels of sanitation and can refuse to work.

Existing obstacles to achieving full port resilience impede full implementation of resilience measures.

- Regulations and "red tape" may restrict operations during disruptive events. During declared emergencies, there has to be a "give-and-take" to enable services, transport goods, and avoid regional atrophy.
- Full and consistent funding for emergency management training and resources is key.
- The biggest threat to the POLA-POLB region is an earthquake, due to fragility of current infrastructure and the lack of modernized infrastructure.

There is sufficient capability in communications usage, but insufficient progress in mitigating cyber threats.

- Terminals operate on separate technology networks, and as such, there is redundancy. However, with the responsibility of cargo management given to individual terminal owners/operators, vulnerabilities may unknowingly exist. The owners/operators have the opportunity to build resilient cyber infrastructure, but there is no consistent standard to require them to do so.
- Information sharing is important to cybersecurity. With increased cyber incident awareness, terminals will become more engaged in cybersecurity.
- Ports have built-in redundancy in communications, due to their diverse communications usage. During a disruption, they leverage command/control centers to send out communications that prevent freight and others from travelling to the port.

II. Pipeline and Surface Transportation Planning and Policy

Building a resilient transportation system starts with a change in the Transportation Systems Sector culture.

- Resilience needs equal footing with other important values in transportation, such as cost/benefit and safety.
- Key aspects to improving Federal and SLTT coordination and advancing resilience include maintaining momentum in inter-agency discussions and working across government silos.
- A close analysis of long-running and established assumptions will illuminate the transportation system fail points and uncover vulnerabilities that may have gone unquestioned and undiscovered.
- Resilience will take a generation or more to work its way through the transportation system.

Resources maintaining the security of the Transportation Systems Sector, such as funding, can be a vehicle to building resilience.

- Funding allocated to building resilience is needed to put resilience plans in place either during the design/build phase or in the rebuilding phase after an emergency event.
- Training, regular exercises, and funding resources need to be emphasized to improve resilience.

The Transportation Systems Sector is composed of smaller systems and interlocking modes; as such it is vulnerable to points of failure and cascading effects.

- The interconnectedness of transportation modes makes them vulnerable to cascading effects:
  - Freight and aviation are two modes that cause and are affected by cascading effects across the transportation sector.
  - Government officials and operators need to understand that although there may not be damage to infrastructure in their state, cascading effects could impact them.
- A critical vulnerability of the Nation's transportation system is the single point of failure nature of interconnecting transportation modes.

The limited exposure of pipeline infrastructure belies its criticality to transportation systems and other sectors.

- There are critical pipeline nodes within the Los Angeles-Long Beach region that, if disrupted or damaged, will cause a tremendous regional effect and cascade beyond the region.
- In California, logistics issues make moving product traditionally transported by pipelines difficult.
  - A majority of the product flowing through the pipeline is transported directly to the facility, and only a minority of refinery output leaves the property by truck.
  - Barges may be too big for terminals, severely restraining activity.
- The transport of hazardous materials by rail can be an effective alternative supply method during an emergency event that disrupts pipeline activity.

The reliance on information technology (IT) leads to both operational efficiencies and vulnerabilities.

- The sector's growing reliance on supervisory control and data acquisition (SCADA) systems and other cyber infrastructure provides operational benefits, but increases system vulnerability. Human capital is needed to decrease the vulnerability of cyber systems.
- There is an organizational disconnect between who runs the IT systems and who needs to protect them.

III. Port Operations and Intermodal Transportation

A whole community approach—including a coordinated effort among Transportation Systems Sector components and response/recovery personnel—is key to successful response and recovery.

- Coordination with local communities is critical to rapid response and recovery, and requires trusted relations built over time and through shared experiences and exercises.
- Localized personnel know how to fix the infrastructure they use a daily basis and how to make it more resilient. The biggest challenge is how to organize knowledge, train the port community, and establish communications between government officials and personnel doing the work on the ground.

Superstorm Sandy was a major event that changed the understanding of port operations during disruptions.

- Superstorm Sandy illuminated the limitations of existing response and recovery preparations for major disasters, and focused attention on the need for resilience to be built into all aspects of preparedness.
- The disaster also underscored the importance of maintaining and prioritizing the restoration of electricity during disruptions. Without power, port operations cease.
- Port authorities and tenants had to develop ad hoc solutions to unanticipated effects. However, authorities, tenants, and stakeholders used their prior experience with major disasters and disruption scenarios to quickly establish communication channels to effectively work through problems.

Further actions can be taken to improve resilience in port operations, and these actions have broad applicability to other modes.

- These actions include:
    - Examining regulations (e.g., Merchant Marine Act/"Jones Act") to see if their requirements can be waived in extraordinary situations to enable rapid recovery
    - Recognizing associations (e.g., American Association of Port Authorities) as key to organizing mutual assistance arrangements among the Nation's ports
    - Providing (through the Federal Government) resilience financing assistance through grants and investment incentives to build resilience into new infrastructure
    - Building resilience into repair work through Federally-supported standards and promoting a culture of resilience
    - Encouraging a dialogue with major retailers about their supply chains
    - Building a cohesive community of responders that exercises and trains often

IV. Resilience in Aviation and General Transportation

Comprehensive implementation of resilience needs a catalyst and the removal of rapid recovery barriers.

- Typically, negative consequences from an actual event are needed to spur substantial infrastructure investment. Investments in emerging issues (e.g. climate adaptation) are difficult to justify when you have immediate needs for safety improvements or increased capacity.
- To rapidly resume operations, aviation would benefit from flexibility in compliance.
- Obtaining fuel was a challenge to resuming operations post-Superstorm Sandy, as roads and bridges were blocked. Federal red tape exacerbated the challenge—there was an inability to transfer fuel to the private sector despite the availability of nearby military resources.

Transportation Systems Sector resilience can be facilitated through collaboration that creates a system-wide common operating picture.

- Associations and council governments could enhance coordination using existing information paths and prior knowledge of who should take action.
- Partnerships in metropolitan areas work better—the farther you move from metropolitan areas, the more partnerships and communication streams are not as well defined.
- There is a need to ensure relationships and connections are in place to address modal dependencies. If one mode is not working, there will be other disruptions down the line. For example, small-scale incidents can have significant disruptions beyond the initial airport. Coordination and dedicated transportation of Federal employees would help expedite and contain disruptions.
- Common messaging, operations, and procedures allow transportation agencies to consistently and appropriately respond to disruptions.

Planning in advance and applying lessons learned would best situate the Transportation Systems Sector to weather disruption.

- Developing COOP plans, practicing procedures, conducting cross-agency and cross-jurisdictional exercises, and working with community members enables organizations to "know the players." This helps them anticipate where disruptions may occur and effectively respond.
- Lessons learned from exercises and specific disruptions can be applied to larger events. For instance, the Asiana Airlines Flight 214 crash illustrated how to better communicate with the public health community. This could be applied to an earthquake.

Transportation systems are growing more reliant on information technology (IT) and have an increased risk of malicious actors exploiting system vulnerabilities.

- Increasingly sophisticated transit systems are exposed to sophisticated cyber-attacks. It is crucial for transit to develop internal cybersecurity capabilities that parallel the growing dependency on IT.
- Transportation IT systems contain indirect singular points of vulnerability, to varying degrees. Localized issues can lead to major disruptions or the shutdown of an entire system (e.g., the

2003 Northeast Blackout was initially a local issue, but ultimately expanded to become a regional issue).

- The aviation mode's cyber risk has these characteristics:
    - Air traffic networks create virtual highways in the sky. The criticality and centralization of air traffic control and management of the national airspace system mean cyber-attacks pose significant issues for air traffic control.
    - The resilience of the aviation system is reliant on the resilience of government systems and assets (e.g., towers, communications, TSA Secure Flight, DHS routers).

There is an immediate need for airports to be resilient.

- They are primary places for multimodal transfer of cargo and facilitate processing passengers and day-to-day commerce activity.
- Small airports can get around fuel difficulties with extemporary alternatives, but larger international gateway airports have little flexibility.
- Airports have implemented collaborative, self-help solutions to wide-ranging challenges. For example, the Southeast Airport Disaster Operations Group (SEADOG) has flexible practices and provides counterparts at airports with assistance or resources to recover from disruptions.

V. Transportation Resilience and Cybersecurity Policy Perspectives

Resilience measures reduce impact and costs but they need a champion to ensure widespread implementation.

- In a study of hazardous material transportation, an accident with a railcar transporting chlorine through New York City resulted in a two-week period of disruption with high costs. Factoring in resilience measures reduced the impact and costs by more than 50 percent.
- State-to-state implementation of transportation resilience options requires endorsement from the Secretary of DHS or even the President.
- Customer-facing resilience options (e.g., altering transportation modes) are less expensive and easier to accomplish than fleet system resilience.

The 2013 Colorado flooding event produced valuable lessons learned in resilience.

- Strong partnerships and relationships between transportation administrations and contractors enabled a rapid restoration of roads and bridges.
- Contracting plans and procedures in place prior to the event enable people to immediately work on damaged roads and bridges.
- Expediting processes for studying environmental impacts facilitated the rapid repair of roads and bridges.
- Leveraging the National Guard allowed for the prioritized opening of critical highways.

The Transportation Systems Sector's level of cybersecurity is inadequate.

- While the sector has increased connectivity, the devices in use are dated and do not have adequate network connectivity or security. Transportation devices can be remotely accessed, which is a major vulnerability.
- Freight and mass transit (buses, rail, and truck) infrastructure cybersecurity is not as advanced as in the light passenger vehicle sector.

Information technology improves transportation resilience, but using technological solutions require understanding and dedicated upkeep.

- Technology improves transportation resilience and transportation system monitoring:
    - It enables the increased use of monitoring and surveillance technologies, many with real time capabilities.
    - Agencies within a jurisdiction can use similar data to better respond to and manage emergencies.
    - Customer-facing technologies are becoming more connected and automated.
- National standards for the sector's cyber infrastructure do not exist. There are different developers, platforms, and governance structures across transportation agencies.
- Unanticipated software patches and technology fixes are costly and complex. More emphasis is needed on cyber-resilience in the design and development of systems.
    - The security architecture built into the private vehicle communications support systems is a good example of how systems can have security and resilience built into their design.

VI. Supply Chain Perspectives

Resilience should be standardized for application within different transportation agencies and disruptions.

- Resilience should have one definition, and the Federal Government should standardize what it is looking for in terms of "resilience."
- Resilience denotes the ability of infrastructure to move goods through any problem and to adapt to the changing economic climate. Rail moves whatever commodity is in high demand, and it needs to have flexibility in times of disruption.

Entities can collaborate to synchronize their approach to resilience issues and solutions.

- Forums such as panel discussions are useful for gathering effective practices from sectors, as well as getting input from sectors that may not have implemented resilience practices.
- Coordination and communication are important to resilience, and conversations should be facilitated across government, transportation agencies, and stakeholders.
- Transportation advisory committees, such as the California Freight Advisory Committee, can be strong tools for effective resilience coordination.
- Government has a tendency to think they have to solve the problem, but there are many people with experiences and expertise on how to get it done and perhaps how to get it done better.

Incentives are needed for resilience investments, particularly in an industry-rich mode such as freight rail.

- Like most transportation, funding is a major challenge for rail. Industry needs incentives to make resilience investments.

The freight rail system can be disrupted by external transportation modes.

- Multimodal planning is inherently resilient. Resiliency is not necessarily in the foreground, but it is always in the background. Redundancy and alternative routes are built into the rail system, and response is expedited to restore service.
- Rail may be faced with severe impacts, but it does not mean trains will fail completely. Rail can fall back on the ability to function manually or can relocate operations centers or remotely conduct operations.
- There are many factors that create bottlenecks and congestions on railroads. You can fix bottlenecks within California (e.g., building the Alameda Corridor), but future issues may create congestion along other points of the supply line.

VII. Freight Rail Transportation Resilience

Resilience is inherently built into the freight rail transportation system.

- Freight rail has built-in system resiliency and flexibly leverages the massive freight rail grid.
- Resilience is fostered at every level in a rail company. They recognize that it is more than just a strategic issue and that if you don't address the small stuff (e.g., training, workforce issues) it will manifest itself somewhere in the system and cause problems.
- In a disruption of a freight node, such as a major port, you are going to (a) hold until you can find an alternative location to send cargo, or (b) induce a shift in how it is handled, such as directing cargo to a warehouse instead of distribution.

The unique consolidation of industry ownership in freight rail enables them to invest in infrastructure in a way that promotes resilience.

- With dedicated maintenance, rail infrastructure can stand the test of time. Re-designs are completed to address new issues that reach beyond the limits of current infrastructure. Private investments are made to expand freight networks, ensure infrastructure meets demands, and increase velocity.
- Maintenance needs to be prioritized. Freight rail incorporates the costs to build and maintain infrastructure into the onset of projects.
- Freight rail prioritizes the protection of their infrastructure and avoids building in high-risk flood areas.
- The following is an example of built-to-last infrastructure: In the 1990s, renovations were made to the freight rail bridge crossing Lake Pontchartrain. In 2005, Hurricane Katrina washed the track off the bridge. However, the bridge itself weathered the storm well, because the infrastructure was maintained and built to be easily restored. Responders were able to restore the bridge in 12 days.

The freight rail transportation system has a collaborative nature, which fosters resilience.

- Despite the differences among freight rail classifications (Class I, II, III), freight rail companies work together to effectively address disruptions.
- Larger rail companies come to the aid of short line rail companies and provide them with needed capabilities, such as by sharing cars and lines or cooperating to clear rail lines.
- The freight rail industry relies on public-private partnerships for problems that overwhelm their capacity.

Freight rail recognizes and works to mitigate cyber threats.

- Freight rail information technology systems are insular, difficult to access, and supported by a substantial IT security team. Freight rail also uses information sharing to obtain cyber threat information.
- In many cases, if the system is compromised, it shuts down and stops the train.
- The cyber-physical nature of the rail system causes substantial threats, such as in a hurricane destroying data or control centers. However, freight rail responds in a resilient manner by hardening facilities or leveraging adjacent centers.

During disruptions, external sources may hamper freight rail response and recovery efforts.

- During derailments, rail companies involve multiple jurisdictions, but defer to appropriate authorities.
- However, government involvement can slow the response/recovery process. Conflicting agencies may claim jurisdiction, resulting in a lack of clear command or control.

There are specific actions the Federal Government can take to improve modal resilience:

- Provide loan programs for small freight rail companies
- Facilitate public-private coordination to achieve resilience goals and engage industry
- Improve the coordination and speed of decision making during disruptions, and foster a process that is short-term, specific, and non-invasive

Appendix M: References and Research Resources

References

"The Alameda Corridor Route Map." *Railway-technology.com*. http://www.railway-technology.com/projects/alameda/alameda1.html.

"America's crumbling infrastructure: Bridging the gap." *The Economist*. June 26, 2014. http://www.economist.com/news/united-states/21605932-country-where-everyone-drives-america-has-shoddy-roads-bridging-gap.

"America's transport infrastructure: Life in the slow lane." *The Economist*. April 28, 2011. http://www.economist.com/node/18620944.

"Automation Emerging as Key Issue in West Coast Port Negotiations." *Supply Chain Digest*. September 25, 2014. http://www.scdigest.com/ontarget/14-09-25-1.php?cid=8521.

"The end of the port strike: Dock around the clock." *The Economist*. November 28, 2002. http://www.economist.com/node/1468299.

"New Orleans Getting New Biodiesel Buses." *Automotive Fleet*. October 11, 2008. http://www.automotive-fleet.com/news/story/2008/10/new-orleans-getting-new-biodiesel-buses.aspx.

"Panama Canal Expansion Ready at Start of 2016, President Says." *New York Times*. September, 9, 2014. http://www.nytimes.com/2014/09/10/business/international/panama-canal-expansion-ready-at-start-of-2016-president-says.html?_r=0.

"San Pedro and LA Harbor Area Local Transit." *SanPedro.com*. http://www.sanpedro.com/spcom/san-pedro-local-transit.htm.

"U.S., Canada announce new oil train rules." *EUCI* blog. May 6, 2015. http://blog.euci.com/?p=394.

Administración Portuaria Integral de Lázaro Cárdenas. "Two new Super Post Panamax cranes for container terminal make it the most equipped in Mexico." March 27, 2014. http://www.puertolazarocardenas.com.mx/plc25/news/475-two-new-super-post-panamax-cranes-for-container-terminal-makes-it-the-most-equipped-in-mexico.

Alameda Corridor Transportation Authority. "Corridor Stats." Section on homepage. http://www.acta.org/index.asp.

Alameda Corridor Transportation Authority. *Trade Impact Study Report*. April 2009. http://www.acta.org/newsroom/Releases/Alameda%20Corridor%20Trade%20Impact%20Study_April%209%202009.pdf.

Alaska Railroad. "The Alaska Railroad Corporation (ARRC)." 2012. http://www.alaskarailroad.com/corporate/AboutARRC/tabid/451/Default.aspx.

All Hazards Consortium, Multi-State Fleet Response Working Group. http://www.fleetresponse.org/.

American Association of State Highway and Transportation Officials, *2015 AASHTO Bottom Line Report.* 2015. http://bottomline.transportation.org/Documents/Bottom%20Line%202015%20Executuve%20Version%20FINAL.pdf.

American Association of Port Authorities. "Glossary of Maritime Terms." 2013. http://www.aapa-ports.org/Industry/content.cfm?ItemNumber=1077.

American Association of Port Authorities. "U.S. Public Port Facts." http://www.aapa-ports.org/Industry/content.cfm?ItemNumber=1032&navItemNumber=1034.

American Public Transportation Association. "20. Transit Operating Statistics – Service Supplied and Consumed – Train Statistics: Rail Modes." In *Resource Library*. 2014. http://www.apta.com/resources/statistics/Pages/NTDDataTables.aspx.

American Public Transportation Association. *2014 Public Transportation Fact Book*. 2014. http://www.apta.com/resources/statistics/Documents/FactBook/APTA_2012_Fact%20Book.pdf .

American Society of Civil Engineers. *2013 Report Card for America's Infrastructure*. 2013. http://www.infrastructurereportcard.org/a/#p/home.

American Society of Civil Engineers. *Authorization of the Nation's Surface Transportation Program: A Blueprint for Success*. 2013. http://cms.asce.org/Public-Policies-and-Priorities/Public-Policy-Statements/Authorization-of-the-Nation-s-Surface-Transportation-Funding-Program--A-Blueprint-for-Success/ .

American Society of Civil Engineers. *Failure to Act: The Economic Impact of Current Investment Trends in Airports, Inland Waterways, and Marine Ports Infrastructure*. 2012. http://www.asce.org/uploadedFiles/Infrastructure/Failure_to_Act/Failure%20To%20Act%20Ports%20Economic%20Report.pdf.

American Society of Civil Engineers. *Failure to Act: The Economic Impact of Current Investment Trends in Surface Transportation Infrastructure*. 2011. http://www.asce.org/uploadedfiles/infrastructure/report_card/asce-failuretoactfinal.pdf.

American Society of Civil Engineers. *Failure to Act: The Impact of Current Infrastructure Investment on America's Economic Future*. 2013. http://www.asce.org/uploadedfiles/Infrastructure/failure_to_act/failure_to_act_report.pdf.

Amtrak. "Amtrak National Facts." http://www.amtrak.com/servlet/ContentServer?c=Page&pagename=am%2FLayout&cid=1246041980246.

Amtrak. "California Stations." http://www.amtrak.com/california-train-bus-stations.

Anderson, Susan E. et al. *Towards the Future: The Promise of Intermodal and Multimodal Transportation Systems*. University of Texas, Center for Transportation Research. 1995. http://library.ctr.utexas.edu/digitized/swutc/60017_71249-3.pdf.

Association of American Railroads. "Overview of America's Freight Railroads." April 2014. https://www.aar.org/BackgroundPapers/Overview%20of%20Americas%20Freight%20Railroads.pdf.

Association of Oil Pipelines. "About Pipelines." http://www.aopl.org/pipeline-basics/about-pipelines/.

Association of Oil Pipelines. "Pipeline 101." http://www.aopl.org/pipeline-basics/pipeline-101/.

Aylward, Anee. Remarks in *The Nation's Requirements for an Intermodal Transportation System: A 20-Year Perspective*, webinar sponsored by the John A. Volpe National Transportation Systems Center, October 30, 2014.

Baltimore Metropolitan Council. *Freight Planning in the Baltimore Region*. 2013. http://www.ampo.org/wp-content/uploads/2013/11/Aris_Freight-planning-in-the-Baltimore-region.pdf.

Banham, Russ. "Reducing Disruption in the Global Supply Chain." *Wall Street Journal*. http://online.wsj.com/ad/article/managingrisk-disruption.

Boardman, Joe. Interview on CBS News, 60 Minutes, November 23, 2014. http://www.cbsnews.com/news/falling-apart-america-neglected-infrastructure/.

Borrero, J. et al. "Could It Happen Here?" *Civil Engineering* 75, no. 4 (2005). https://www.usc.edu/dept/tsunamis/2005/pdf/2005_03_28_socalTsunami2.pdf.

California Department of Transportation. "Appendix B-3-6: Long Beach Airport." In *California Freight Mobility Plan*. http://dot.ca.gov/hq/tpp/offices/ogm/CFMP_docs/appendixb-3-6_longbeach_090314.docx.

California Department of Transportation. "Appendix B-4-5: Port of Los Angeles." In *California Freight Mobility Plan*. http://dot.ca.gov/hq/tpp/offices/ogm/CFMP_docs/appendixb-4-5_portlosangeles_090314.docx.

California Department of Transportation. "Caltrans Freight Rail Fact Sheet." http://www.dot.ca.gov/hq/tpp/offices/ogm/trains/Freight_Railroad_Fact_Sheet_122413jhm.docx.

California Emergency Management Agency. *Golden Guardian 2010 After Action Report*. September 2010. http://www.calema.ca.gov/TrainingandExercises/Documents/Golden%20Guardian/AARs/GG%202010%20AAR%20Executive%20Summary.pdf.

California Maritime Security Council. *Port Recovery and Business Continuity Planning Considerations Guide*. 2010. http://aapa.files.cms-plus.com/PDFs/Recovery%20Planning%20Guide.pdf.

Canadian Chamber of Commerce. *The Foundations of a Competitive Canada: The Need for Strategic Infrastructure Investment.* December 2013. http://www.chamber.ca/media/blog/131218-The-Foundations-of-a-Competitive-Canada/131218_The_Foundations_of_a_Competitive_Canada.pdf.

Carlson, L. *Resilience: Theory and Applications*. Argonne National Laboratory. 2012. http://www.dis.anl.gov/pubs/72218.pdf.

Case, Brendan. "ICA CEO Sees Mexico Infrastructure Spending Rising by 56%." *Bloomberg*. September 17, 2012. http://www.bloomberg.com/news/articles/2012-09-17/ica-ceo-sees-mexico-infrastructure-spending-rising-by-56-.

Cassidy, William B. "Top 50 Trucking Companies Rode Their Brakes in 2013." *JOC.com*. April 16, 2014. http://www.joc.com/trucking-logistics/top-50-trucking-companies-rode-their-brakes-2013_20140416.html.

City College of New York. *Final Report: Lessons from Hurricane Sandy for Port Resilience*. 2013. http://ntl.bts.gov/lib/51000/51200/51237/Final-Hurricane-Sandy-Resilience.pdf.

City of Los Angeles. *Hazard Mitigation Plan*. July 2011. http://emergency.lacity.org/stellent/groups/departments/@emd_contributor/documents/contributor_web_content/lacityp_019906.pdf.

City of New York. *A Stronger, More Resilient New York*. 2013. http://www.nyc.gov/html/sirr/html/report/report.shtml.

Clark, Meagan. "Aging US Power Grid Blacks Out More Than Any Other Developed Nation." *International Business Times*. July 17, 2014. http://www.ibtimes.com/aging-us-power-grid-blacks-out-more-any-other-developed-nation-1631086.

Colliers International. *North American Port Analysis: Preparing for the First Post-Panamax Decade*. 2012. http://www.colliers.com/-/media/Files/MarketResearch/Unitedstates/2012-NA-Highlights-Reports/2012%20Q2/Colliers_PortReport_2012q2_final.pdf?campaign=Colliers_Port_Analysis_NA_Aug-2012.

Community and Regional Resilience Institute. *Building Community Resilience: A Summary of Case Studies from Charleston, Gulfport, and Memphis*. 2010. http://www.resilientus.org/wp-content/uploads/2013/03/CARRi_Research_Report_9_Craig_Colten_1276602180.pdf.

Congressional Budget Office. *The Economic Costs of Disruptions in Container Shipments*. March 2006. http://www.inforum.umd.edu/papers/otherstudies/2003/03-29-Container_Shipments.pdf.

Congressional Research Service. *U.S. Rail Transportation of Crude Oil: Background and Issues for Congress*. 2014. http://fas.org/sgp/crs/misc/R43390.pdf.

Council on Foreign Relations, *Road to Nowhere: Federal Transportation Infrastructure Policy*. 2012. http://www.cfr.org/infrastructure/road-nowhere-federal-transportation-infrastructure-policy/p28419.

Davies, Alex. "A Single Fire Can Cripple America's Aging Air-Traffic System. Here's Why." Wired. September 30, 2014. http://www.wired.com/2014/09/faa-chicago-fire-air-traffic-control/.

Delaware Valley Regional Planning Commission. *Connections 2040: Transportation Investment Scenarios*. 2012. http://www.dvrpc.org/reports/13004.pdf.

Detroit Historical Society. "Ambassador Bridge." *Encyclopedia of Detroit.* http://detroithistorical.org/learn/encyclopedia-of-detroit/ambassador-bridge.

DRI-WEFA. *The National Economic Impact of a West Coast Port Shutdown*. Prepared for the U.S. Department of Labor, Office of the Assistant Secretary for Policy. May 29, 2002.

Egli, Dane S. *Beyond the Storms: Strengthening Preparedness, Response, & Resilience in the 21st Century*. Johns Hopkins University. 2013. http://scholarcommons.usf.edu/jss/vol6/iss2/3/.

Ekern, David, and Joe Crossett. *Roles and Implications of Transportation Systems in Homeland Security*. American Association of State Highway and Transportation Officials, Special Committee on Transportation Security and Emergency Management. http://scotsem.transportation.org/Pages/default.aspx.

Embry-Riddle Aeronautical University. *Next Generation ERAU Applied Research*. 2014. http://daytonabeach.erau.edu/Assets/daytonabeach/forms/near-brochure-2014.pdf.

Estrada, Gilbert. *Brief History of the Ports of Los Angeles and Long Beach*. 2014. http://www.kcet.org/socal/departures/710-corridor/brief-history-of-the-ports-of-los-angeles-and-long-beach.html.

European Commission, ERTRAC-ERRAC-Waterborne-ACARE-ECTP Task Force. *Roadmap for Cross-Modal Transport Infrastructure Innovation towards a Performing Infrastructure: A Coordinated Approach to Addressing Cross-Modal Infrastructure Issues for an Integrated European Transport System*. June 30, 2013. http://www.ertrac.org/uploads/documentsearch/id2/joint-etp-task-force-roadmap_84.pdf.

European Commission, Management of Weather Events in the Transport System. *Cross-modal substitutability in European transport system to mitigate the impact of extreme weather and natural disasters*. 2014. http://www.mowe-it.eu/wordpress/wp-content/uploads/2013/02/D2-Cross-modal-substitutability.pdf.

European Union. *Roadmap for Cross-Modal Transport Infrastructure Innovation*. 2013. http://ec.europa.eu/eip/raw-materials/en/system/files/ged/87%2039D2769v1_ETP_Roadmap_-_Publisha.pdf.

Fausset, Richard. "Mexico's Lazaro Cardenas port thrives — with commerce and crime." *Los Angeles Times*, November 7, 2013. http://articles.latimes.com/2013/nov/07/world/la-fg-mexico-port-20131107.

Fawcett, James. "Chapter 10 – Port Governance and Privatization in the United States: Public Ownership and Private Operation." In *Devolution, Port Governance and Port Performance.* Ed. Mary Brooks and Kevin Cullinane. *Research in Transportation Economics* 17 (2007): 207–235. http://202.114.89.60/resource/pdf/2069.pdf.

FedEx. "FedEx Hub Network Map." http://www.fedex.com/us/smart-post/network.html.

Finucane, Melissa, et al. *The Hurricane Sandy Rebuilding Task Force's Infrastructure Resilience Guidelines: An Initial Assessment of Implementation by Federal Agencies*. RAND. 2014. http://www.rand.org/pubs/research_reports/RR841.html.

Flynn, Stephen E. *America the Vulnerable*. HarperCollins. 2004.

Flynn, Stephen E. *The Edge of Disaster: Rebuilding a Resilient Nation*. Random House. 2007.

Flynn, Stephen E., and Sean P. Burke. *Critical Transportation Infrastructure and Societal Resilience*. Center for National Policy. 2012. http://cnponline.org/wp-content/uploads/2014/04/Critical-Transportation-Infrastructure-and-Societal-Resilience.pdf.

Freedman, Andrew. "U.S. Airports Face Increasing Threat from Rising Seas." *Climate Central*. June 18, 2013. http://www.climatecentral.org/news/coastal-us-airports-face-increasing-threat-from-sea-level-rise-16126.

Giesecke, James et al. *Assessment of the Regional Economic Impacts of Catastrophic Events: CGE Analysis of Resource Loss and Behavioral Effects of an RDD Attack Scenario*. 2012. http://research.create.usc.edu/cgi/viewcontent.cgi?article=1201&context=published_papers.

Gulf Coast Research Center for Evacuation and Transportation Resiliency. *Resilient Transportation Systems in a Post-Disaster Environment: A Case Study of Opportunities Realized and Missed in the Greater New Orleans Region*. 2010. http://ntl.bts.gov/lib/43000/43700/43782/10-01.pdf.

Harding, Robin, Richard McGregor, and Gabriel Muller. "U.S. public investment falls to lowest level since war." *Financial Times.* November 3, 2013. http://www.ft.com/cms/s/0/f0e71a16-4487-11e3-a751-00144feabdc0.html#slide0.

Idaho National Laboratory. *Critical Infrastructure Interdependency Modeling: A Survey of U.S. and International Research*. 2006. https://inlportal.inl.gov/portal/server.pt/document/65202/critical_infrastructure_modeling_pdf .

Indiana Toll Road. "ITR Management." 2014. http://www.ezpassin.com/ceos-message-2/.

Intermodal Container Transfer Facility-Joint Powers Authority. "Fast Facts." http://www.ictf-jpa.org/fast_facts.php.

Jenkins, Brian Michael et al. *Potential Terrorist Uses of Highway-Borne Hazardous Materials*. Mineta Transportation Institute. 2010. http://transweb.sjsu.edu/MTIportal/research/publications/documents/2981-terrorist-uses-highway-borne-hazardous-materials.pdf.

John A. Volpe National Transportation Center. *Transportation System Resilience, Extreme Weather and Climate Change*. September 2014. http://ntl.bts.gov/lib/52000/52800/52855/Transportation_System_Resilience_Extreme_Weather_and_Climate_Change.pdf.

John A. Volpe National Transportation Systems Center. *Final Report: Beyond Bouncing Back*. 2013. http://www.volpe.dot.gov/events/final-report-beyond-bouncing-back.

John A. Volpe National Transportation Systems Center. *Infrastructure Resiliency: A Risk-Based Framework*. 2013. http://www.volpe.dot.gov/events/infrastructure-resiliency-risk-based-framework.

John A. Volpe National Transportation Systems Center. *Transit Security Design Considerations*. 2005. http://transit-safety.volpe.dot.gov/security/securityinitiatives/designconsiderations/CD/front.htm#toc.

Jones, D. et al. *Supply Chain Vulnerabilities and Potential Freight Flow Impacts of the 'ShakeOut Scenario' Earthquake*. Sandia National Laboratories. 2008.

Jung, J. et al. "International Trade Inoperability Input-Output Model (IT-IIM): Theory and Application." *Risk Analysis* 29, no. 1 (2009): 137-54. http://www.ncbi.nlm.nih.gov/pubmed/18808394.

Kelle, Peter and Mingzhou Jin. *Development of Performance Measurement for Freight Transportation*. NCITEC Project No 2012-34, January 2014. http://www.ncitec.msstate.edu/wp-content/uploads/2012-34FR.pdf.

Kramek, Joseph. *The Critical Infrastructure Gap: U.S. Port Facilities and Cyber Vulnerabilities*. Brookings. 2013. http://www.brookings.edu/~/media/research/files/papers/2013/07/02%20cyber%20port%20security%20kramek/03%20cyber%20port%20security%20kramek.pdf.

Laing, Keith. "Foxx: Obama transportation bill would boost 'local control'." The Hill. June 12, 2014. http://thehill.com/policy/transportation/209185-foxx-obama-transportation-bill-would-boost-local-control.

Lavigne, Grace M. "Port of Seattle to Modernize Terminal 5 for Mega-Ships." *JOC.com*, May 22, 2014. http://www.joc.com/port-news/us-ports/port-seattle/port-seattle-modernize-terminal-5-mega-ships_20140522.html.

Los Angeles County Metro. "System Maps." Section in "Maps & Timetables." http://www.metro.net/riding/maps/.

Los Angeles Department of Transportation Transit Services. "DASH" and "Commuter Express." http://www.ladottransit.com/.

Los Angeles Harbor Department. "Chapter 3.10 Transportation/Circulation." *Southern California International Gateway Project Final Environmental Impact Report (EIR)*. DRAFT. n.d. http://www.portoflosangeles.org/EIR/SCIG/FEIR/03_Modifications_SCIG_FEIR.pdf.

Los Angeles World Airports. "News and Facts." In "General Description." 2014. http://www.lawa.org/welcome_lax.aspx?id=40.

Madhusudan, C., and G. P. Ganapathy. "Disaster resilience of transportation infrastructure and ports – An overview." *International Journal of Geomatics and Geosciences* 2, no. 2 (2011). http://www.ipublishing.co.in/jggsvol1no12010/voltwo/EIJGGS3037.pdf.

Maritime Connector. *Panamax and New Panamax*. http://maritime-connector.com/wiki/panamax/.

Markovich, Steven J. "Transportation Infrastructure: Moving America." *Council on Foreign Relations.* 2014. http://www.cfr.org/infrastructure/transportation-infrastructure-moving-america/p18611.

Maryland Port Administration. *The Economic Impacts of the Port of Baltimore*. 2011. http://www.mpa.maryland.gov/_media/client/planning/2012/EconomicImpact.pdf.

Massachusetts Bay Transportation Authority. "T-Projects." http://www.mbta.com/about_the_mbta/t_projects/.

Matherly, Deborah, et al. *A Transportation Guide for All-Hazards Emergency Evacuation*. 2013. http://www.worldtransitresearch.info/research/4853/.

McKinsey Global Institute, *Infrastructure productivity: How to save $1 trillion a year. McKinsey & Company*. January 2013. http://www.mckinsey.com/~/media/mckinsey/dotcom/insights/engineering%20construction/infrastructure%20productivity/mgi%20infrastructure_full%20report_jan%202013.ashx.

Meade, Charles, and Roger C. Molander. *Considering the Effects of a Catastrophic Terrorist Attack*. RAND. 2006. http://www.rand.org/content/dam/rand/pubs/technical_reports/2006/RAND_TR391.pdf.

Memphis and Shelby County Port Commission. *The Economic Impact of the Port of Memphis on the Memphis Economy*. 2011. http://www.portofmemphis.com/vit_exec_summary.asp.

Meyer, Michael. *Transportation Congestion and Mobility: A Toolbox for Transportation Officials*. Institute of Transportation Engineers. 1996. http://www.fhwa.dot.gov/publications/research/operations/its/98436/toolbox.pdf.

Mills-Knapp, Sara et al. *Climate Change Adaptation and Sustainable Design at the Port Authority of New York & New Jersey*. 2011. http://www.earth.columbia.edu/sitefiles/file/education/capstone/Capstone_final_5_11_11_reduced.pdf.

Minnesota Department of Health. "May 6, 2012: Operation Medicine Delivery." http://www.health.state.mn.us/oep/postal.html.

Mongelluzzo, Bill. "Big ships build up LA-Long Beach." *JOC.com.* June 9, 2014. http://www.joc.com/port-news/us-ports/port-long-beach/big-ships-build-la-long-beach_20140609.html.

Mongelluzzo, Bill. "Profound Challenges Confront Seattle, Tacoma Ports." *JOC.com.* April 18, 2014. http://www.joc.com/port-news/us-ports/port-tacoma/profound-challenges-confront-seattle-tacoma-ports_20140418.html.

Mongelluzzo, Bill. "Vancouver penalty system cutting truck turn times." *JOC.com.* July 29, 2014. http://www.joc.com/port-news/international-ports/port-metro-vancouver/vancouver-penalty-system-cutting-truck-turn-times_20140729.html.

Mongelluzzo, Bill. "West Coast Ports Building — Overcapacity?" *JOC.com.* February 22, 2013. http://www.rcslogistics.com/wp-content/uploads/2013/02/West-Coast-Ports-Building-%E2%80%94-Overcapacity-2-24-13.pdf.

Moving Ahead For Progress in the 21st Century Act. Pub. L. No. 112-141, 126 Stat. 405. July 6, 2012.

Murphy, John. Presentation on NPPD Office of Cyber and Infrastructure Analysis at Virginia Tech. October 9, 2014. http://ncr.vt.edu/research/presentation/VA_Tech_Leadership_Seminar.pdf.

Nagle, Kurt J. Kurt J. Nagel to David V. Aguilar, Thomas S. Winkowski, and David T. Matsuda, March 25, 2013. From the American Association of Port Authorities. http://www.aapa-ports.org/files/David%20Aguilar,%20Thomas%20Winkowski,%20David%20Matsuda%20-%20re%20Jones%20Act.pdf.

Narayan, Chandrika, Ted Rowlands, and Ralph Ellis. "Air travel still hobbled after Chicago fire." *CNN.* September 29, 2014. http://www.cnn.com/2014/09/28/travel/chicago-ohare-midway-flights-stopped/.

National Academies. *Disaster Resilience: A National Imperative*. 2012. http://nas-sites.org/resilience/disaster-resilience-report/.

National Association of Manufacturers. Testimony from 2/25/15 Hearing from Tom Riordan. 2015. http://www.shopfloor.org/2015/02/manufacturing-leader-underscores-importance-of-upgraded-infrastructure-and-map-21-reauthorization/33246.

National Association of Manufacturers and the National Retail Federation. *The National Impact of a West Coast Port Stoppage*. June 2014. https://nrf.com/sites/default/files/Port%20Closure%20Full%20Report.pdf.

National Center for Intermodal Transportation for Economic Competitiveness. "Projects." http://www.ncitec.msstate.edu/research/projects/.

National Economic Council and the President's Council of Advisers. *An Economic Analysis of Transportation Infrastructure Investment.* July 2014. https://www.whitehouse.gov/sites/default/files/docs/economic_analysis_of_transportation_investments.pdf.

National Freight Advisory Committee. *Recommendations to U.S. Department of Transportation for the Development of the National Freight Strategic Plan*. 2014. http://www.dot.gov/sites/dot.gov/files/docs/NFAC%20Task%201-Recommendations%20for%20NFSP-Final(6-12-14).pdf.

National Infrastructure Advisory Council. *A Framework for Establishing Critical Infrastructure Resilience Goals (for Electric and Nuclear Sectors)*. 2010. http://www.dhs.gov/sites/default/files/publications/niac-framework-establishing-resilience-goals-final-report-10-19-10-508.pdf.

National Infrastructure Advisory Council. *Chemical, Biological, and Radiological Events and the Critical Infrastructure Workforce*. 2008. http://www.dhs.gov/sites/default/files/publications/niac-chemical-biological-radiological-final-report-01-08-08-508.pdf.

National Infrastructure Advisory Council. *Convergence of Physical and Cyber Technologies and Related Security Management Challenges*. 2007. http://www.dhs.gov/sites/default/files/publications/niac-physical-cyber-final-report-01-16-07-508.pdf.

National Infrastructure Advisory Council. *Critical Infrastructure Partnership Strategic Assessment*. 2008. http://www.dhs.gov/sites/default/files/publications/niac-ci-partnership-assessment-final-report-10-14-08-508.pdf.

National Infrastructure Advisory Council. *Critical Infrastructure Security and Resilience National Research and Development Plan*. 2014. http://www.dhs.gov/sites/default/files/publications/NIAC-CISR-RD-Plan-Report-Final-508.pdf.

National Infrastructure Advisory Council. *Critical Infrastructure Resilience*. 2009. http://www.dhs.gov/sites/default/files/publications/niac-critical-infrastructure-resilience-final-report-09-08-09-508.pdf.

National Infrastructure Advisory Council. *Cross Sector Interdependencies and Risk Assessment Guidance*. 2004. http://www.dhs.gov/sites/default/files/publications/niac-interdependencies-risk-assess-final-report-01-13-04-508.pdf.

National Infrastructure Advisory Council. *Framework for Dealing with Disasters and Related Interdependencies*. 2009. http://www.dhs.gov/sites/default/files/publications/niac-framework-dealing-disasters-final-report-07-14-09-508.pdf.

National Infrastructure Advisory Council. *Implementation of EO 13636 and PPD-21*. 2013. http://www.dhs.gov/sites/default/files/publications/niac-eo-ppd-implem-final-report-11-21-13-508.pdf.

National Infrastructure Advisory Council. *Intelligence Information Sharing*. 2012. http://www.dhs.gov/sites/default/files/publications/niac-intel-info-sharing-final-report-01-10-12-508.pdf.

National Infrastructure Advisory Council. *Optimization of Resources for Mitigating Infrastructure Disruptions Study*. 2010. http://www.dhs.gov/sites/default/files/publications/niac-optimization-resources-final-report-10-19-10-508.pdf.

National Infrastructure Advisory Council. *Prioritizing Cyber Vulnerabilities*. 2004. http://www.dhs.gov/sites/default/files/publications/niac-cyber-vulnerabilties-final-report-10-12-04-508.pdf.

National Infrastructure Advisory Council. *Public-Private Intelligence Coordination*. 2006. http://www.dhs.gov/sites/default/files/publications/niac-intelligence-coordination-final-report-07-11-06-508.pdf.

National Infrastructure Advisory Council. *Strengthening Regional Resilience*. 2013. http://www.dhs.gov/sites/default/files/publications/niac-regional-resilience-final-report-11-21-13-508.pdf.

National Infrastructure Advisory Council. *The Prioritization of Critical Infrastructure for a Pandemic Outbreak in the United States Working Group*. 2007. http://www.dhs.gov/sites/default/files/publications/niac-pandemic-outbreak-final-report-01-17-07-508.pdf.

National Institute of Standards and Technology. *Developing Guidelines and Standards for Disaster Resilience of the Built Environment: A Research Needs Assessment*. 2013. http://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.1795.pdf.

National Institute of Standards and Technology. *Framework for Improving Critical Infrastructure Cybersecurity*. 2014. http://www.nist.gov/cyberframework/upload/cybersecurity-framework-021214-final.pdf.

National Surface Transportation Policy and Revenue Study Commission. *Transportation for Tomorrow Final Report—Volume III: Section 6, Submissions Sponsored by Commissioners*. September 2007. http://transportationfortomorrow.com/final_report/volume_3_html/06_submissions_commissioners/contentd76e.htm?name=04_rose.

New York State 2100 Commission. *Recommendations to Improve the Strength and Resilience of the Empire state's Infrastructure*. 2013. http://www.governor.ny.gov/assets/documents/NYS2100.pdf.

Omer, Mayada. *The Resilience of Networked Infrastructure Systems*. World Scientific. 2013. Available through: http://www.worldscientific.com/worldscibooks/10.1142/8741.

Organization for Economic Co-operation and Development. *The Competitiveness of Global Port-Cities: Synthesis Report*. 2011. http://www.oecd.org/gov/regional-policy/Competitiveness-of-Global-Port-Cities-Synthesis-Report.pdf.

Orseno, Don. "Metra memo from CEO/Executive Director Don Orseno." June 17, 2015. http://metrarail.com/content/dam/metra/documents/Board_Information/2015/June/Item%2016%20-%20Legislative%20Update%20for%20May.pdf.

Ken Orski, "The Changing Nature of State-Federal Relations in Transportation," *Innovation Newsbriefs* 25, no.11 (2014). http://www.infrastructureusa.org/the-changing-nature-of-state-federal-relations-in-transportation.

Orski, Ken. "Needed: A Fresh Approach to Funding America's Infrastructure." *GovTech.* February 20, 2015. http://www.govtech.com/fs/Needed-A-Fresh-Approach-to-Funding-Americas-Infrastructure.html.

Pacific Maritime Association. *2013 Annual Report*. 2013. http://pma.uberflip.com/i/277369.

Park, J. Y. "The Economic Impacts of Dirty Bomb Attacks on the Los Angeles and Long Beach Ports: Applying the Supply-Driven NIEMO (National Interstate Economic Model)." *Journal of Homeland Security and Emergency Management* 5, no. 1 (2008). http://research.create.usc.edu/cgi/viewcontent.cgi?article=1077&context=nonpublished_reports.

Park, J. Y. et al. "The State-By-State Economic Impacts of the 2002 Shutdown of the Los Angeles- Long Beach Ports." *Growth and Change* 39, no. 4 (2008). http://research.create.usc.edu/cgi/viewcontent.cgi?article=1073&context=nonpublished_reports.

Park, J. Y. et al. *The Economic Costs and Consequences of Terrorism*. Edward Elgar. 2007. http://www-bcf.usc.edu/~pgordon/pdf/200512attackports.pdf.

Perry, Martina. "Port of Prince Rupert hits another tonnage record in 2013." *Northern View*. January 2014. http://www.thenorthernview.com/business/239695391.html.

Petit, F. D. et al. *Resilience Measurement Index: An Indicator of Critical Infrastructure Resilience*. Argonne National Laboratory. 2013. http://www.ipd.anl.gov/anlpubs/2013/07/76797.pdf.

Pew Charitable Trusts. "Funding Challenges in Highway and Transit: A federal-state-local analysis." February 24, 2015. http://www.pewtrusts.org/en/research-and-analysis/analysis/2015/02/24/funding-challenges-in-highway-and-transit-a-federal-state-local-analysis.

POLITICO. "Morning Transportation." June 15, 2015. http://www.politico.com/morningtransportation/.

Port Authority of New York and New Jersey. Homepage. http://www.panynj.gov/.

Port Metro Vancouver. *Land Use Plan*. Draft. December 2013. http://www.portmetrovancouver.com/docs/default-source/planning-land-use-plan/4501-pmv-lup-wireframe-v26.pdf.

Port of Hueneme. Homepage. http://www.portofhueneme.org/home.php.

Port of Long Beach. "Clean Trucks Program: Report of May 2014." http://www.polb.com/civica/filebank/blobdload.asp?BlobID=6591.

Port of Long Beach. "Facts at a Glance." http://www.polb.com/about/facts.asp.

Port of Long Beach. "FAQs." http://www.polb.com/about/faqs.asp.

Port of Long Beach. "Liquid Bulk." http://www.polb.com/economics/cargotenant/liquid/default.asp.

Port of Long Beach. "Port Security." http://www.polb.com/about/security/default.asp.

Port of Long Beach. "Rail Guide." http://www.polb100.com/publications/railguide/index.html.

Port of Long Beach. "Trade/Commerce." http://www.polb.com/economics/default.asp

Port of Long Beach. "Trade/Commerce." http://www.polb.com/economics/default.asp.

Port of Los Angeles. "A Profile of the Port of Los Angeles." http://www.portoflosangeles.org/about/profile.asp.

Port of Los Angeles. "About the Port: Facts and Figures." 2014. http://www.portoflosangeles.org/pdf/POLA_Facts_and_Figures_Card.pdf.

Port of Los Angeles. "Appendix D3: Southern California Petroleum Market Assessment." In *Pacific L.A. Marine Terminal LLC Crude Oil Terminal Draft SEIS/SEIR*. May 2008. http://www.portoflosangeles.org/EIR/PacificLAMarine/SEIR/Appendix_D3_Southern_CA_Petroleum_Market_Assessment.pdf.

Port of Los Angeles. "BCG Clean Truck Program Analysis." 2008. http://www.portoflosangeles.org/ctp/idx_ctp.asp.

Port of Los Angeles. "CA-103 Commodore Schuyler F. Heim/Henry Ford Bridge." http://www.portoflosangeles.org/transportation/ca_103.asp.

Port of Los Angeles. "Cybersecurity Tabletop Exercise After-action Report/Improvement Plan." August 2014. Redacted.

Port of Los Angeles. "Goods Movement." http://www.portoflosangeles.org/maritime/good_movements.asp.

Port of Los Angeles. "Intermodal Container Transfer Facility (ICTF) (Near-dock)." Section in "Rail & Intermodal Yards." http://www.portoflosangeles.org/facilities/rail_intermodal_yards.asp.

Port of Los Angeles. "Intermodal Traffic Control." Section in "Rail & Intermodal Yards." http://www.portoflosangeles.org/facilities/rail_intermodal_yards.asp.

Port of Los Angeles. "Liquid Bulk Facilities." http://www.portoflosangeles.org/facilities/liquid_bulk.asp.

Port of Los Angeles. "Overview of Public Trust Doctrine." http://www.portoflosangeles.org/about/publictrust.asp.

Port of Los Angeles. "Rail & Intermodal Yards." http://www.portoflosangeles.org/facilities/rail_intermodal_yards.asp.

Port of Los Angeles. "San Pedro Bay Ports Clean Truck Program: CTP options analysis." March 2008. http://www.portoflosangeles.org/ctp/CTP_Analysis.pdf.

Port of Los Angeles. "Security." http://www.portoflosangeles.org/idx_security.asp.

Port of Los Angeles. "Southern California Petroleum Market Assessment." 2008. http://www.portoflosangeles.org/EIR/PacificLAMarine/SEIR/Appendix_D3_Southern_CA_Petroleum_Market_Assessment.pdf.

Port of Los Angeles. "Transportation." http://www.portoflosangeles.org/EIR/SCIG/DEIR/03.10.Transportation.pdf.

Port of Los Angeles. "Waterfront Red Car Line." http://www.portoflosangeles.org/recreation/waterfront_rcl.asp.

Port of Oakland. "Fact & Figures." http://www.portofoakland.com/maritime/factsfigures.aspx.

Port of Portland. "Columbia River Forecast." http://www.portofportland.com/Nvgt_Rvr_Frcst.aspx.

Port of Portland. "Port of Portland Marine Terminal Statistics, 1983 – 2013." http://www.portofportland.com/SelfPost/A_20141221618 38AnnualHistoryfrom1978web.pdf.

Port of Prince Rupert. "Facilities." http://www.rupertport.com/facilities.

Port of Seattle. "2013 Foreign Waterborne Trade Report." http://www.portseattle.org/About/Publications/Statistics/Seaport/Documents/Summary_Foreign_Waterborne_Trade.pdf.

Port of Tacoma. "Facilities & Services: 2014 Summary." http://portoftacoma.com/sites/default/files/FacilityAndServiceGuide-Oct2013.pdf.

Porter, Keith. *The ShakeOut Scenario: A Hypothetical Mw7.8 Earthquake on the Southern San Andreas Fault*. 2011. http://research.create.usc.edu/cgi/viewcontent.cgi?article=1189&context=published_papers.

PwC. "Interview with Pat Foye: In preparing for disasters, don't fight the last war." http://www.pwc.com/gx/en/capital-projects-infrastructure/disaster-resilience/airport-resilience.jhtml.

Reilly, Sean. "As punctuality plummets, Amtrak confronts freight in Supreme Court battle." *Greenwire*. October 31, 2014. http://www.eenews.net/greenwire/stories/1060008220/print.

Rodrigue, Jean-Paul et al. "The Economic Importance of Transportation." In *The Geography of Transport Systems*. Hofstra University. 2013. https://people.hofstra.edu/geotrans/eng/gallery/Geography%20of%20Transport%20Systems_1ed.pdf.

Rodrigue, Jean-Paul et al. "The Financing of Transportation Infrastructure." In *The Geography of Transport Systems*. Hofstra University. 2013. http://people.hofstra.edu/geotrans/eng/ch7en/appl7en/ch7a2en.html.

Rosati, Julie Dean. *Method to Assess Resilience of the Marine Transportation System*. U.S. Army Corps of Engineers. 2014. PowerPoint presentation provided to the National Infrastructure Advisory Council.

Rosati, Julie Dean, contributor. *Coastal Modeling System: Mathematical Formulations and Numerical Methods*. USACE. 2014. Available at: http://www.researchgate.net/profile/Julie_Rosati/publications.

Rose, A., and D. Wei. "Estimating the Economic Consequences of a Port Shutdown: The Special Role of Resilience." *Economic Systems Research* 25, no. 2 (2012). http://research.create.usc.edu/cgi/viewcontent.cgi?article=1203&context=published_papers.

Rosoff, H., and D. von Winterfeldt. "A Risk and Economic Analysis of Dirty Bomb Attacks on the Ports of Los Angeles and Long Beach." *Risk Analysis* 27, no. 3 (2007). http://research.create.usc.edu/cgi/viewcontent.cgi?article=1051&context=published_papers.

San Francisco Bay Conservation and Development Commission. *Transportation and the San Francisco Bay*. 2005. http://www.bcdc.ca.gov/pdf/planning/reports/transportation.pdf.

Schaper, David. "U.S., Canada Announce New Safety Standards for Oil Trains." NPR. May 1, 2015. http://www.npr.org/2015/05/01/403597786/transportation-officials-announce-tough-standards-for-railcars-carrying-oil.

Schultz, Martin T. et al. *The Quantification and Evolution of Resilience in Integrated Coastal Systems*. U.S. Army Corps of Engineers. 2012. http://el.erdc.usace.army.mil/elpubs/pdf/tr12-7.pdf.

Schwartz, Bernard. "Remarks Prepared for Delivery by Bernard L. Schwartz at Third Way & The Atlantic's Infrastructure 2.0 Panel." Washington, D.C. September 30, 2013. http://perspectives.thirdway.org/?p=3152.

Seaport Outlook. *Port, Airport & Global Infrastructure Research*. 2014. http://www.us.jll.com/united-states/en-us/Research/PAGI-Seaport-JLL-2014.pdf.

Sheridan, John. "Future of Air Navigation: Resilience to Vulnerability." *Aviation International News*. May 2014. http://www.ainonline.com/aviation-news/aviation-international-news/2014-05-02/future-air-navigation-resilience-vulnerability.

Sherman, Rexford. *Seaport Governance in the United States and Canada*. American Association of Port Authorities. http://www.aapa-ports.org/files/pdfs/governance_uscan.pdf.

Skyway Concession Company, LLC. "Chicago Skyway." 2005. http://www.chicagoskyway.org/.

Smythe, Tiffany C. *Assessing the Impacts of Hurricane Sandy on the Port of New York and New Jersey's Maritime Responders and Response Infrastructure*. 2013. http://www.colorado.edu/hazards/research/qr/submitted/smythe_2013.pdf.

Southeastern Pennsylvania Transportation Authority. *Revenue & Ridership Report: SEPTA Revenue & Ridership Management*. 2014. www.septa.org/reports/pdf/revenue-ride.pdf.

Surface Transportation and Public Transportation Information Sharing and Analysis Centers. Homepage. https://www.surfacetransportationisac.org/.

Tate, Curtis. "More oil spilled from trains in 2013 than in previous 4 decades, federal data show," McClatchy Washington Bureau. January 20, 2014. http://www.mcclatchydc.com/2014/01/20/215143/more-oil-spilled-from-trains-in.html.

Tioga. *Container Port Capacity and Utilization Metrics*. June 2012. http://onlinepubs.trb.org/onlinepubs/conferences/2012/Metrics/presentations/5-Smith.pdf.

Transportation Research Board. *Data and Statistics for Valuing Transportation Infrastructure and Transportation's Contribution to the Economy*. Workshop. July 2014. http://onlinepubs.trb.org/onlinepubs/circulars/ec192.pdf.

Transportation Research Board. *A Guide to Emergency Response Planning at state Transportation Agencies*. 2010. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_525v16.pdf.

Transportation Research Board. *Airport Climate Adaption and Resilience*. 2012. http://www.mowe-it.eu/wordpress/wp-content/docs/general/TRB_2012AirportClimateAdaptationResilience.pdf.

Transportation Research Board. *Climate Change Risk Assessment and Adaptation Planning at Airports*. 2014. http://rip.trb.org/view/2014/P/1335321.

Transportation Research Board. *Climate Change, Extreme Weather Events, and the Highway System: Practitioner's Guide and Research Report*. 2014. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_750v2.pdf.

Transportation Research Board. *FloodCast: A Framework for Enhanced Flood Event Decision Making for Transportation Resilience*. 2014. http://rip.trb.org/view/2014/P/1331583.

Transportation Research Board. *Lessons from Hurricane Sandy for Port Resilience*. 2013. http://rip.trb.org/view/2013/P/1234681.

Transportation Research Board. *Making U.S. Ports Resilient as Part of Extended Intermodal Supply Chains*. 2014. http://www.as-w.com/wp-content/uploads/ncfrp_rpt_030.pdf.

Transportation Research Board. *Methodologies to Estimate the Economic Impacts of Disruptions to the Goods Movement System*. 2012. http://www.trb.org/Main/Blurbs/167969.aspx.

Transportation Research Board. *Potential Impacts of Climate Change on U.S. Transportation*. 2008. http://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf .

Transportation Research Board. *Public and Private Sector Interdependencies in Freight Transportation Markets*. NCRFP Report 1. 2009. http://onlinepubs.trb.org/onlinepubs/ncfrp/ncfrp_rpt_001.pdf.

Transportation Research Board. *Traffic Capacity, Intermodal Transportation, Freight Transportation*. 2013. http://rip.trb.org/view/2013/P/1264094.

Transportation Research Board. *TRB and Resilience*. January 2015. http://onlinepubs.trb.org/onlinepubs/dva/securityactivities.pdf.

Transportation Research Board. *The Marine Transportation System and the Federal Role: Measuring Performance, Targeting Improvement*. 2004. http://www.cmts.gov/downloads/TRB_279_Report.pdf.

Urban Land Institute and Ernst & Young. *Infrastructure 2013: Global Priorities, Global Insights*. 2013. http://uli.org/wp-content/uploads/ULI-Documents/Infrastructure-2013.pdf.

U.S. Army Corps of Engineers, Institute for Water Resources. *U.S. Port and Inland Waterways Modernization: Preparing for Post-Panamax Vessels*. 2012. http://www.iwr.usace.army.mil/Portals/70/docs/portswaterways/rpt/June_20_U.S._Port_and_Inland_Waterways_Preparing_for_Post_Panamax_Vessels.pdf.

U.S. Army Corps of Engineers. *North Atlantic Coast Comprehensive Study Report and Related Documents*. 2015. http://www.nad.usace.army.mil/CompStudy.aspx.

U.S. Census Bureau. "Population Clock." http://www.census.gov/popclock/.

U.S. Coast Guard Houston-Galveston Vessel Traffic Service. *VTS Houston/Galveston: A Brief History*. 2014. http://www.uscg.mil/vtshouston/docs/history.pdf.

U.S. Coast Guard Navigation Center. *Port Risk Assessment for Philadelphia*. 2003. http://www.navcen.uscg.gov/pdf/pawsa/workshopReports/Philadelphia.pdf.

U.S. Coast Guard Office of Waterways Management. *Ports and Waterways Safety Assessment Workshop Report*. 2009. http://www.uscg.mil/vtshouston/docs/PAWSA%20HG%20Workshop%20report%2021%20September%202009.pdf.

U.S. Coast Guard. *Executive Order 13636 – Improving Critical Infrastructure Cybersecurity Section 10(a) and 10(b) Report on the United States Coast Guard and Maritime Critical Infrastructure Cyber Security Standards*. 2013. http://www.dhs.gov/sites/default/files/publications/EO%2013636%20Section%2010%28a_b%29%20Report%20for%20USCG_Final.pdf.

U.S. Coast Guard. *Synopsis of Resilience in Coast Guard Activities*. Presentation to the National Infrastructure Advisory Council by a U.S. Coast Guard representative. May 20, 2014.

U.S. Committee on the Maritime Transportation System. Federal Funding Handbook for MTS Infrastructure, 2013. http://www.cmts.gov/downloads/MTS_Funding_Handbook_(Final).pdf.

U.S. Congress, House of Representatives. Transportation Committee. Testimony by Dana A. Goward to House Subcommittee on Coast Guard and Marine Transportation, Hearing on "Finding Your Way – the Future of Federal Aids to Navigation," February 4, 2014. http://transportation.house.gov/uploadedfiles/2014-02-04-goward.pdf.

U.S. Congress, Senate. Testimony by Jayan Dhru to the Committee on Finance, Hearing on "New Routes for Funding and Financing Highways and Transit: Hearing Before the Committee on Finance, United States Senate," May 6, 2014. http://www.finance.senate.gov/imo/media/doc/Dhru%20Testimony.pdf.

U.S. Congress, Senate. Testimony by Chris Edwards to the Committee on Finance, Hearing on "America's Crumbling Infrastructure and How to Fix It," July 24, 2013. http://www.cato.org/publications/testimony/encouraging-private-infrastructure-investment.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service. "What percentage of the American population lives near the coast?" http://oceanservice.noaa.gov/facts/population.html.

U.S. Department of Energy. *Climate Change and Infrastructure, Urban Systems, and Vulnerabilities*. 2014. http://www.eenews.net/assets/2014/03/06/document_cw_01.pdf.

U.S. Department of Energy. *Electricity Subsector Cybersecurity Capability Maturity Model (ES-C2M2)*. 2012. http://energy.gov/sites/prod/files/Electricity%20Subsector%20Cybersecurity%20Capabilities%20Maturity%20Model%20(ES-C2M2)%20-%20May%202012.pdf.

U.S. Department of Energy. *The Smart Grid: An Introduction*. 2008. http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/DOE_SG_Book_Single_Pages%281%29.pdf.

U.S. Department of Homeland Security, Federal Emergency Management Agency. "Critical Infrastructure Resource Center: Postal and Shipping." http://training.fema.gov/EMIWeb/IS/IS860b/CIRC/postal1.htm.

U.S. Department of Homeland Security, Federal Emergency Management Agency. *Crisis Response and Disaster Resilience 2030: Forging Strategic Action in an Age of Uncertainty*. January 2012. http://www.fema.gov/media-library-data/20130726-1816-25045-5167/sfi_report_13.jan.2012_final.docx.pdf.

U.S. Department of Homeland Security, Federal Emergency Management Agency. "Federal Insurance & Mitigation Administration Programs." https://www.fema.gov/what-mitigation/federal-insurance-mitigation-administration#4.

U.S. Department of Homeland Security, Federal Emergency Management Agency. "Incident Command System Resources." https://www.fema.gov/national-incident-management-system/incident-command-system-resources.

U.S. Department of Homeland Security, Federal Emergency Management Agency. *Inventory of Lifelines in the Cajon Pass, California*. February 1, 1992. http://www.fema.gov/media-library-data/20130726-1514-20490-7673/fema_225.pdf.

U.S. Department of Homeland Security, Federal Emergency Management Agency. "National Incident Management System." https://www.fema.gov/national-incident-management-system.

U.S. Department of Homeland Security, Federal Emergency Management System. *National Incident Management System (NIMS) Incident Command System (ICS) Forms Booklet, FEMA 502-2*. http://www.fema.gov/media-library-data/20130726-1922-25045-7047/ics_forms_12_7_10.pdf.

U.S. Department of Homeland Security, Federal Emergency Management Agency. "National Planning Frameworks." https://www.fema.gov/national-planning-frameworks.

U.S. Department of Homeland Security, Federal Emergency Management Agency. *National Preparedness Goal*. 2011. http://www.fema.gov/media-library-data/20130726-1828-25045-9470/national_preparedness_goal_2011.pdf.

U.S. Department of Homeland Security, Federal Emergency Management Agency. *National Strategy for Recommendations: Future Disaster Preparedness*. September 6, 2013. http://www.fema.gov/media-library-data/bd125e67fb2bd37f8d609cbd71b835ae/FEMA%20National%20Strategy%20Recommendations%20(V4).pdf.

U.S. Department of Homeland Security, Federal Emergency Management Agency. *The Stafford Act: Robert T. Stafford Disaster Relief and Emergency Assistance Act, as amended, Pub. L. 93-288*. April 2013. http://www.fema.gov/media-library-data/1383153669955-21f970b19e8eaa67087b7da9f4af706e/stafford_act_booklet_042213_508e.pdf.

U.S. Department of Homeland Security, Federal Emergency Management Agency. "Strategic Foresight Initiative." https://www.fema.gov/strategic-planning-analysis-spa-division/strategic-foresight-initiative.

U.S. Department of Homeland Security, Infrastructure Information Collection Division. *Infrastructure Taxonomy*. 2008. http://www.hsdl.org/?view&did=14605.

U.S. Department of Homeland Security, Office of Cyber and Infrastructure Analysis. *National Risk Estimate: Aging and Failing Critical Infrastructure Systems*. December 2014.

U.S. Department of Homeland Security, Science and Technology Directorate. "Visionary Goals." http://www.dhs.gov/science-and-technology/visionary-goals.

U.S. Department of Homeland Security, Transportation Security Administration. "Commercial Airlines." http://www.tsa.gov/stakeholders/commercial-airlines.

U.S. Department of Homeland Security, Transportation Security Administration. "Cross Modal." http://www.tsa.gov/stakeholders/cross-modal.

U.S. Department of Homeland Security, Transportation Security Administration. "Ensuring Security and Resiliency in the Postal and Shipping Sector." PowerPoint presentation. April 2012. http://npf.org/pdfs/presentations/2012/EnsuringtheSecurity-ResiliencyofthePostalandShippingSector.pdf.

U.S. Department of Homeland Security, Transportation Security Administration. "Intermodal Transportation Systems." http://www.tsa.gov/stakeholders/intermodal-transportation-systems.

U.S. Department of Homeland Security, Transportation Security Administration. "Partnerships and Collaboration: Highway and Motor Carrier Branch." August 6, 2014.

http://www.tsa.gov/stakeholders/partnerships-and-collaborations/highway-motor-carrier-branch.

U.S. Department of Homeland Security, Transportation Security Administration. "Pipeline Security." August 18, 2014. http://www.tsa.gov/stakeholders/pipeline-security.

U.S. Department of Homeland Security, Transportation Security Administration, Office of Security Policy and Industry Engagement. *Highway and Motor Carrier Branch 2012 Annual Report*. 2012. http://www.tsa.gov/sites/default/files/publications/pdf/stakeholders_PDF/final_2012_annual_report.pdf.

U.S. Department of Homeland Security. "About the National Cybersecurity and Communications Integration Center." http://www.dhs.gov/about-national-cybersecurity-communications-integration-center.

U.S. Department of Homeland Security. "Critical Infrastructure Partnership Advisory Council." Homepage. http://www.dhs.gov/critical-infrastructure-partnership-advisory-council.

U.S. Department of Homeland Security. "DHS Announces New International Trade Crossing." February 18, 2015. http://www.dhs.gov/news/2015/02/18/dhs-announces-new-international-trade-crossing-0.

U.S. Department of Homeland Security. "Evaluating Port Security: Progress Made and Challenges Ahead." Written testimony for Senate Committee on Homeland Security and Governmental Affairs Hearing. June 4, 2014. http://www.dhs.gov/news/2014/06/04/written-testimony-plcy-uscg-cbp-tsa-fema-senate-committee-homeland-security-and.

U.S. Department of Homeland Security. "Regional Resiliency Assessment Program." Homepage. http://www.dhs.gov/regional-resiliency-assessment-program.

U.S. Department of Homeland Security. "Science & Technology Directorate Centers of Excellence." 2014. http://www.dhs.gov/st-centers-excellence.

U.S. Department of Homeland Security. "Transportation Systems Sector." http://www.dhs.gov/transportation-systems-sector.

U.S. Department of Homeland Security. *Budget-in-Brief: Fiscal Year 2014*. 2014. http://www.dhs.gov/sites/default/files/publications/MGMT/FY%202014%20BIB%20-%20FINAL%20-508%20Formatted%20(4).pdf.

U.S. Department of Homeland Security. *CIPAC Annual*. 2012. http://www.dhs.gov/sites/default/files/publications/cipac-%202012-final-508-%20compliant-%20version.pdf.

U.S. Department of Homeland Security. N*ational Infrastructure Protection Plan*. 2006. http://www.dhs.gov/xlibrary/assets/NIPP_Plan_noApps.pdf.

U.S. Department of Homeland Security. *National Infrastructure Protection Plan: Partnering to enhance protection and resiliency*. 2009. http://www.dhs.gov/xlibrary/assets/NIPP_Plan.pdf.

U.S. Department of Homeland Security. *National Infrastructure Protection Plan: Postal and Shipping Sector*. 2011. http://www.dhs.gov/xlibrary/assets/nppd/nppd-ip-postal-and-shipping-snapshot-2011.pdf.

U.S. Department of Homeland Security. *NIPP 2013: Partnering for Critical Infrastructure Security and Resilience*. 2013. http://www.dhs.gov/sites/default/files/publications/NIPP%202013_Partnering%20for%20Critical%20Infrastructure%20Security%20and%20Resilience_508_0.pdf.

U.S. Department of Homeland Security. *Results of Fiscal Year 2014 Research and Development. Fiscal Year 2015 Report to Congress*. February 2, 2015. http://www.dhs.gov/sites/default/files/publications/st/FY14%20Research%20and%20Development%20Accomplishments-508.pdf.

U.S. Department of Homeland Security. *Roadmap to Secure Control Systems in the Transportation Sector*. 2012. https://ics-cert.us-cert.gov/sites/default/files/ICSJWG-Archive/TransportationRoadmap20120831.pdf.

U.S. Department of Homeland Security. *Transportation Systems Sector-Specific Plan*. 2010. http://www.dhs.gov/xlibrary/assets/nipp-ssp-transportation-systems-2010.pdf.

U.S. Department of the Treasury and Council of Economic Advisors. "A New Economic Analysis of Infrastructure Investment." 2012. http://www.treasury.gov/resource-center/economic-policy/Documents/20120323InfrastructureReport.pdf.

U.S. Department of Transportation, Bureau of Transportation Statistics. *Passenger Travel Facts and Figures*. 2014. http://www.rita.dot.gov/bts/publications/passenger_travel.

U.S. Department of Transportation, Bureau of Transportation Statistics. *2015 Pocket Guide to Transportation*. 2015. http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/pocket_guide_to_transportation/2015.

U.S. Department of Transportation, Bureau of Transportation Statistics. *Multimodal Transportation Indicators*. October 2014. http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/entire_10_2014.pdf.

U.S. Department of Transportation, Bureau of Transportation Statistics. "Table 1-14: U.S. Automobile and Truck Fleets by Use (Thousands)." http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_01_14.html_mfd.

U.S. Department of Transportation, Bureau of Transportation Statistics. *Intermodal Transportation Database*. http://www.rita.dot.gov/bts/data_and_statistics/intermodal_transportation_database.html.

U.S. Department of Transportation, Bureau of Transportation Statistics. *Transportation Statistics Annual Report 2013*. http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/TSAR_2013.pdf.

U.S. Department of Transportation, Federal Aviation Administration. "NextGen Update 2014." 2014. https://www.faa.gov/nextgen/media/NextGenUpdate2014.pdf.

U.S. Department of Transportation, Federal Aviation Administration. "Commercial Service Airports, based on Calendar Year 2013 Enplanements." September 29, 2014. http://www.faa.gov/airports/planning_capacity/passenger_allcargo_stats/passenger/media/cy13-commercial-service-enplanements.pdf.

U.S. Department of Transportation, Federal Aviation Administration. *General Aviation Airports: A National Asset*. 2012. http://www.faa.gov/airports/planning_capacity/ga_study/media/2012AssetReport.pdf.

U.S. Department of Transportation, Federal Aviation Administration. *Destination 2025*. n.d. https://www.faa.gov/about/plans_reports/media/Destination2025.pdf.

U.S. Department of Transportation, Federal Highway Administration. "Climate Change Resilience Pilots." June 11, 2015. http://www.fhwa.dot.gov/environment/climate_change/adaptation/ongoing_and_current_research/vulnerability_assessment_pilots/index.cfm.

U.S. Department of Transportation, Federal Highway Administration. "Motor Fuel Data and the Highway Trust Fund." http://www.fhwa.dot.gov/policyinformation/motorfueldata.cfm.

U.S. Department of Transportation, Federal Highway Administration. "Moving Ahead for Progress in the 21st Century Act (MAP-21): A Summary of Highway Provisions." July 17, 2012. https://www.fhwa.dot.gov/map21/summaryinfo.cfm.

U.S. Department of Transportation, Federal Highway Administration. "Fact Sheets." *Moving Ahead for Progress in the 21st Century Act (MAP-21)*.https://www.fhwa.dot.gov/map21/factsheets/.

U.S. Department of Transportation, Federal Highway Administration. *FHWA National Gateways and Corridors Concepts*. 2013. http://www.fhwa.dot.gov/planning/border_planning/gateways_and_corridors/gateway_ops/gtwy.pdf.

U.S. Department of Transportation, Federal Highway Administration. "Status of the Highway Trust Fund." http://www.fhwa.dot.gov/highwaytrustfund/index.htm.

U.S. Department of Transportation, Federal Highway Administration. "Summary of FHWA Climate Adaptation Initiatives." March 27, 2014. http://www.fhwa.dot.gov/environment/climate_change/adaptation/ongoing_and_current_research/summary/index.cfm.

U.S. Department of Transportation, Federal Highway Administration. "Intermodal Connectors." http://www.fhwa.dot.gov/planning/national_highway_system/intermodal_connectors/.

U.S. Department of Transportation, Federal Highway Administration. *FHWA National Gateways and Corridors Concepts*, August 2013. http://www.fhwa.dot.gov/planning/border_planning/gateways_and_corridors/gateway_ops/gtwy.pdf.

U.S. Department of Transportation, Federal Highway Administration. "Interstate Multimodal Corridors." Section in *Southern California Regional Freight Study*. December 3, 2013. http://www.ops.fhwa.dot.gov/freight/freight_analysis/reg_ind_studies/so_cal_study.htm.

U.S. Department of Transportation, Federal Highway Administration. "Major Freight Corridors Map." http://www.ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/mjrfreightcorridors.htm.

U.S. Department of Transportation, Federal Highway Administration. *Assessment of state of the Practice and state of the Art in Evacuation Transportation Management*. 2006. http://www.ops.fhwa.dot.gov/publications/fhwahop08015/lit1_2.htm.

U.S. Department of Transportation, Federal Highway Administration. *Freight Facts and Figures 2013*. Table 4-1, citing U.S. Department of Commerce, Bureau of Economic Analysis data. http://www.ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/13factsfigures/table4_01.htm.

U.S. Department of Transportation, Federal Highway Administration. "The Dwight D. Eisenhower System of Interstate and Defense Highways." http://www.fhwa.dot.gov/interstate/finalmap.cfm.

U.S. Department of Transportation, Federal Highway Administration, Freight Management and Operations. "Major Freight Corridors." http://ops.fhwa.dot.gov/freight/freight_analysis/freight_story/major.htm.

U.S. Department of Transportation, Federal Motor Carrier Safety Administration. *2012-2016 Strategic Plan*. 2012. http://www.fmcsa.dot.gov/mission/fmcsa-2012-2016-strategic-plan.

U.S. Department of Transportation, Inspector General. *Top Management Challenges for FY 2013: Federal Aviation Administration Year End Progress Reports*. 2013. http://www.faa.gov/about/plans_reports/media/FY13MgmtChallengesATR.pdf.

U.S. Department of Transportation, Maritime Administration. *Panama Canal Expansion Study. Phase I Report: Developments in Trade and National and Global Economies*. 2013. http://www.marad.dot.gov/documents/Panama_Canal_Phase_I_Report_-_20Nov2013.pdf.

U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration. *Summary of Proceedings: Pipeline Emergency Response Forum*. 2011. http://opsweb.phmsa.dot.gov/pipelineforum/pipeline_emergency_response_forum/Pipeline%20Emergency%20Response%20Proceedings%20-%20FINAL.pdf.

U.S. Department of Transportation. "About TIGER Grants." 2014. http://www.dot.gov/tiger/about.

U.S. Department of Transportation. "Ensuring Transportation Infrastructure and System Resilience." 2012. http://www.georgetownclimate.org/resources/us-department-of-transportation-climate-adaptation-plan-ensuring-transportation-infrastruc.

U.S. Department of Transportation. "Security Policy and Plans Division." http://www.dot.gov/mission/administrations/intelligence-security-emergency-response/security-policy-plans-division.

U.S. Department of Transportation. *Beyond Traffic 2045: Trends and Choices*. 2015. http://www.dot.gov/sites/dot.gov/files/docs/Draft_Beyond_Traffic_Framework.pdf.

U.S. Department of Transportation. *Budget Highlights: Fiscal Year 2016*. http://www.dot.gov/sites/dot.gov/files/docs/FY2016-DOT-BudgetHighlights-508.pdf.

U.S. Department of Transportation. *Budget Highlights: Fiscal Year 2015*. http://www.dot.gov/sites/dot.gov/files/docs/BudgetHighlightsFY2015.pdf.

U.S. Department of Transportation. *Budget Highlights: Fiscal Year 2014*. http://www.dot.gov/sites/dot.dev/files/docs/FY%202014%20Budget%20Highlights.pdf.

U.S. Department of Transportation. *Climate Adaptation Plan: Ensuring Transportation Infrastructure and System Resilience*. 2012. http://www.dot.gov/sites/dot.dev/files/docs/DOT%20Adaptation%20Plan.pdf.

U.S. Department of Transportation. Federal Highway Administration. "Freight Transportation in a Changing Business Environment." http://www.ops.fhwa.dot.gov/freight/publications/fhwaop03004/change.htm.

U.S. Department of Transportation. Research and Innovative Technology Administration. "DSRC: The Future of Safer Driving." http://www.its.dot.gov/factsheets/dsrc_factsheet.htm.

U.S. Energy Information Administration. "Petroleum." Section in *California State Profile and Energy Estimates: Profile Analysis*. June 19, 2014. http://www.eia.gov/state/analysis.cfm?sid=CA.

U.S. Geological Survey and California Geological Survey. *The ShakeOut Scenario*. May 2008. http://pubs.usgs.gov/of/2008/1150/.

U.S. Geological Survey. *The SAFRR (Science Application for Risk Reduction) Tsunami Scenario*. 2013. http://pubs.usgs.gov/of/2013/1170/.

U.S. Government Accountability Office. *Emergency Transportation Relief: Agencies Could Improve Collaboration Begun during Hurricane Sandy Response*. May 2014. http://www.gao.gov/assets/670/663627.pdf.

U.S. Government Accountability Office. *Ensuring Maritime Commerce: GAO Reviews of Resilience and Ports*. Presentation to the Transportation Research Board during a conference on "Ensuring a Resilient Maritime Transportation System." June 24, 2014. http://onlinepubs.trb.org/onlinepubs/conferences/2014/MTS2014/Caldwell.pdf.

U.S. Government Accountability Office. *Maritime Critical Infrastructure Protection*. June 2014. http://www.gao.gov/assets/670/663828.pdf.

U.S. Government Accountability Office. *Rail Security: TSA Improved Risk Assessment but Could Further Improve Training and Information Sharing*. June 14, 2011. http://www.gao.gov/assets/130/126416.pdf.

U.S. Office of Management and Budget. "Fiscal Year 2016 Budget Overview." *The Budget.* http://www.whitehouse.gov/omb/overview

U.S. Postal Regulatory Commission. *Form 10-K for FY 2013*. 2013. http://about.usps.com/who-we-are/financials/10k-reports/fy2013.pdf.

Unified Port of San Diego. "Overview." http://www.portofsandiego.org/maritime/tenth-avenue-terminal.html.

Unified Port of San Diego. "Ports Bring Home the Goods." http://www.portofsandiego.org/maritime.html.

University of Southern California Sea Grant Program. *Sea Level Rise Vulnerability Study for the City of Los Angeles*. 2013. http://www.usc.edu/org/seagrant/research/SeaLevelRise_docs/hires_pdfs/City%20of%20LA%20SLR%20Vulnerability%20Study%20FINAL%20Summary%20Report%20Online%20Hyperlinks.pdf .

University Transportation Research Center. *Final Report: Lessons from Hurricane Sandy for Port Resilience*. 2013. http://ntl.bts.gov/lib/51000/51200/51237/Final-Hurricane-Sandy-Resilience.pdf.

Wachs, Martin. "Transportation, Jobs, and Economic Growth." *Access*. Fall 2014. http://www.accessmagazine.org/articles/spring-2011/transportation-jobs-economic-growth/.

White House. *Executive Order – Promoting Private Sector Cybersecurity Information Sharing*. February 13, 2015. http://www.whitehouse.gov/the-press-office/2015/02/13/executive-order-promoting-private-sector-cybersecurity-information-shari.

White House. *Executive Order 13636 – Improving Critical Infrastructure Cybersecurity*. February 12, 2013. http://www.gpo.gov/fdsys/pkg/FR-2013-02-19/pdf/2013-03915.pdf.

White House. *Executive Order 13653 – Preparing the United States for the Impacts of Climate Change*. November 1, 2013. https://www.whitehouse.gov/the-press-office/2013/11/01/executive-order-preparing-united-states-impacts-climate-change.

White House. *National Security Strategy*. May 2010. www.whitehouse.gov/sites/default/files/rss_viewer/national_security_strategy.pdf.

White House. *National Strategy for Global Supply Chain Security*. January 2012. http://www.whitehouse.gov/sites/default/files/national_strategy_for_global_supply_chain_security.pdf.

White House. *Presidential Policy Directive – Critical Infrastructure Security and Resilience (PPD-21)*. 2013. http://www.whitehouse.gov/the-press-office/2013/02/12/presidential-policy-directive-critical-infrastructure-security-and-resil.

White House. *Presidential Policy Directive / PPD-8: National Preparedness*. 2011. http://www.dhs.gov/presidential-policy-directive-8-national-preparedness.

White House. *Surface Transportation Security Priority Assessment*. 2010. http://www.whitehouse.gov/sites/default/files/rss_viewer/STSA.pdf.

World Economic Forum. *Building Resilience in Supply Chains*. 2013. http://www.weforum.org/reports/building-resilience-supply-chains.

World Economic Forum, *Competitiveness Rankings: 2014-2015*, 2nd Pillar: Infrastructure, A. Transport Infrastructure, Sections 1.1, Table 3, p. 13. 2014. http://www3.weforum.org/docs/WEF_GlobalCompetitivenessReport_2014-15.pdf.

World Shipping Council. "Top 50 World Container Ports." 2014. http://www.worldshipping.org/about-the-industry/global-trade/top-50-world-container-ports.

Research Resources

A great number of resources are available to researchers examining the subject of resilience in the transportation sector. Among the sources of research consulted for this report, the following are especially noteworthy:

Transportation Research Board

The TRB (http://www.trb.org/Main/Home.aspx) is a component of the National Research Council (NRC)—one of four organizations comprising the National Academies. TRB's mission is to promote innovation and progress in transportation through research. It facilitates information sharing on transportation practices and policies by researchers and practitioners, stimulates research and offers research management services that promote technical excellence, provides expert advice on transportation policies and programs, and disseminates research results broadly and encourages their implementation. TRB annually engages more than 7,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia; these stakeholders participate on TRB committees, panels, and task forces. The program is supported by state transportation departments, Federal agencies including DOT, and other organizations and individuals interested in the development of transportation. TRB reports and other documents can be accessed through many topic-specific portals on the program's website. A useful composite list of publications can be found here: http://www.trb.org/Main/Blurbs.aspx?fields=ENewsletterType|Recently%20Released%20TRB%20Publications, and here: http://www.trb.org/Research/Research1.aspx. Studies related specifically to security and resilience can be found here: http://onlinepubs.trb.org/Onlinepubs/dva/SecurityActivities.pdf. For related information, see the TRB's "Transportation Research International Documentation" (http://trid.trb.org/), http://www.trb.org/Publications/PubsTRBENewsletter.aspx, http://www.trb.org/AboutTRB/Public/AboutCooperativeResearchPrograms.aspx, http://www.trb.org/Projects/Projects2.aspx, and http://www.trb.org/SynthesisPrograms/SynthesisProgram.aspx.

Volpe, The National Transportation Systems Center

Volpe (http://www.volpe.dot.gov/) is DOT's National Transportation Systems Center. Its mission is to improve transportation by anticipating and addressing emerging issues and advancing technical, operational, and institutional innovations across all modes. Volpe is a unique Federal agency that is 100% funded by sponsor projects. It partners with public and private organizations to assess the needs of the transportation community, evaluate R&D endeavors, assist in the deployment of state-of-the-art transportation technologies, and inform decision making and policy making through comprehensive

analyses. Most of its publications, developed over 40 years, can be accessed through the Volpe Library: http://www.volpe.dot.gov/library. Current work and projects by the seven Volpe technical centers can be accessed at http://www.volpe.dot.gov/featured-work.

Eno Center for Transportation

The Eno Center for Transportation in Washington, DC, is a non-partisan think-tank seeking continuous improvement in transportation and its public and private leadership in order to increase the system's mobility, safety, and sustainability. A non-profit charitable foundation, Eno often works in partnership with government agencies, professional organizations, and other private organizations. Ongoing projects include working groups focused on the Next Generation Air Transportation System (NextGen) and on public-private partnerships as an alternative to direct public investment in transportation systems. In addition, Eno's Freight Working Group brings together truckers, railroads, ports, and shippers to discuss proposals for funding a multimodal freight program. Its publications and projects may be accessed here: http://www.enotrans.org/.

State Resources

Many states have notable transportation programs or research centers, many of which are part of DOT's RITA (http://www.rita.dot.gov/). RITA's National Transportation Library can be found at: http://ntl.bts.gov/.

- University of Southern California's Center for Risk and Economic Analysis of Terrorism Events (CREATE) (http://create.usc.edu/). Established in 2004, CREATE is an interdisciplinary national research center based at the University of Southern California in the School of Policy, Planning, and Development and the Viterbi School of Engineering. CREATE is funded by DHS. The Center focuses on risk and economic analysis and comprises a team of experts from across the country, including partnerships with numerous universities and research institutions. Its many publications can be accessed here: http://research.create.usc.edu/.
- Mineta Transportation Institute (MTI) (http://transweb.sjsu.edu/). MTI, which is based at California's San José state University College of Business, conducts research, education, and information and technology transfer, focusing on multimodal surface transportation policy and management issues. It was established by Congress in 1991 as part of the Intermodal Surface Transportation Efficiency Act. The Institute is funded by Congress through RITA; by the California Legislature through the California Department of Transportation (Caltrans); and by other public and private grants and donations, including grants from DHS. MTI publications can be found at: http://transweb.sjsu.edu/MTIportal/research/Publications.html.
- Intermodal Transportation Institute (http://www.du.edu/transportation/index.html). The Institute, which is at the University of Denver in Colorado, focuses on educating future leaders and executives in managing intermodal transportation systems that integrate all modes—surface, water, and air. Its publications may be accessed here: http://www.du.edu/transportation/research-resources/index.html.

U.S. Department of Transportation

Key components of DOT (http://www.dot.gov/) include the FAA, FHWA, FTA, FRA, and MARAD. Each of these DOT components has extensive resources available to the public.

- Federal Aviation Administration (http://www.faa.gov/). The FAA oversees safety of civil aviation. Many of its publications can be found at: http://www.faa.gov/about/office_org/headquarters_offices/apl/aviation_forecasts/.
- Federal Highway Administration (http://www.fhwa.dot.gov/). The FHWA provides stewardship over the construction, maintenance, and preservation of the Nation's highways, bridges, and tunnels. Its resources can be located through links provided at: http://www.fhwa.dot.gov/resources/topics/. The FHWA also maintains a list of state Departments of Transportation, many of which have useful documents available. The list of state Departments of Transportation, with their links, can be found here: http://www.fhwa.dot.gov/webstate.cfm.
- Federal Transit Administration (http://www.fta.dot.gov/index.html). The FTA provides financial and technical assistance to local public transit systems. Its library can be accessed at: http://www.fta.dot.gov/about/library.html.
- Federal Railroad Administration (http://www.fra.dot.gov/Page/P0001). The FRA oversees the safety and environmental impact of rail transportation. Its electronic library can be found here: http://www.fra.dot.gov/eLib/Find.
- Maritime Administration (http://www.marad.dot.gov/). The MARAD oversees development and maintenance of U.S. merchant marine systems. Its many documents and other resources can be accessed here: http://www.marad.dot.gov/library_landing_page/Library_landing_page.htm.

The DOT "National Transportation Library" (http://ntl.bts.gov/) is maintained by the Research and Innovative Technology Administration (RITA).

U.S. Department of Homeland Security

Within DHS, the key components dealing with transportation issues are the TSA and the USCG. Both of these agencies have resources available to the public.

- Transportation Security Administration (http://www.tsa.gov/). TSA works to strengthen the security of the Nation's transportation systems and to ensure the freedom of movement for people and commerce. Most of its publicly available information, including remarks by TSA officials, can be found here: http://www.tsa.gov/press.
- U.S. Coast Guard (http://www.uscg.mil/). The USCG safeguards the Nation's maritime interests, protects the maritime economy and the environment, defends U.S. maritime borders, and saves those in peril. Many of its publications can be found through the USCG Library homepage: http://www.uscg.mil/top/library/.

Associations

The various modes of the transportation sector have numerous associations representing their interests. These include the following:

- American Association of Airport Executives: http://www.aaae.org/.
- American Association of state Highway and Transportation Officials, Special Committee on Transportation Security and Emergency Management: http://scotsem.transportation.org/Pages/default.aspx.
- American Petroleum Institute: http://www.api.org/.
- American Public Transportation Association: http://www.apta.com/Pages/default.aspx.
- American Trucking Association: http://www.truckline.com/.
- Association of American Railroads: https://www.aar.org/.
- Intermodal Association of North America: http://www.intermodal.org/.
- National Air Transportation Association: http://www.nata.aero/.

Appendix N: Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ACRP	Airport Cooperative Research Program
AMSC	Area Maritime Security Committee
AMSP	Area Maritime Security Plan
API	American Petroleum Institute
ASCE	American Society of Civil Engineers
ATS	Aviation Transportation System
BART	Bay Area Rapid Transit
BASE	Baseline Assessment for Security Enhancements
BNSF	Burlington Northern Santa Fe
BTS	Bureau of Transportation Statistics
C3RS	Confidential Close Call Reporting System
CalTrans	California Department of Transportation
CBP	Customs and Border Patrol
CBRNE	Chemical, biological, radiological, nuclear, and explosive
CEO	Chief Executive Officer
CERT	Computer Emergency Readiness Team
CERT-RMM	CERT Resilience Management Model
CIKR	Critical Infrastructure and Key Resources
CIPAC	Critical Infrastructure Partnership Advisory Committee
CMTS	Committee on Marine Transportation Systems
COE	Centers of Excellence
COOP	Continuity of Operations
CPO	Community Post Office
CPU	Contract Postal Unit
CTC	Centralized Traffic Control
C-TPAT	Customs-Trade Partnership Against Terrorism
DHS	Department of Homeland Security
DHS S&T	Department of Homeland Security Science & Technology Directorate
DHS-IP	DHS Office of Infrastructure Protection
DOC	Department of Commerce
DoD	Department of Defense

DOE	Department of Energy
DoS	Denial of service
DOT	Department of Transportation
EA	Environmental Assessment
EIS	Environmental Impact Statement
EO	Executive Order
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
FHTF	Federal Highway Trust Fund
FHWA	Federal Highway Administration
FLMA	Federal Land Management Agencies
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railway Administration
FTA	Federal Transit Administration
GCC	Government Coordinating Council
GDP	Gross Domestic Product
GHG	Greenhouse Gas Emissions
GPS	Global Positioning System
HAZMAT	Hazardous Materials
HMCRP	Hazardous Materials Cooperative Research Program
HMGP	Hazard Mitigation Grant Program
HMT	Harbor Maintenance Tax
HSIN-CI	Homeland Security Information Network for Critical Infrastructure
HSPD	Homeland Security Presidential Directive
ICS	Incident Command System
ICTF	Intermodal Container Transfer Facility
IED	Improvised Explosive Device
I-STEP	Intermodal Security Training Exercise Program
IT	Information Technology
ITS	Intelligent Transportation Systems
LACM	Los Angeles County Metro
LADOT	Los Angeles Department of Transportation
LAX	Los Angeles International Airport

LGB	Long Beach Airport
MAP-21	Moving Ahead for Progress in the 21st Century Act
MARAD	United States Maritime Administration
MARSEC	Maritime Security
MPO	Metropolitan Planning Organization
MTA	Metropolitan Transportation Authority
MTC	Metropolitan Transportation Commission
MTI	Mineta Transportation Institute
MTS	Maritime Transportation System
MTSRU	Maritime Transportation System Recovery Unit
NAS	National Airspace System
NCCIC	National Cybersecurity and Communications Integration Center
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NextGen	Next Generation Air Transport System
NFAC	National Freight Advisory Committee
NHTSA	National Highway Traffic Safety Administration
NIAC	National Infrastructure Advisory Council
NICHI	National Institute for Coastal and Harbor Infrastructure
NIPP	National Infrastructure Protection Plan
NIST	National Institute for Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NRF	National Response Framework
OCIA	Office of Cyber and Infrastructure Analysis
ODNI	Office of the Director of National Intelligence
OECD	Organization for Economic Cooperation and Development
OMB	Office of Management and Budget
ORION	On-Road Integrated Optimization and Navigation
OSTP	Office of Science and Technology Policy
PAGP	Public Assistance Grant Program
PDM	Pre-Disaster Mitigation
PHL	Pacific Harbor Line
PHMSA	Pipeline and Hazardous Materials Safety Administration

PNT	Position, Navigation, and Time
POLA-POLB	Port of Los Angeles – Port of Long Beach
PPD	Presidential Policy Directive
PRC	Postal Regulatory Commission
QR	Quadrennial Review
R&D	Research and Development
RITA	Research and Innovative Technologies Administration
RRIF	Railroad Rehabilitation and Improvement Financing
RSD	Resilient Systems Division
SCADA	Supervisory Control and Data Acquisition
SCC	Sector Coordinating Council
SLSDC	Saint Lawrence Seaway Development Corporation
SLTT	State, Local, Tribal, Territorial
SME	Subject Matter Expert
SRIA	Sandy Recovery Improvement Act
SSA	Sector Specific Agency
SSP	Sector Specific Plan
STB	Surface Transportation Board
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century
TFHRC	Turner Fairbank Highway Research Center
TIFIA	Transportation Infrastructure Finance and Innovation Act
TIGER	Transportation Investment Generating Economic Recovery
TRB	Transportation Research Board
TRIAD	Transit and Rail Intelligence Awareness Daily
TSA	Transportation Security Administration
TSSRA	Transportation Sector Security Risk Assessment
TTX	Tabletop Exercise
UP	Union Pacific
UPS	United Parcel Service
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
USPS	United States Postal Service
VIPR	Visible Intermodal Prevention and Response

Volpe	John A. Volpe National Transportation Systems Center
VPO	Village Post Office
WEF	World Economic Forum