Beyond Bouncing Back

A Roundtable on

Critical Transportation Infrastructure Resilience

April 30, 2013

U.S. Department of Transportation
Research and Innovative Technology Administration
Volpe, The National Transportation Systems Center

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Overview

Global transportation infrastructure today is confronted with significant vulnerabilities — an aging infrastructure; a growing concentration of populations at high-density coastal urban areas; increasing interdependencies among the nation's physical and cyber infrastructures; co-location of many transportation systems with large-scale and potentially hazardous production facilities; and the escalating threats of climate change. Together, they have coalesced to create significant challenges for the nation's critical infrastructure systems.

A framework for enhancing critical transportation infrastructure resiliency could serve as a roadmap for addressing some of these pressing global challenges. Recently, the concept of resiliency, however, has become a buzzword used to characterize a system that recovers rapidly from a disruption in order to resume normal functions. But, RESILIENCY IS MORE THAN BOUNCING BACK.

The U.S. Department of Transportation's Volpe Center hosted a roundtable of experts to explore resiliency in the context of challenges facing the nation's transportation system. The experts concurred that resiliency requires a change in focus from near-perfect efficiency to planned redundancy, flexibility, fault-tolerance, and resourcefulness. A resilient transportation infrastructure will be able to anticipate threats—both natural and man-made—and will be able to absorb shocks and adapt to changing conditions. With a resilient approach, we can rebuild better—and smarter—recognizing that no infrastructure exists in isolation. Resiliency will make our future infrastructure reliable, sustainable, and survivable.

Defining Resilience

RESILIENCY is an overarching concept characterizing a complex transportation system that is able to better withstand disruptions. The transportation system includes physical, technical, social, and institutional elements that are all critical to resilience. A resiliency framework should be viewed as one that enables us to strategically harness capabilities and know-how to build or rebuild a transportation system that is much less vulnerable to disruption and better than the current transportation system. A resilient transportation system has design-level robustness so that it can withstand severe blows; it is adaptable so that it can respond appropriately to threats and it can mitigate the consequences of threats through response and recovery operations.

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John A. Volpe National Transportation Systems Center

Left to right: Robert C. Johns, Vivien Li, Thomas Fisher, Christine Pommerening, Randell H. Iwasaki, Gregory D. Winfree, and Michael Dinning

The Program	The Expert Panel
Welcome and Introductions	**Robert C. Johns,** Associate Administrator and Director, Volpe Center
Keynote Remarks	**Gregory D. Winfree,** J.D. Deputy Administrator, Research and Innovative Technology Administration, U.S. Department of Transportation
Our Fracture-Critical Transportation System	**Thomas Fisher,** Ph.D. Dean, College of Design, University of Minnesota
Resilience in Organizations, Systems, and Communities	**Christine Pommerening,** Ph.D. Assistant Research Professor, George Mason University
A State and Local Transportation Perspective	**Randell H. Iwasaki,** Executive Director Contra Costa Transportation Authority
Preparing for the Rising Tide	**Vivien Li,** President The Boston Harbor Association
Note: The views of non-DOT participants do not necessarily reflect the views of the U.S. Department of Transportation.	

Man-Made and Natural Threats

"Our capability to prepare for such events, monitor evolving threats, detect looming hazards, and respond and problem solve after the worst has materialized is critical to planning and operating a resilient infrastructure system."

- **Robert C. Johns, Associate Administrator and Director**
  Volpe, The National Transportation Systems Center

- Recent tragedies in Boston illustrate the risks we face in our globalized world, but also the strengths, resourcefulness, agility, and problem-solving capabilities of our nation.
- Our capability to prepare for such events, monitor evolving threats, detect looming hazards, and respond and problem solve after the worst has materialized is critical.
- Community resourcefulness, combined with advanced data collection and problem solving and adaptive agency responses, can significantly contribute to the resiliency of a city in the face of a natural or man-made hazard.
- The resiliency of our nation in the face of recent catastrophic events is a testimony to our success in harnessing the risks of today's global interconnectedness, physical and cyber-attacks, and natural hazards such as Hurricane Katrina and Superstorm Sandy.

Critical Transportation Infrastructure Resilience

"Our infrastructures are becoming increasingly dependent on information technology and networks, and the interdependencies among transportation, the power grid, our communications systems, and other infrastructures are complex."

- **Gregory D. Winfree, J.D., Deputy Administrator**
  Research and Innovative Technology Administration

- Resiliency is about the ability of a system to predict, resist, prevent, and absorb disturbances and still retain its basic function and structure.
- Resiliency provides the bridge between the static condition of a system and a new dynamic equilibrium, reflecting adaptive improvements.
- Resilient systems can anticipate disruptions, seek preventive solutions, actively adapt to adverse conditions, and survive the blows when the unavoidable disasters do happen. We don't just react and cope. We improve.
- Infrastructure systems that are robust and fault-tolerant can survive disruption because they take preventive measures to reduce vulnerabilities and to avoid deterioration. They have redundant components in place and the capabilities to mitigate the effects of a disaster or attack, and limit loss of life, property damage, and impacts on the ecosystem.
- A resilient system has the capability to anticipate, withstand, absorb, and adapt resourcefully to attain a new equilibrium.
- Through a resiliency approach we can begin to rebuild better and smarter, getting away from ad hoc approaches to building infrastructures in isolation.

Our Fracture-Critical Transportation System

"Nature is organized locally…It is organized in small, local ecosystem 'patches;' as one ecosystem patch collapses, adjacent patches step in and reorganize to form a new structure."

- **Thomas Fisher, Ph.D.**
  Dean, College of Design, University of Minnesota

- Our infrastructure is one of many post-World War II systems exhibiting a "fracture-critical" failure pattern: they are efficient but unsustainable, have no built-in redundancies, and will fail. In situations where this type of failure or collapse is common, we can learn from nature about how to recover.
- Many of our infrastructures today are fracture-critical structures. We must design ourselves out of this. We must recognize the stress curves before they collapse.
- Our current infrastructure is about to rapidly change, due to the escalating challenge of obtaining oil, more frequent natural disasters brought on by climate change, the economic impossibility of maintaining our existing infrastructure, and the increased likelihood of pandemics that will spread via air travel and hit hardest in major cities.
- We need a new framework to address the way our natural and built systems are interlinked. The concept of "panarchy" views the dynamics of today's complex systems as a cross-scale (local, national, global) and cross-disciplinary phenomenon that is in continual adaptive cycles of growth, accumulation, restructuring, and renewal.
- The next industrial revolution will be a change to mass customization and distributed systems based on renewable materials. The new organizational metaphor will be that of a network.
- New technology based on 3D printing will lead to tremendous variety in vehicle design and will decentralize production. It will dramatically change how and why we move goods, utterly changing our need for a transportation infrastructure.
- By 2030, 40 to 50 percent of the workforce will telecommute, so rush hour traffic will disappear. We should stop designing for these rush hour capacities.

Resilience in Organizations, Systems, and Communities

"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."

- **Christine Pommerening, Ph.D.**
  Assistant Research Professor, George Mason University

- The concepts behind resilience relate to three principles that help organizations or infrastructure systems to adapt most successfully:
  - *Complex-Adaptive Systems* are characterized by technical reliability, flexibility of people and processes, and cultural openness; their components interact to support change as a

result of a learning process;
  - *Normal Accidents Theory* maintains that complex systems that are tightly coupled for efficiency and have few redundancies, can be very susceptible to failure in a disruption;
  - *High Reliability Organizations* are characterized by decentralized authority, structural redundancy, technical competence, and a culture of error-tolerance so that small errors can be used to improve performance.
- In the transportation sector, resiliency 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.
- 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 towards using data about the systems themselves, their vulnerabilities, and the consequences regardless of the type of disruption.
- First responders are local authorities. One framework recommends a decentralized, local approach to resilience, based on local knowledge of the infrastructure. There are two key questions: 1) Which functions within the transportation subsystem are vital to our community? 2) Which resources are available to perform these functions? A resilient system will have many answers to the second question.

A State and Local Transportation Perspective

"Redundancy is basic to resiliency and is built into the California highway system. We can shut down a mile of freeway for a week if needed with no impact on local traffic."

- **Randell H. Iwasaki**
  Executive Director, Contra Costa Transportation Authority

- Disasters are good teachers, illustrating exactly which infrastructure is vulnerable and needs to be protected or improved. After earthquakes damaged bridges—notably the Bay Bridge—Caltrans prioritized retrofits of all known and suspected bridge faults in the highway system.
- Under emergency provisions after a disaster, it is possible to rebuild faster so that critical infrastructure is rapidly safeguarded.
- On 9/11, Caltrans realized there was no resiliency built into seven heavily-traveled toll bridges that collect substantial fees each day. Right away, they obtained funding for an emergency contract to immediately install state-of-the-art security systems on the bridges.
- Fracture-criticality applies to many bridges built in the 1950s and 1960s, in which form was prioritized over function. Anticipating frequent earthquake tremors Caltrans' emergency seismic-resistant retrofit of all its bridges reassigned risk factors and prioritized stability.
- Funding is always a challenge for this type of work, but people are willing to pay local taxes dedicated to improvements they can see and understand. Our local authorities bear much of the financial burden for retrofits and maintenance. How can this all be funded by gasoline taxes?

- Transportation authorities must make hard choices about where to invest and what user impacts to accept. Resiliency is one priority among many.
- San Francisco has torn down freeways to improve the quality of life. Caltrans predicted that gridlock would result, but San Franciscans are resilient and have found other pathways.
- Providing incentives – e.g., offering toll credits for people driving during off-peak periods or promoting growth management programs geared to sustainability of resource use – has proven an effective strategy.

Preparing for the Rising Tide

"If Superstorm Sandy had hit Boston 5½ hours earlier, at high tide, 30 percent of Boston's land mass would have been flooded."

- **Vivien Li**
  President, The Boston Harbor Association

- Today's 100-year flood could be 2050's annual flood and 2100's high tide. Essential elements of the future preparedness are identification of vulnerable structures and implementation of cost-effective and flexible adaptation plans. We encourage organizations to think creatively about analyzing their vulnerabilities and what measures they can take.
- The private sector can and should develop building-specific preparedness plans. Boston property owners and water transportation businesses have been proactive in adapting to the threat of sea level rise. Maps of probable sea level and storm surge levels in 2050 and 2100 are effective in convincing people to think ahead, especially in the wake of Superstorm Sandy.
- Essential elements of the future preparedness should include balancing robustness with flexibility; including no-regret and co-benefit solutions; and favoring resilience over resistance.
- In a university-dense urban area there is already a lot of data; it's helpful for businesses and agencies to share data and creative ideas. This is not just an environmental justice issue: the most affluent areas in Boston would have been flooded if Sandy had hit at high tide.
- Boston organizations are looking ahead. A major priority is redoing utilities that have been in place and underground for 40 years. UMASS Boston is raising their mechanicals, redesigning their roads, and raising new buildings by three and a half feet. A waterfront hotel maintains emergency food and water supplies and holds regular sand bag drills. The brand new Spaulding Rehab Hospital in the Charlestown Navy Yard was designed based on lessons learned from New Orleans hospitals that survived Hurricane Katrina.
- It isn't only the most obvious impacts that must be considered. MassPort could put up a barrier to protect Logan Airport runways—but no passengers would be able to reach the airport because all the tunnels would be flooded.
- The public sector strategies to pursue include the implementation of Boston's Climate Action Plan, surveys of preparedness of all public buildings and the MBTA, inclusion of climate preparation as a design component for future developments, and increased enforcement of flood proofing standards for property owners.

Moderated Discussion

Michael Dinning, Director, Transportation Logistics and Security Technical Center at Volpe moderated the discussion. Highlights of the roundtable include:

- How do we incentivize people to prioritize investment in transportation infrastructure? Superstorm Sandy got everyone's attention. Government officials in Boston recognized what would have been flooded if the storm had hit five hours earlier. The insurance industry will play a role in motivating businesses and individuals to prepare better.
- Local officials struggle with many aspects of disaster planning, yet disasters often are localized. We all need to participate in questions of land use and preparedness.
- We need to better engage local officials in thinking more broadly about their resources. If there is a pandemic, how will local hospitals get resources if all the airports are closed? A sustainability philosophy should be added to every comprehensive planning process.
- Since World War II, the American people have assumed there will be no more disasters and have given up taking care of themselves in an emergency. They expect someone else to take care of everything, so there's a complete breakdown when "the system" breaks down. Everyone needs their own backup plan and links to their community. In a disaster, the people who survive will be the ones who know their neighbors.
- The Internet is an example of one of our most resilient systems. Even though terrorists make use of the Internet— a distributed system—they only attack centralized systems. We need to think about radically distributing our transportation system so it's impossible to fully bring it down—so there's no place to attack.
- Good models for these concepts are the practices of developing countries—they are the most resilient economies on the planet and know how to do a lot with very few resources. Our highly centralized industrial solutions did not help Haiti as much as the distributed, patchy solutions created by the local people.
- The weakness of the federal government is that we are very risk averse and we wait until a potential solution is fail-safe. We're still working with a century-old infrastructure and tweaking it, while the commercial world adopts new technology every day and gets it out there to be used. Any new federal plan should link funding to incentives, to encourage state DOTs to make their systems more resilient.
- The federal role may need to change—to move away from its 20th-century silos and cluster around challenges instead of departments—especially since many solutions are going to be decentralized and local. A recent example is the collaboration among DOT, HUD, and EPA around the issue of sustainable communities. For transportation, perhaps the federal government should adjust its focus from *access* to *movement* across state and national boundaries.
- The federal government can think globally and act locally by funding pilot projects. It can take its strength in R&D and implement that locally, especially after a disaster when there is so much opportunity to restructure and reconfigure.

About the Colloquia Series

Continuing its long tradition of facilitating knowledge exchange across the transportation community, the Volpe Center has designed a new Colloquia Series on Transportation Challenges and Opportunities that brings together thought leaders and experts from government, academia, and the private sectors to discuss emerging transportation issues and fresh approaches to addressing these issues. The series supports effective policy decisions by focusing on the core issues that underlie today's most pressing transportation challenges. The series is available via webinar and members of the transportation community are encouraged to participate in question and answer periods.

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