Measuring Transportation Infrastructure Resilience: A Case Study with Amtrak

Gina Tonn, PhD, PE, CFM | Delaware DNREC
ASFPM 2019
Overview

- Need for transportation infrastructure resilience
- Barriers to improving transportation infrastructure resilience
- Infrastructure resilience metrics
- Case study with Amtrak
Focus on Transportation Infrastructure

- Responsible for movement of people and goods
- Vital to the U.S. economy and way of life
- Subject to disruptions associated with natural disasters, infrastructure failures, accidents, and terrorist attacks
- Extent of damage and speed of restoration are critical determinants of how quickly a disaster stricken area recovers
- Owned publicly and privately
Resilience is “the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions” – Executive Order 13,653

“The ability of the transportation sector to perform reliably, safely, and efficiently is undermined by a changing climate” - Fourth National Climate Assessment
Barriers to improving transportation infrastructure resilience

Tonn, Czajkowski, Kunreuther (2018) Improving US Transportation Infrastructure Resilience through Insurance and Incentives
Resilience metrics

- Provide quantitative, structured mechanism to measure and evaluate resilience (Cutter 2016)
- Enable decision-makers to assess impacts of investments and policies (Sun et al. 2018)
- Assist decision-makers in selecting resilience improvements (Sun et al. 2018)
- Have potential linkages in setting/choosing insurance coverage types, amounts, and premiums
- Cover physical aspects of system, along with other features like communication and leadership
Using metrics for resilience analysis

Two important aspects of resilience analysis using metrics:

1. Quantification of factors that influence performance during a disruption
2. Study of outputs/performance during and after a disruption
Amtrak Case Study
Amtrak and the Northeast Corridor

- Private corporation of the Federal government providing medium- and long-distance intercity passenger rail transportation in the U.S.

- Roughly 95% of operating expenses covered by ticket sales; public support necessary for remaining costs

- Northeast Corridor (NEC) spans from Washington DC to Boston
  - Amtrak owns most of its infrastructure in this region
  - Busiest railroad in the nation; one of the most complex transportation systems in the world
  - Amtrak’s rail assets in NEC include track, power, signal infrastructure; stations, O&M facilities, tunnels, numerous bridges
Amtrak’s Northeast Corridor

https://nec.amtrak.com/nec-projects-stations/
## Amtrak’s climate risks
(adapted from Booz Allen Hamilton 2014)

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Risks (selected)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme heat</td>
<td>• track expansion and buckling</td>
</tr>
<tr>
<td></td>
<td>• equipment overheating</td>
</tr>
<tr>
<td></td>
<td>• track work bans during hot weather</td>
</tr>
<tr>
<td>Extreme cold</td>
<td>• brittle or fractured tracks</td>
</tr>
<tr>
<td></td>
<td>• track work bans during cold weather</td>
</tr>
<tr>
<td>Precipitation</td>
<td>• flooding of tracks, stations, tunnels, storage yards, and equipment</td>
</tr>
<tr>
<td></td>
<td>• bridge scouring</td>
</tr>
<tr>
<td></td>
<td>• landslides</td>
</tr>
<tr>
<td>Winter precipitation</td>
<td>• broken rails</td>
</tr>
<tr>
<td></td>
<td>• ice/snow accumulation on tracks</td>
</tr>
<tr>
<td></td>
<td>• switch failures</td>
</tr>
<tr>
<td>Wind</td>
<td>• speed restrictions</td>
</tr>
<tr>
<td></td>
<td>• falling trees on railway and/or catenary</td>
</tr>
<tr>
<td>Sea level rise</td>
<td>• long-term/permanent track flooding</td>
</tr>
</tbody>
</table>
Case Study Purpose

- Sets of resilience metrics have been developed by researchers
- Little application to real-world infrastructure systems
- Study the usefulness, challenges, and opportunities in implementing actionable metrics to understand
  - efficient and effective application to transportation infrastructure
  - how metrics are used in practice
  - feasibility
Case Study Overview

- Collaboration between Wharton Risk Center and Amtrak’s Environmental & Sustainability Management System Steering Committee, Climate Change Strategy sub-committee
- Metrics framework for resilience to climate change in Amtrak’s Northeast Corridor
- Framework established through review and selection of existing metrics
- Outcomes to track following a disaster with linkages to metrics
- Completion of baseline metrics scoring
Metrics framework development steps

1. Identify and review infrastructure resilience metrics
2. Evaluate metrics for applicability to Amtrak
3. Establish initial metrics framework
4. Select top metrics
5. Finalize top metrics framework and link to outcomes
Metrics review

- 24 sets of applicable metrics reviewed in depth
- Resilience of: communities, cities, infrastructure systems, environmental systems
- Resilience to: floods, earthquakes, climate change, terrorism, all-hazards

Los Angeles County MTA Resiliency Indicator Framework
- 61 metrics
- 1 to 4 measurement scale
- Technical and organizational resilience

Zurich Flood Resilience Measurement Tool
- 88 sources of resilience
- A to D rating scale
- Physical, social, human, natural, financial AND redundancy, resourcefulness, rapidity, and robustness

UNISDR Disaster Resilience Scorecard for Cities
- Focus on 10 essentials for making cities resilient
- Scorecard format describing sets of assessments
Metrics selection process

- Review and evaluation at a workshop
  Initial metrics (65)

- Intermediate metrics (45)
  • Reduction and combination of metrics

- Group voting on metric importance
  Top metrics (21)
## Top 21 Resilience Activities

<table>
<thead>
<tr>
<th>Physical Resilience</th>
<th>Organizational Readiness</th>
<th>Organizational Leadership</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Maintenance (day to day)</td>
<td>• Warnings (general public)</td>
<td>• Insurance coverage</td>
</tr>
<tr>
<td>• Vulnerability assessment</td>
<td>• Communication systems</td>
<td>• Insurance information gathering</td>
</tr>
<tr>
<td>• Resilience design criteria</td>
<td>• Sensors</td>
<td>• Defined response staff</td>
</tr>
<tr>
<td></td>
<td>• Weather data</td>
<td>• Capital availability for resilient infrastructure</td>
</tr>
<tr>
<td></td>
<td>• Backup critical information</td>
<td>• Operational funding for resilience</td>
</tr>
<tr>
<td></td>
<td>• Risk assessment and business continuity</td>
<td>• Resilient integration</td>
</tr>
<tr>
<td></td>
<td>• Joint/external planning</td>
<td>• Information sharing</td>
</tr>
<tr>
<td></td>
<td>• Understanding of emerging threats and new stressors</td>
<td>• Defined roles, responsibilities, and authorities</td>
</tr>
<tr>
<td></td>
<td>• Training/drills</td>
<td>• Leadership engagement with staff</td>
</tr>
</tbody>
</table>
Outcomes to measure following a disruption

- Cost
- Customer Satisfaction Index (CSI)
- Safety (incidents, injuries, claims)
- Organizational development
- On-time performance
# Example Resilience Activities

<table>
<thead>
<tr>
<th>Resilience Activity</th>
<th>Description</th>
<th>Measurement Scale</th>
<th>Cost</th>
<th>eCSI</th>
<th>Safety</th>
<th>Org Dev</th>
<th>OTP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design - Vulnerability</td>
<td>Vulnerability assessment has been conducted to identify if asset(s) is exposed to climate-related hazards (e.g. flooding and extreme heat.)</td>
<td>4 – Vulnerability assessment carried out for all climate related hazards and documentation available</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Assessment</td>
<td>3 – Vulnerability assessment carried out for all climate related hazards</td>
<td>2 – Vulnerability assessment carried out for some climate related hazards</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 – No vulnerability assessment carried out for any climate related hazard</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resilient Integration</td>
<td>Capital spending projects are systematically reviewed for potential to improve resilience.</td>
<td>4 - Documented and demonstrated review of resilience benefits of capital spending projects</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 - Documented review with inconsistent application</td>
<td>2 - Process not defined and may or may not be included in review</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 - No review of resilience benefits</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Analysis – improving resilience

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>Customer Satisfaction Index</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Safety</td>
<td>3</td>
<td>7</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>Organizational development</td>
<td>3</td>
<td>5</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>On-time performance</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>9</td>
</tr>
</tbody>
</table>
Analysis – improving resilience

18 - Resilient Integration: Capital spending projects are systematically reviewed for potential to improve resilience

20 - Defined Roles, Responsibilities, and Authorities: Defined responsibilities and roles for resilience planning with regular meetings and documented process

Action: Implement capital expenditure resilience review process

Cost outcomes improved:
- Lost revenue
- Operating expenses
Conclusions

- Metrics are a useful tool to
  - Encourage organizational thinking about resilience
  - Link physical and organizational aspects of resilience to outcomes

- Challenges and Opportunities
  - Balancing comprehensiveness with practicability
  - Interdepartmental collaboration

- Future research needs
  - Tracking metrics following disruption and reassessment of resilience activity scores
  - Application to other transportation infrastructure systems
Thanks!

Acknowledgments

- Co-authors
  - Wharton Risk Center: Jeffrey Czajkowski, Howard Kunreuther
  - Amtrak: Kara Angotti, Karen Gelman

- Partial funding for this research provided by the Critical Infrastructure Resilience Institute (CIRI), a Department of Homeland Security Center of Excellence

Contact Information

Gina.Tonn@Delaware.gov
Extra slides
Number of U.S. Loss events (Insurance Info. Inst., 2019)

- 29 billion dollar flood events since 1980
  (not including tropical cyclones)
Amtrak in Delaware
Top 21 Resilience Activities: Physical Resilience

- Maintenance – Day to Day
- Design – Vulnerability Assessment
- Develop Resilience Design Criteria
Top 21 Resilience Activities: Organizational Readiness

- Warnings – General Public
- Communication Systems - Staff
- Sensor Installation and Use
- Collect Current Weather Data
- Backup Critical Information
- Risk Assessment, Scenario Planning, and Business Continuity Procedures
- Combined Joint/External Planning
- Internal Understanding of Emerging Threats and New Stressors
- Training/Drills
Top 21 Resilience Activities: Organizational Leadership

- Insurance Coverage
- Insurance Information Gathering
- Defined Response Staff
- Capital Availability for Resilient Infrastructure
- Operational Funding for Resilience Initiatives
- Resilient Integration
- Information Sharing – External
- Defined Roles, Responsibilities and Authorities
- Leadership Engagement and Communication to Staff and New Employees