Transportation Systems Resilience: Effective measures and research needs

National Science Foundation: National Workshop on Resilience Research

October 22, 2015

Steve Winkelman
Director
Transportation and Adaptation
OVERVIEW

1. CCAP approach
2. Transportation, climate change and critical infrastructure
3. Matching vulnerabilities and solutions
4. Implementation strategies
5. Research needs
CCAP: CENTER FOR CLEAN AIR POLICY (SINCE 1985)

CCAP WORLDWIDE

CCAP works with policymakers around the world to develop, promote and implement innovative, market-based solutions to major climate, air quality and energy problems.

CCAP Approach
• Thought leadership
• Applied research
• On-the-ground support
• Expert dialogue

Key CCAP Themes
• GHG Mitigation
• Climate Finance
• Public-private collaboration
• Distributed Energy
• Urban Sustainability
• Climate Adaptation

www.ccap.org
Ask the Climate Question

How will key policies and infrastructure investments affect GHGs and Climate Resilience?

↓ GHGs 😊 or ↑ GHGs 😞 ?

↑ Resilience 😊 or ↑ Vulnerability 😞 ?

CCAP's Urban Leaders Adaptation Initiative partners asked the Climate Question across departments and functions

- Thank you to Ron Sims and Jim Lopez
CCAP’s Vision of Resilience:
We can get to work

Washington DC, Chinatown Metro. Source: Amazon AWS
THE LIGHTS STAY ON

Washington DC. Source: Panoramio
AND WE CAN STILL HAVE FUN
Climate Adaptation & Transportation: Identifying Information and Assistance Needs

Severe Weather & Critical Infrastructure Resilience: Preparing Washington D.C.

Growing Wealthier: Smart Growth, Climate Change, & Prosperity

Green Infrastructure and Climate Adaptation

Lessons Learned on Local Climate Adaptation

Ask the Climate Question

Green Resilience: Climate Adaptation & Mitigation Synergies
Transportation, Climate and Critical Infrastructure
Presidential Policy Directive: Critical Infrastructure Security and Resilience - 2013 assigns responsibility to DHS and DOT

- Department of Homeland Security: Transportation Systems Sector-Specific Plan - 2010
- Department of Transportation Adaptation Plan – 2012 (updated 2014)
Federal Highway Administration (FHWA)
- Planning: 19 pilot studies, Superstorm Sandy lessons learned, Albuquerque adaptation scenario analyses
- Asset management: FHWA guidance on engineering practices
- Other tools and resources: Climate Change Sensitivity Matrix, Climate data processing tool, Vulnerability assessment tool…

Federal Transit Administration (FTA)
- Transit agency adaptation assessment: 7 pilot studies
- Funding for Safety, Resiliency and All-Hazards Emergency Response and Recovery Research Demonstrations
TRANSPORTATION IS TELECOM DEPENDENT

- SATELLITE COMMUNICATIONS
- TERRESTRIAL BROADCAST
- MOBILE
- ITS-G5
  - Crash Avoidance
- MAN
  - Navigation
- Vehicle to Vehicle
  - Adaptive Cruise Control
- Fleet Management
- Travel Assistance
- Toll Collection
- Traffic Signs
- WLAN
  - Trip Planning
- Passenger Information
- Intermodal Communications

© ETSI 2012
Reading the matrix from left-to-right shows which systems the designated operator relies on. For example, Airports have a strong interaction with regional roads, but a limited interaction with natural gas.

Reading the matrix from top-to-bottom shows which systems rely on the designated operator. For example, all systems have a strong interaction with the fuel system.
TRANSPORT INFORMATION AND CONTROL SYSTEMS VULNERABLE TO CLIMATE IMPACTS

- Direct and indirect infrastructure damage
  - Flooding
  - Wind damage
  - Heat

Power outages → signal outages

Increased demand for information services during extreme events

Photo: www.shutterstock.com/Cheryl A. Meyer
RESILIENT TRANSPORTATION SHOULD

- Protect transportation infrastructure itself
- Protect transportation telecom infrastructure
- Protect infrastructure that transportation telecom depends upon
- Plan & design transportation systems to function during telecom outages
Matching vulnerabilities and solutions
What can we do when... THE STREETS FLOOD?

Photo source: Keystone USA-ZUMA/Rex Features
What can we do when…

ROADS ARE WASHED OUT?

Chris Schneider AP
What can we do when...

TRAIN STATIONS FLOOD?

PA NY/NJ
What can we do when…

WILDFIRES STRIKE?

Photo source: New York Daily News
What can we do when…

EXTREME HEAT BUCKLES RAIL?
What can we do when...

RUNWAYS SOFTEN?

Phillip Dugaw/Reddit
What can we do when...

MILITARY FACILITIES FLOOD

Source: Old Dominion University Sea Level Rise Initiative

U.S. Navy photo

Naval Station Norfolk
Hurricane Isabel September 2003
What can we do when…

EVACUATION IS NECESSARY

Houston: Hurricane Rita evacuation, 2005
Source: www.houstonfreeways.com
SECONDARY AND CASCADING EFFECTS ARISE?

- System interactions and interdependencies
  - Power, transport, water, telecom

- Hurricane shuts Galveston Port and Mississippi barge traffic
  - Droughts can do the same

- Floods in Thailand disrupt global supply chains

- Storm → branches → river → culvert → road outage

- Multiple storms → soil saturation → sewer overflow, flooding

- Pine beetles + Heat wave → Fires, then storms → erosion

- Derecho → power out → Metro & signal lights out → traffic
WHAT SOLUTIONS DO WE HAVE?

A variety of measures:

• Engineering, design, planning, policy
• Short-term and long-term
• Narrowly focused and broad scale
• Directionally-correct and comprehensive
• Cross-cutting and sector specific
Problem
NYC subway flooding after a 2007 storm.
Source: MTA NYC Transit

Partial Solution
MTA NYC Transit has allocated nearly $90 million toward raising ventilation grates and installing stair pads at subway entrances.
Source: MTA NYC Transit
MIND THE GAP

PA NY/NJ
DEPLOYABLE SOLUTIONS

Portable barriers (ACSE)

Inflatable tunnel plug (NYC)
GREEN INFRASTRUCTURE TO SHADE PEDESTRIAN & CYCLING FACILITIES
GREEN INFRASTRUCTURE TO REDUCE URBAN FLOODING AND HEAT

Chicago Climate Action Plan
ALTERNATIVE MODES & NETWORK REDUNDANCIES
MIX EVACUATION STRATEGIES

Pre designated evacuation locations
Source: Adaptation stories.com

Evacuate in Place

Florida International University – fortified library
Source: Miami-Dade County
How a checklist could save $4 million!

Source: D. MacLeod, Toronto
A 2005 storm in Toronto caused $647 million in damages, including destruction of this culvert (left, $4 million) in losses, which was replaced with a larger, more resilient culvert (right). Source: Toronto Environment Office.
Photo credit for damaged culvert: Jane-finch.com.

Photo credit for new culvert: City of Toronto Transportation Services.
ELECTRICITY SECTOR RISKS

- **Power outages**: business interruptions
  - US: $20 - 55 billion loss / year

- **Drought**: limited water for hydroelectricity and for thermal power plant cooling

- **Heat**: fires disrupt grid, increase demand for A/C

- **Flooding**: generating facilities, substations

- **Wind storms**: downed power lines
ELECTRICITY SECTOR
GREEN RESILIENCE OPPORTUNITIES

- **Energy efficiency**
  - ↓ GHGs
  - ↓ grid overload, maintain continuity

- **Distributed energy:** on-site renewables, Microgrids, storage, CHP, District energy systems
  - ↓ GHGs
  - ↑ resilience -- **business continuity**

- **Water use efficiency** (power plant & public)
  - ↓ energy, GHGs, drought prep
  - Use treated wastewater for cooling

- **Protect equipment**
  - Elevate, weatherize, relocate, underground
  - Keeps the lights on!
# BUILDINGS / ENERGY: GREEN RESILIENCE NEXUS

<table>
<thead>
<tr>
<th>MEASURE</th>
<th>Mitigation</th>
<th>Adaptation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Code updates</td>
<td>↑ energy efficiency</td>
<td>↑ resilience to wind, flooding earthquakes</td>
</tr>
<tr>
<td>Protect / elevate mechanical and electrical systems</td>
<td>(↓ GHGs from re-building)</td>
<td>Maintain business continuity.</td>
</tr>
<tr>
<td>Water efficiency, grey water reuse</td>
<td>↓ GHGs from water distribution &amp; treatment</td>
<td>Prepare for declining water supplies.</td>
</tr>
<tr>
<td>Green infrastructure (green roofs, green walls, landscaping)</td>
<td>Cooling -- ↓ air conditioning energy use, ↓ water treatment needs</td>
<td>↓ urban heat island, ↓ stormwater runoff, ↑ flood resilience, Maintain ecosystem services</td>
</tr>
</tbody>
</table>
PROTECT VULNERABLE LINKS ON SUPPLY CHAIN

2011 Flooding in Thailand
• $15 - $20 billion in losses
• Heaviest flooding in 50 years
• ~800 deaths
• Damaged automotive and electronics plants
• > 10,000 factories were forced to close
• > 350,000 workers while production was suspended.
• Disrupted global supply chains
• Increased insurance costs

Integrated Solutions
• Reinsurance and Insurance
• Relocate out of flood plains
• Building resilience
• Energy efficiency
• Microgrids, on-site CHP
• Review supply chain vulnerabilities
Implementation Strategies
WHAT’S NEEDED FOR IMPLEMENTATION?

RESILIENCE AND ADAPTATION PLANNING

• Document past events, known vulnerabilities
• Project future impacts
• Assess vulnerabilities
• Evaluate resilience strategies
• Identify and pursue implementation opportunities

CHALLENGES

• Analytical (physical and economic)
• Policy/Legal
• Institutional
• Staff Capabilities
• Budgetary
CCAP’s *Growing Wealthier* matrix

<table>
<thead>
<tr>
<th>Business</th>
<th>Household</th>
<th>Municipal / Regional</th>
<th>National</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Return on Investment</strong></td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td><strong>Savings on Expenditures</strong></td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td><strong>Improved Quality of Life</strong></td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
CONSIDER GREEN RESILIENCE: ADAPTATION + MITIGATION SYNERGIES

Adaptation
- Afforestation, Open space preservation
- Land use changes, Relocation
- Infrastructure protection, Building design
- Flood mitigation
- Emergency Response
- Business Continuity plans
- Community engagement

Mitigation
- Green Infrastructure
- Power System Resilience
- Protect Sustainable Transportation
- Water & Energy Conservation
- Building Weatherization

- Energy efficiency
- Renewable energy
- Combined heat and power
- Sustainable transportation
- Methane capture and use
- Industrial process improvements
- Carbon sinks
Green Resilience measures can:

✓ Increase return on investments
  – Mitigation, Adaptation
  – Infrastructure

✓ Expand funding sources
  – Adaptation, Mitigation, Infrastructure, disaster relief, development…

✓ Multiple benefits can garner support from multiple champions and accelerate implementation
Does this investment:

- Reduce GHG emissions?
- Increase resilience?

Follow the Money

- Climate and Infrastructure investments
- A lot of climate resilience comes down to state of good repair and good planning, both of which are under-funded.
## 3x3 Green Resilience Matrix

### Identifying Climate Adaptation + Mitigation Synergies

**WHAT ARE YOUR TOP 3 INVESTMENTS?**

<table>
<thead>
<tr>
<th>Investments</th>
<th>Adaptation</th>
<th>Mitigation</th>
<th>Infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>$10,000,000 Dune restoration</td>
<td>$10,000,000 Wind turbines &amp; Photovoltaics</td>
<td>$2,000,000,000 Roads</td>
</tr>
<tr>
<td>#2</td>
<td>$5,000,000 Green Infrastructure</td>
<td>$5,000,000 Green Buildings</td>
<td>$1,000,000,000 Water treatment facilities</td>
</tr>
<tr>
<td>#3</td>
<td>$1,000,000 Vulnerability Assessment</td>
<td>$500,000 Education &amp; Outreach</td>
<td>$500,000,000 Transit system improvements</td>
</tr>
</tbody>
</table>
Research Needs
Information on local, *non-climate* factors can be more important than climate science information.

- Adaptation starts with determining how well critical infrastructure is adapted to *current* climate and weather
- **Infrastructure** elevation, state of repair, culvert capacity
- **Land development trends**
- **Natural factors**: soil saturation, tide levels, river flows
- **Interactions**, cascading impacts

*Climate Adaptation & Transportation: Identifying Information and Assistance Needs*
- CCAP & EESI for NOAA (2012)
Recommendations for Federal Agencies (CCAP/EESI 2012)

- **Research and Analysis**
  - Costs and benefits of resilience measures
  - Data improvement
  - Risk management methods
  - Transportation structure, component, and material vulnerabilities

- **Capacity Building**
  - Technical assistance (planning, design, construction, maintenance)
  - Selecting and applying data and analytical tools
  - Evaluation of measures (effectiveness, costs, benefits)

- **Policy**
  - Integrating adaptation into planning processes, asset management
  - Integrate adaptation with other environmental goals (GHG mitigation)
  - Performance management guidelines on climate resilience

MUCH IS UNDERWAY ALREADY
First International Conference on
Surface Transportation System Resilience to
Climate Change and Extreme Weather Events

September 16–18, 2015
National Academy of Sciences Building
2101 Constitution Avenue, NW
Washington, D.C.

Sponsored by
Federal Highway Administration
Federal Transit Administration
American Association of State Highway and Transportation Officials
WSP|Parsons Brinckerhoff

Topics
• Climate data availability
• Climate model downscaling
• Asset management
• Decision support tools
• Best planning practices
• Cost-benefit analysis
• Risk management
• Engineering and design
• Green infrastructure
• Information systems
• Policy
• State and local case studies
RESEARCH NEEDS:
INTERCONNECTING VULNERABILITIES

• Methods for identifying key nodes with multiple critical infrastructure elements, such as bridges or viaducts with transport, telecom and energy elements

• Developing metrics on cross-vulnerabilities

• Connecting critical infrastructure state-of-repair data with information on past extreme weather events and projected risks
  – assembling existing information, identifying data needs and developing methodologies to cross-reference data sets.

• Assessing impacts of multi-modal accessibility and network redundancies on resilience to extreme events & disruptions
  – Pre-, during, post-
• Measuring the opportunity costs of inaction to extreme weather events and infrastructure disruptions
  – Infrastructure repair/replacement (more typically included)
  – Business interruption (in need of more research)

• Costs of resilience measures
  – Incremental costs (typical approach)
  – Costs of better upfront planning (often minimal)
RESEARCH NEEDS: IT OPERATIONS AND CONTROL

- Transport/telecom interactions
  - Vulnerabilities and resilience measures for traffic signals, navigation systems, bus scheduling, freight routing, tolling, etc.

- Future autonomous vehicle IT systems
  - Evaluating performance in the case of IT network outages due to extreme weather or other disruptions

Source: www.ictas.vt.edu
Assess key factors for effective implementation

- Why do cost-effective technologies and policies get implemented in some places and not others?
- Compare factors such as:
  - Local economic and market conditions
  - Political leadership
  - Private sector champions
  - Institutional coordination
  - Stakeholder engagement
  - Community involvement
  - Quantification and communication of costs and benefits, including quality of life and security impacts
  - Detailed finance plans linked with current infrastructure plans and budgets
CLOSING THOUGHTS

• Knowing the solutions is only half the battle
  – Effective stakeholder engagement, communication, marketing and lobbying are key
• Common sense can go a long way
• **Accidental Resilience:**
  Solutions often not driven by climate change concerns
  – Business owners just want to save energy costs and keep the lights on
  – Passive building design maintains building temperature during power outages.
• **Intentional Resilience:**
  Plan ahead to avoid conflicts and maximize synergies.
  – Boston refueling facility: PV + batteries ↓ GHGs & ↑ preparedness for power outages.
• Strategic Opportunism
  – Build upon policy momentum and market trends
  – Identify catalytic opportunities for short-term results
• Ask the Climate Question and Respond via Changed Spending Decisions
• Pursue Resilience Research
  – Interconnected vulnerabilities, cost/benefit, IT operations and controls, implementation
Thank you to:

Steve Winkelman
Director, Transportation and Adaptation Programs

swinkelman@ccap.org

Thank you to:

Chuck Kooshian
Senior Transportation Policy Analyst
ckooshian@ccap.org