Flooded Bus Barns and Buckled Rails:
Public Transportation and Climate Change Adaptation

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Key Themes

• Proactive instead of reactive
• Risk management approach
• Integrate approaches into existing procedures
Outline

• Background
• Climate change impacts on transit
• Risk assessment tools and how they can be applied to transit
• Adaptation strategies
• Incorporating adaptation into existing processes.
• 4 Case Studies – NY, LA, Mobile, London
• FTA activities

1. Background
Why Important to FTA?

Climate change directly impacts top FTA goals:
- State of Good Repair
- Safety

FTA is steward of $10 billion/yr federal investment in public transportation, which will be impacted by changes in climate.

New mandate from White House Council on Environmental Quality

Climate adaptation is responsible risk management

Background: Large Increase in Greenhouse Gas Emissions

- CO2 concentrations in atmosphere up 36% since industrial revolution.
- CO2 concentration likely to be 2 to 3 times higher than highest level in 800,000 years in absence of strong control measures.
Global Temperature and Carbon Dioxide

- Average temp up 1.5°F since 1900
- Projected to increase another 2-11.5°F by 2100


Impacts Vary by Emissions Scenario

Current emissions are above the highest modeled scenario
USGCRP Key Findings

• Global warming is unequivocal and primarily human-induced.
• Climate changes and impacts are occurring now and are expected to increase.
• Thresholds will be crossed, leading to large changes in climate and ecosystems. (Species extinction, coral reefs, rainforests)
• Future climate change and its impacts depend on choices made today.


Need Both Mitigation and Adaptation

• **Mitigation**: “An intervention to reduce the causes of changes in climate,” such as
  – reduce greenhouse gas (GHG) emissions to the atmosphere.
  – sequester carbon by reforestation and preventing deforestation
  – Need 80% reduction by 2050

• **Adaptation**: “Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects.”
  – Needed because climate impacts already occurring,
  – and additional impacts already built in to system given level of long-lived emissions already in atmosphere.

Definitions from National Academy of Sciences
2. Impacts

4 Transit Impacts

↑ Intense Precipitation
   (very likely, >90%)
   • Flooding of track, bus ways, tunnels, lots, facilities
   • Landslides

↑ Very Hot Days & Heat Waves
   (very likely, >90%)
   • Track buckling leads to slow order or derail
   • Customer comfort issue
   • Worker safety issue

Rising Sea Levels
   (virtually certain, >99%)
   • Flooded track, bus ways, tunnels, lots, facilities
   • Higher groundwater level floods tunnels

↑ Hurricane Intensity
   (likely, >66%)
   • Flooding from storm surge, rain
   • High winds – debris, wind damage
   • Transit provision of evacuation service
Climate Impacts Already Occurring

- "When it rains, it pours"
- Note that largest impact is in Northeast, home of some of largest and oldest rail transit systems.

*defined as the heaviest 1 percent of all daily events

Source: Groisman et al as cited in USGCRP 2009.

2007 Flooding in NYC Overwhelmed System – Projected to be more common

- 1.5 – 3.5 inches of rain fell in New York in 2 hour period August 8, 2007
- Overwhelmed regional drainage systems and MTA pumps designed to handle no more than 1.75 inches an hour
- Disruptions on 19 major segments forced shutdown of much of the subway system. 2 – 2.5 million customers affected
- Columbia University experts project threat of similar floods to increase.
Nashville Flood, May 2010

Photos courtesy of Nashville MTA

Cumberland River floods MTA property on Nestor Street
Sea Level Rise – San Francisco Bay Area

Blue: Areas that could be inundated by 16 inch sea level rise

Purple: Areas that could be inundated by 55 inches sea level rise

Source: San Francisco Bay Conservation and Development Commission, Living with a Rising Bay: Vulnerability and Adaptation in San Francisco Bay and on its Shoreline, April 7, 2009.

Sea-level Rise + Bigger Storms = More Flooding

Boston

Dark blue hashed area = current 100-yr flood zone

Light blue = projected 100-yr flood zone

Source: UCS / NECIA
Combined Sea Level Rise and Hurricane Storm Surge – New York

Source: Jacob et al. in preparation

NYC Subway - 100 yr flood + 4 ft Sea Level Rise

Blue lines: flooded subway tunnels
Orange: < 30 ft elevation
(subway tracks are typically 20 feet below the street level)
100 yr storm surge ~8 ft

Impacts of Climate Change on U.S. Public Transportation: High Heat Projections

Legend
- Bus
- Rail and Ferry
- Rail, Rail, and Ferry
- Rural Transit

Rail Buckling
3. Risk Assessment

London Underground Risk Map

1. Extreme Hot Weather - Key track, signals, & communications assets and staff & passengers.
2. Rain & Flooding - Track & signal drainage
3. Cold & Freeze - Impact on track integrity
4. Rain & Flooding - Key infrastructure drainage
5. Drought - Vegetation impact
6. Snow - track, signalling and depot operations
7. Cold & Freeze - Train system components
8. Cold & Freeze - Slips/trips for staff and customers.
9. Rain, Flooding and snow - Damage to inside of carriages
10. Wind - Damage to infrastructure, track and vegetation.
11. Drought - Ground stability impacts
State of the Practice: Transit & Adaptation

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<tr>
<th>Transit Agency</th>
<th>Adaptation Actions</th>
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<tr>
<td>Los Angeles MTA</td>
<td>Conducting climate change risk assessment of assets, to be completed July</td>
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<tr>
<td>New Jersey Transit</td>
<td>Conducting climate change risk assessment of assets, to be completed Oct. Participating in FHWA adaptation pilot</td>
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<td>Waves Transit, AL</td>
<td>Part of multi-modal US DOT Gulf Coast Study, Phase II</td>
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<tr>
<td>TriMet</td>
<td>Participating in regional adaptation efforts</td>
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<tr>
<td>Cape Cod Transit</td>
<td>Part of interagency climate change pilot, assessment of sea level rise impacts.</td>
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<td>Honolulu Transit</td>
<td>Participating in FHWA adaptation pilot</td>
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<td>King County Metro</td>
<td>Stakeholder in county adaptation efforts, which are at forefront of field</td>
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<td>Transport for London</td>
<td>Adaptation included in risk and asset management systems. Adding air conditioning, addressing flooding to existing system. Climate impacts incorporated into design of major project – “Crossrail.”</td>
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<td>Istanbul</td>
<td>New rail link built for 3 ft sea level rise + 1 in 10,000 yr flood</td>
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<td>Taipei</td>
<td>After typhoon dumped 50 inches of rain in two days, set new standards for entrances: 2-4’ above ground + 6” above 100 yr flood, tunnel floodgates</td>
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4. Adaptation Strategies
NYCT Adaptation Strategies

Raised ventilation grate for NYC subway with street furniture
Photos courtesy of New York City Transit

Green roof captures rainwater, sequesters emissions, lowers building HVAC costs

Kansas City Bus Rapid Transit

Rain Gardens

Pervious Pavement

Flow: through rain garden in bumpout designed to collect runoff from road and sidewalk. Trees planted back of curb at higher soil level.
Tucson Streetcar
Double-Tiered Shade Structures

London’s famous red buses are now white from above . . .
Adaptation Options Under Consideration by Los Angeles Metro

- Combining weather/climate information with infrastructure monitoring and maintenance?
- Exploring the use of more heat-resistant track materials?
- Improving “flood defense” at sensitive locations (like underground stations)?
  Examples: expanded “greener” stormwater management; changes to vents, or elevation of pumps
- Options during construction?
  Examples: siting, alignment alternatives, labor schedules

5. Incorporating adaptation into existing processes
Mainstreaming Adaptation into Transit Agency Structures & Processes

- Asset management systems: offer useful framework for incorporating climate adaptation into capital plans and budgets.
- Metropolitan and Statewide Transportation Planning
- Environmental Management Systems
- Environmental Review and Project Development
- Floodplain Assessment
- Real Estate Acquisition and Relinquishment of Assets
- Design and Construction
- Retrofit
- Maintenance
- Emergency Preparedness, Response, and Recovery
- Performance Measures
- Organizational Culture and Budget Priorities

Element of Asset Management System | Opportunity to Incorporate Climate Change Adaptation
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Goals and Policies | Incorporate climate change considerations into asset management goals and policies; these could be general statements concerning adequate attention of potential issues, or targeted statements at specific types of vulnerabilities (e.g., sea-level rise).
Asset Inventory | Map infrastructure assets in vulnerable areas, using GIS where possible; inventory critical assets that are susceptible to climate change impacts.
Condition Assessment and Performance Monitoring | Monitor asset condition in conjunction with environmental conditions (e.g., temperature, precipitation, winds) to determine if climate change affects performance; incorporating risk appraisal into performance modeling and assessment; identification of high risk areas and highly vulnerable assets. Use of “smart” technologies to monitor the health of infrastructure assets.
Alternatives Evaluation and Program Optimization | Include alternatives that use probabilistic design procedures to account for the uncertainties of climate change; possible application of climate change–related evaluation criteria, smart materials, mitigation strategies, and hazard avoidance approaches.
Short and Long Range Plans | Incorporate climate change considerations into activities outlined in short- and long-range plans; incorporate climate change into design guidelines; establish appropriate mitigation strategies and agency responsibilities.
Program Implementation | Include appropriate climate change strategies into program implementation; determine if agency is actually achieving its climate change adaptation and monitoring goals.
Performance Monitoring | Monitor asset management system to ensure that it is effectively responding to climate change; possible use of climate change–related performance measures; “triggering” measures used to identify when an asset or asset category has reached some critical level.

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<th>Stage in Planning Process</th>
<th>Opportunity to Include Climate Change Adaptation</th>
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<td>Establish a vision</td>
<td>Emphasize preservation of the system in the face of shifts in climate.</td>
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<td>Set goals, objectives, and performance measures</td>
<td>Establish objectives for asset conditions. Include performance measures related to adaptation.</td>
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<td>Stakeholder identification and outreach</td>
<td>Engage environmental and state and local government agencies, additional infrastructure providers, and other organizations relevant to climate action planning. Coordinate to leverage adaptation work of other stakeholders.</td>
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<td>Conduct analyses</td>
<td>Assess the vulnerability of the transportation system to climate change during this stage, in which agencies characterize the existing system relative to performance criteria, gather input from stakeholders and the public on priority deficiencies, and forecast future issues.</td>
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<td>Develop alternative plan scenarios</td>
<td>Identify alternatives that facilitate adaptation to climate change. Specific strategies and improvement projects can be included in the alternatives developed. In this stage agencies develop various approaches for achieving the stated objectives and distill several diverse, manageable alternatives. Agencies typically identify fiscal constraints and opportunities at this stage as well.</td>
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<td>Evaluate alternatives</td>
<td>Examine the impacts of proposed adaptation strategies to ensure that the selected alternative appropriately addresses climate change. It is important to note that decisions often include tradeoffs among community goals.</td>
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<td>Programming</td>
<td>Use performance measures related to climate change to prioritize projects for funding. The transportation improvement program (TIP) details what near-term projects are going to be built and when, based on funding cycles.</td>
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<td>Project Development</td>
<td>Incorporate adaptive design considerations based on a risk assessment process.</td>
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<td>System monitoring</td>
<td>Monitor the vulnerability and resilience of the transportation system to climate impacts.</td>
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FTA Adaptation Work

- **Report** examines climate impacts on U.S. transit, adaptation strategies, risk management tools, and incorporation into organizational structures and processes.
- **Pilots** of transit agency adaptation assessments – applications due August 25 (one to focus on asset management systems)
- **FTA Policy Statement** – signed May 2011; explains impact of climate change on state of good repair and safety; commits FTA to taking action

Learn more: [www.fta.dot.gov/sustainability](http://www.fta.dot.gov/sustainability) click on “climate change”

Thank You!

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