U.S. Transportation and Climate Change: Addressing the Adaptation Challenge

UNECE International Conference on Adaptation of Transport Networks to Climate Change

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ICF International
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Climate Change & Road Infrastructure: Service Life vs. Climate Impacts

Facility Service Life

Transportation Planning Process

- Project Concept
- Adopted Long-Range Plan

Engineering and Design

Construction

In Service

Years

0 10 20 30 40 50 60 70 80 90 100
Hurricane Katrina Damage to Highway 90 at Bay St. Louis, MS

The USACE has identified over 180 communities that are threatened by erosion in Alaska
## Climate Impacts on Roads*

<table>
<thead>
<tr>
<th>CLIMATE EFFECT</th>
<th>IMPACTS</th>
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</table>
| More hot days                          | • Asphalt deterioration  
• Thermal expansion of bridge joints, paved surfaces  
• Pavement & structural design changes |
| Wind speeds                            | • More frequent sign damage  
• Need for stronger materials |
| More frequent, intense precipitation   | • Increased flooding  
• Increased peak stream flow could affect scour rates  
• Standing water could affect structures adversely |
| Increased coastal storm intensity     | • Increased storm surge and wave impacts  
• Decreased expected lifetime of structures  
• Erosion of land supporting coastal infrastructure |
| Sea level rise                         | • Permanent inundation  
• Erosion of road base  
• May amplify storm surges in some cases |

Transportation Agencies in the U.S.

- State-level Departments of Transportation and regional Metropolitan Planning Organizations
- Highly diverse
  - Geography, development patterns, population
  - Climate stressors that are most relevant
  - Organizational size, resources, capacity
  - Policy context
Supporting transportation decision makers in the context of constrained resources

- What are the risks and vulnerabilities? How bad may they be?
- Which of them matter most?
- What are my options?
- What happens first?
Climate Risk Screening Process for Transportation

- **Assess Criticality**
- **Assess Sensitivity**
- **Assess Exposure**

\[
\text{Vulnerability} = f(\text{Exposure, Sensitivity, Adaptive Capacity})
\]

\[
\text{Climate Risk} = f(\text{Vulnerability, Hazard, Probability})
\]
Gulf Coast Study Phase 2 - Goals

- Provide essential information on local, multimodal impacts in a single Metropolitan Planning Organization to inform Long-Range Transport Planning
  - Screen **critical assets**:
    - Data: inventories, socio-economic information, expert judgment
    - Tools: transportation modeling, redundancy testing, stakeholder input
  - Screen for **sensitivity**:
    - Data: design standards, historical and geographic analogues, expert input
    - Tools: sensitivity matrix
  - Screen for **exposure**:
    - Data: downscaled climate model data, weather extremes, indicators of relevance
    - Tools: sea level rise and storm surge exposure analysis, adaptive capacity analysis
- Develop tools that can be applied by transportation agencies nation-wide
Criticality Screening

- Service and Operational Considerations
  - Trip volumes, functional classification, operations and maintenance, control and enforcement

- Societal Considerations
  - Health and safety, geographic influence, availability of redundant systems

- Financial Considerations
  - Value to commerce, replacement value, total life cycle cost, NPV of services

- Environmental Considerations
  - Ecological services, hazardous materials; threatened and endangered species, Clean Water Act...

- Cultural and Aesthetic Considerations
  - Iconic status, historical value
Risk Screening

Criticality Screening

In Gulf Coast 2 study, scoring matrix based on:

- Transportation modeling and redundancy testing
- Collection of socio-economic information
- Expert judgment to fill gaps
- Stakeholder input on what is regionally or culturally important

<table>
<thead>
<tr>
<th>Facility</th>
<th>Socioeconomic - Locally Identified Priority Corridors</th>
<th>Socioeconomic - Functions as Community Connection</th>
<th>Socioeconomic - System Redundancy</th>
<th>Socioeconomic - Serves Regional Economic Centers</th>
<th>Operational - Functional Classification (Intestate, etc.)</th>
<th>Operational - Usage</th>
<th>Operational - Intermodal Connectivity</th>
<th>Health &amp; Safety - Identified Evacuation Route</th>
<th>Health &amp; Safety - Component of Disaster Relief and Recovery Plan</th>
<th>Health &amp; Safety - Component of National Defense System</th>
<th>Health &amp; Safety - Provides Access to Health Facilities</th>
<th>Criticality Score (1 - Low, M - Medium, H - High)</th>
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<tbody>
<tr>
<td>Airport Blvd (West of Snow Rd)</td>
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<td>Bellingrath Rd (North of Industrial Rd)</td>
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<td>Broad Street (North of Spring Hill Ave)</td>
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<td>Broad Street (South of Spring Hill Ave)</td>
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## Impact Thresholds for Transportation Assets

<table>
<thead>
<tr>
<th>Asset Categories</th>
<th>Mode Sub-Mode</th>
<th>Sea Level Rise and Storms</th>
<th>Precipitation</th>
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<tbody>
<tr>
<td><strong>Bridges</strong></td>
<td>Bridge (Superstructure)</td>
<td>Damage increases substantially when Storm Surge Height = Low Chord Bridge Elevation</td>
<td>Design standards require bridges in Mobile to withstand a 130-150 mph wind. Bridge likely closed to traffic at 56 mph.</td>
</tr>
<tr>
<td><strong>Bridge (Substructure, Abutment and Approach)</strong></td>
<td>Sea level rise increases the base elevation of water during storm surge, thereby increasing damage due to scour, wave action, uplift and other stressors. Design standards require that bridge foundations withstand scour resulting from a 100 year storm.</td>
<td>Strong winds create more powerful waves which can stress the bridge superstructure and substructure.</td>
<td>Scour at bridge foundations should designed to withstand the 100-year flood storm surge.</td>
</tr>
<tr>
<td><strong>Operator Houses (movable bridges) and electrical parts</strong></td>
<td>If exposed, electrical components are very sensitive to low levels of salt water flooding. Movable bridges may begin to close operations at wind speeds of around 40 mph. Physical damage to operator houses has occurred historically at wind levels of 125 mph. Damage from wind tends to be minor.</td>
<td>Damage would require wind or storm damage to expose operator house and electrical equipment.</td>
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<tr>
<td><strong>Roads and Highways</strong></td>
<td>Paved roads (surface and subsurface)</td>
<td>Direct damage to road begins occurring once storm surge overtops road, particularly if waves are in direct contact with road structure. There is some protection from wave action if road is deeply overtopped or covered with sand.</td>
<td>While lower functional class roadways are typically designed for the 10-25 year storm, Mobile County roads are generally designed for larger storms.</td>
</tr>
<tr>
<td>Unpaved roads</td>
<td>Most coastal roads do not have unpaved surfaces. However, if exposed, unpaved roads are more sensitive to erosion and damage caused by sea level rise than paved. Moderate winds stir up dust from unpaved roads, resulting in minor discomfort and damage. No documented relationship, but high sensitivity to washout from flooding likely.</td>
<td>No documented impacts, but high sensitivity to washout from flooding likely.</td>
<td>No documented relationship, but some sensitivity is likely.</td>
</tr>
</tbody>
</table>
Sea-level Rise and Storm Surge Scenarios

Gulf Coast Study, Phase 2

- **Sea Level Rise (SLR)**
  - Potential inundation from three sea level rise scenarios (30cm by 2050; 75cm by 2100; 200cm by 2100)
  - Accounting for land subsidence using InSAR and BM data (USGS)

- **Storm Surge and Wave Modeling**
  - 11 scenarios
    - Effect of SLR on moderate hurricane?
    - Potential for increase in intensity?
  - **Storm Surge Modeling (ADCIRC)**
    - Output includes surge distribution and depth
    - Local guidance provided by South Coast Engineers
  - **Wave Modeling (STWAVE) Model**
    - Inputs from ADCIRC output and boundary conditions
    - Outputs include key aspects of wave energy

- **GIS analysis**
  - Exposure of transportation systems to SLR, SS/wave action
In GC2 study, worked with transportation engineers to derive indicators of immediate relevance.

Downscaling of climate information conducted by USGS. Figures show draft results.

Full results are currently being written up in a final report.
Quantitative exposure & impact assessment

- Developing tools to distinguish both incremental and catastrophic impacts
The Data Paradox

- **There is not enough data**
  - High quality elevation data (LIDAR) not always available
  - Data on facility location, condition, costs (of inaction/action) unavailable
  - Data are often poorly managed or non-existent

- **There is too much data**
  - Lots of climate data, but much of it is conflicting or at temporal or geographic scales that are not relevant
  - Available data are provided in disparate formats and even spatial information requires significant manipulation
  - The number of tools, websites, and resources are overwhelming – making it difficult to know where to begin
FHWA’s Climate Effects Typology

- FHWA published *Regional Climate Change Effects: Useful Information for Transportation Agencies*

- Latest scientific projections of potential climate change by US region

- Short-cuts decisions on timeframes, scenarios, regions, models, variables
Risk framework – New York City

Figure 8: Two-dimensional risk framework used by the New York City Climate Change Adaptation Task Force. Adoption of a common framework (such as the one pictured here) can allow managers and decision-makers to compare impacts and vulnerabilities across units within an installation, or among installations. (Source: NPCC 2010)
## Possible Adaptation Solutions

<table>
<thead>
<tr>
<th>Approach</th>
<th>Possible Activities</th>
</tr>
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<tbody>
<tr>
<td>Protect</td>
<td>• Construct storm surge barriers</td>
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<tr>
<td></td>
<td>• Strengthen bridges/substructures</td>
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<tr>
<td>Accommodate</td>
<td>• Elevate structures</td>
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<td>• Increase maintenance</td>
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<td>• Improve flood tolerance</td>
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<td>• Use easy to repair materials</td>
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<td></td>
<td>• Dredge more frequently</td>
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<tr>
<td>Retreat</td>
<td>• Retreat inland</td>
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<tr>
<td></td>
<td>• Relocate</td>
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<tr>
<td>Planning Flexibility</td>
<td>• Reduce irreversible investment</td>
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<td></td>
<td>• Reduce lease lengths</td>
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</tbody>
</table>
Reliability Under a Range of Conditions

New approaches: scenario planning and risk assessment

Risk Assessment
- Exposure
- Vulnerability
- Resilience

Adaptation Response
- Protect
- Accommodate
- Retreat

Greater Resilience

Appropriate, pre-emptive actions will be less costly.

Uncertainty makes monitoring essential.
Mainstreaming Adaptation

- Asset management as adaptation
  - Culvert inventories (mentioned in all peer exchanges)

- Hazard mitigation as adaptation
  - Resonated with MPOs both in the Midwest and in New England
  - FEMA flood maps do not accurately reflect risk; alternative approaches offer opportunities to consider true flood risk
  - FEMA post-disaster processes may undermine community efforts to reduce future vulnerabilities when rebuilding after a disaster
Addressing Vulnerabilities Indirectly
Adaptation as an Add-On

- Adaptation measures are not always implemented for the sake of adaptation
  - Culverts in Pacific NW are being increased in size to improve salmon runs; a co-benefit is that they are less likely to wash out during heavy precipitation events
  - A major component of USAID’s adaptation work is to mainstream climate change adaptation into existing development and risk management activities
  - Increased redundancy can increase resilience to other hazards besides climate-related events
- Integration within existing planning and risk management processes, ensures better overall outcomes
FHWA Pilots: A Few Lessons Learned

- **Get to the decision:** Often too much time on the climate scenarios -- little time to consider implications, options for action, and implementation

- **Extremes vs. means:** Low-probability/high-consequence events can be much more important than mean impacts

- **Integration is key:** Start with existing decision making paradigms; don’t start from scratch

- **Stakeholders matter:** There are usually multiple stakeholders with widely varying perspectives and potentially lots of controversy

- **Focus on robust actions:** Uncertainty can paralyze decision making. Build a strategy that is robust under many outcomes
Questions? Comments?

Thank you!

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