Climate Change and Transportation System Adaptation: Defining Characteristics from International and National Examples

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## Extent of Nation’s Transportation Infrastructure

### Highways (public)
- 46,873 miles of Interstate highway
- 115,500 miles NHS roads
- 3,849,259 miles of other roads
- 580,000 bridges

### Airports
- 5,270 public use airports

### Rail
- 95,664 Class 1 miles
- 15,388 regional miles
- 29,197 local miles
- 23,000 Amtrak miles

### Transit (directional miles)
- 165,854 bus miles
- 4,407 commuter rail
- 1,596 heavy rail
- 1,097 light rail

### Transit stations
- 1,153 commuter rail
- 1,023 heavy rail
- 723 light rail

### Navigable channels
- 26,000 miles

### Commercial waterway facilities
- Great Lakes (600 deep/150 shallow draft)
- 2,320 Inland shallow draft
- 4,298 ocean deep/1,761 shallow draft
- 257 locks

### Pipeline
- 60,043 miles crude
- 71,310 miles product
- 298,000 miles transmission
- 1,139,800 miles distribution
60,000 miles in FEMA coastal flood zone; 36,000 bridges within 15 nautical miles of coasts
Gulf Coast Study
Freight Rail Lines Vulnerable to Storm Surge of 18 feet
Transportation infrastructure that is vulnerable to 18 feet of storm surge includes:

- 51% of interstate miles, 56% of arterial miles, and most transit authorities
- 98% of port facilities vulnerable to surge and 100% to wind
- 33% of rail miles operated, 43% of freight facilities, 22 airports in the study area at or below 18 feet MSL
- Potentially significant damage to offshore facilities
<table>
<thead>
<tr>
<th>Environmental Factor</th>
<th>Facility</th>
<th>Possible Effect</th>
<th>Cause</th>
<th>Formula #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall intensity/frequency increase</td>
<td>Roadway foundation</td>
<td>Foundation weakening</td>
<td>Saturation</td>
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<td>Erosion</td>
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<td>Groundwater elevation increase</td>
<td>300, 301</td>
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<td>Foundation and roadway loss</td>
<td>Flooded culvert or bridge failure</td>
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<td>Roadway pavement</td>
<td>Surface deterioration</td>
<td>Base and sub-base saturation</td>
<td>403, 404, 405, 406</td>
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<td>Surface loss</td>
<td>Flooded culvert failure</td>
<td>100-106</td>
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<td>Roadside slopes</td>
<td>Slope failure</td>
<td>Erosion</td>
<td>302</td>
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<td>Soil saturation</td>
<td>302</td>
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<td></td>
<td>Roadside planting</td>
<td>Species growth</td>
<td>Hydration</td>
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<td>Bridge-water crossing</td>
<td>Structural damage</td>
<td>Scour</td>
<td>100-106</td>
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<td>Water load</td>
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<td>Soils pressure change</td>
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<td>Failure</td>
<td>Floodwater erosion</td>
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<tr>
<td>Storm sewer</td>
<td>Surcharge</td>
<td>High runoff rate</td>
<td>100</td>
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<tr>
<td>Open channel</td>
<td>Flooding</td>
<td>High runoff rate</td>
<td>100-108</td>
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<td>Erosion from high runoff rate and/or volume</td>
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<td>Stream mitigation</td>
<td>Erosion from high runoff rate and/or volume</td>
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</table>

Similar information for rainfall decrease.....
A Typical Infrastructure Segment

- Subsurface
- Materials
- Foundations
- Structures
- Typical Cross Sections
- Drainage

Structure Unit 1: Fixed Bearings
Water, for example, .......
Critical Components of Infrastructure Design

1. Subsurface conditions
2. Materials specifications
3. Cross sections/standard dimensions
4. Drainage and erosion
5. Structures
6. Location engineering
Corridor Impacts

- Erosion, runoff & drainage impacts on natural resources
- Right-Of-Way Maintenance such as mowing, evasive species & erosion control
- Outside of Right-Of-Way Environmental Mitigation
- Construction Practices & Activities

Right-Of-Way line
Scotland’s Climate Adaptation Planning Framework

Diagram 3: Model for adapting to climate change in Scotland

Vulnerability to changes in climate:
- Exposure
  - Reduce emissions*
- Adaptive capacity
- Competing pressures

Adaptation framework actions:
- Pillar 1: Provide the evidence base
- Pillar 2: Equip decision makers with skills & tools
- Pillar 3: Integrate adaptation into regulation and public policy

Deliver adaptation actions that are sensitive to local needs

Aim: Increase the resilience of Scotland’s communities, and the natural and economic systems on which they depend, to the impacts of climate change.

* Scotland’s Climate Change Adaptation Framework will focus on achieving climate change adaptation but opportunities to reduce emissions will also be sought.
<table>
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<th>Understand the consequences of a changing climate</th>
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<td>1. Gather more detailed information on the susceptibility of transport networks to the effects of climate change and impact of severe weather. This will guide contingency planning for the types of incidents which cause significant widespread disruption.</td>
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<tr>
<td>2. Assess future adaptation requirements for road and rail networks in light of the UK Climate Projections 2009.</td>
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<th>Equip decision makers with skills and tools</th>
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<td>3. Develop the role of Transport Emergency Planning and Consequence Management.</td>
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<tr>
<td>4. <strong>Scottish Road Network Climate Change Study:</strong> Take forward the program of design, research and policy initiatives that were identified in the study.</td>
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<tr>
<td>5. <strong>Landslides Study:</strong> Implement recommendations from the Study.</td>
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<td>6. <strong>2007 TRL Rockslope Risk Assessment:</strong> Implement recommendations of this Assessment.</td>
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<th>Integrate adaptation into public policy and regulation</th>
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<td>7. <strong>Scotland's National Transport Strategy:</strong> Review the Strategy, including the consideration of strategic climate change adaptation issues.</td>
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<td>8. <strong>Scottish Ferries Review:</strong> This Review will inform the Scottish Government's long term strategy for lifeline ferry services and influence the next round of procurement of ferry services and supporting infrastructure.</td>
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<td>9. <strong>High Wind Strategy:</strong> Implement the Strategy for the management of the impact of high winds on road networks</td>
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### Primary Climatic Changes

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<tr>
<td>Increase in average temperatures</td>
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<tr>
<td>Increase in maximum temperatures</td>
</tr>
<tr>
<td>Increase in winter rainfall</td>
</tr>
<tr>
<td>Reduction in summer rainfall</td>
</tr>
<tr>
<td>More extreme rainfall events</td>
</tr>
<tr>
<td>Reduction in snowfall</td>
</tr>
<tr>
<td>Increased wind speed for worst gales</td>
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<td>Sea level rise</td>
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FHWA’s Climate Adaptation Model

Inventory of Assets
- Develop inventory of assets
  - How important is each asset?
    - Less important
    - Low likelihood/ Low magnitude

Monitor and revisit as resources allow

Risk
- Low vulnerability
  - Is the asset vulnerable to projected climate effects?
    - High or medium vulnerability
      - What is the likelihood that future stressors will measurably impact the asset?
      - What is the consequence of the impact on the asset?
          - Low risk
          - High or medium risk

What is the integrated risk?
- Low risk
  - Identify, analyze, and prioritize adaptation options
- High or medium risk

Climate Information
- Gather climate information (observed and projections)
  - What is the likelihood and magnitude of future climate changes?
    - High likelihood/High magnitude
    - High likelihood/Low magnitude
    - Low likelihood/High magnitude

Existing data sets
- Existing inventories
- Existing priorities, evaluation tools

Monitor and revisit as resources allow

Within scope of Risk Assessment pilot

Outside of scope of Risk Assessment pilot
NCHRP 20-83(5)
Climate Change and the Highway System: Impacts and Adaptation Approaches
Proposed Diagnostic Framework for Climate Adaptation Planning – NCHRP 20-83(5)

1. Identify critical performance measures
2. Identify critical assets in the network
3. Identify predominant climate change trends and factors for region
4. Identify impact of these changes on local environmental conditions
5. Identify vulnerabilities of highway system to these changing conditions
6. Conduct risk appraisal of vulnerabilities and environmental changes
7. Identify trigger levels
8. Assess feasibility and cost effectiveness of adaptation strategies
   - Asset A
   - Asset B
   - Asset C
   - Asset X
9. Network Functions
10. Identify affected highway agency functions
11. Change design standards
12. Change operating strategies
13. Change maintenance practices
14. Change construction practices
15. Etc.
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Additional steps:
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Each one of these steps represents research needs and further investigation of how to conduct credible and effective climate adaptation planning.
Importantly, climate adaptation is not just design oriented….it also includes operations, maintenance, construction, location engineering, land use and public policy (just to name a few).
How urgent is climate adaptation, and what is involved in adaptation?

How difficult and expensive will adaptation be for the transport sector? Can adaptation in this case be handled through normal transportation engineering and finance mechanisms, or does this need broader and higher attention?

Does the ability to adapt to a changing climate preclude the need to mitigate GHG emissions?