

# Transportation Adaptation to Global Climate Change





WHITE PAPER

# Transportation Adaptation to Global Climate Change

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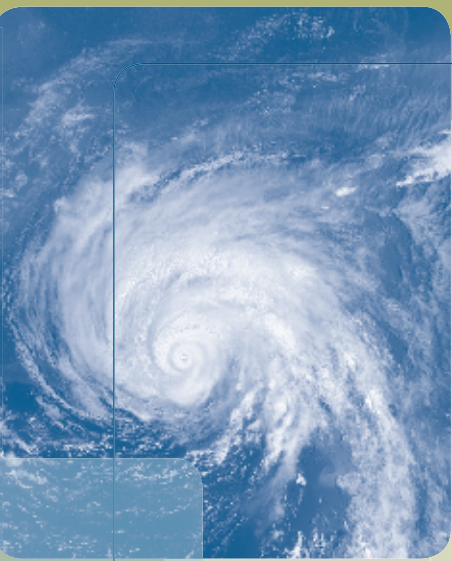
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## Executive Summary

### Background

Climate change will impact many sectors of the economy, and while required adaptations for some sectors already have been studied in depth, the same cannot be said of transportation infrastructure.

Rising sea levels, greater weather variability, and more extreme weather events like hurricanes, permafrost thawing, and melting Arctic sea ice are just some of the important changes that will impact transportation networks and infrastructure. Coastal areas are particularly vulnerable. A large portion of the nation's transportation infrastructure is in coastal zones: nearly half of the U.S. population lives within fifty miles of the coast,<sup>1</sup> and many roads, rail lines, and airports were built at or near water's edge to take advantage of available right-of-way and land. Increasingly intense storm activity and surges, exacerbated by rising sea levels, are putting an ever-increasing range of this coastal infrastructure at risk.

The costs of these climate impacts will most likely run into the billions of dollars. Costs will likely be highly variable — extreme events will incur large capital costs in very short periods of time, while other impacts (such as

<sup>1</sup> [http://www.census.gov/Press-Release/www/emergencies/coast\\_areas.html](http://www.census.gov/Press-Release/www/emergencies/coast_areas.html).



sea level rise) will require investments spread out over long periods, integrated with capital replacement cycles. In a recent example of response to extreme events, the Mississippi Department of Transportation (DOT) spent an estimated \$1 billion on debris removal, highway and bridge repair, and rebuilding the Biloxi and Bay St. Louis bridges in the four years following Hurricane Katrina, and CSX spent \$250 million rebuilding thirty miles of destroyed rail line. Longer term, a study by Associated British Insurers estimated that climate change could increase the annual costs of flooding in the United Kingdom almost 15-fold by the 2080s.<sup>2</sup>

At the heart of these policy discussions must be the recognition that strong efforts to reduce greenhouse gas (GHG) emissions from the transportation sector will not eliminate the need to prepare for the impacts of climate change processes that are already underway, and that proactive GHG reduction strategies and adaptation planning need to be undertaken concurrently. Because transportation infrastructure is built to last decades, and represents substantial national investment, it is critical that climate factors be incorporated in transportation siting, investment, and design decisions.

Taking action now to increase the transportation system's resilience will reduce long-term costs from climate change. The National Transportation Policy Project (NTPP) and the National Commission on Energy Policy (NCEP) commissioned this white paper to identify the policy options available to support proactive measures for addressing climate change adaptation in transportation. This white paper is intended to inform Congress and other policy-makers about policy options at the federal level that will ensure a robust transportation system in the face of a changing climate.

“A large portion of the nation’s transportation infrastructure is in coastal zones: nearly half of the U.S. population lives within fifty miles of the coast, and many roads, rail lines, and airports were built at or near water’s edge to take advantage of available right-of-way and land.”

### Recommended Climate Adaptation Policies for Short-Term Federal Legislative Action

Only the federal government can do the necessary interdisciplinary climate impact research, data gathering, modeling and forecasting, mapping, and structuring of the comprehensive planning necessary to ensure the resilience of our nation’s multimodal transportation systems, and the communities and businesses they serve. This federal legislative session provides a unique opportunity to address these emerging climate related infrastructure impacts. New federal surface transportation authorization is needed by October 1, 2009 and both Congressional leaders and the Administration have identified comprehensive climate and energy legislation as a priority this year.

#### Surface Transportation Authorization

The most important climate adaptation policy strategies for the federal-aid transportation system that should be incorporated into the next authorization are:

#### Support for Research Recommendations

- *Fund climate research. Authorize funding for the U.S. DOT and its Climate Center to fully*

<sup>2</sup> CCSP, 2008: *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I*. A Report by the U.S. Climate Change Science Program and Subcommittee on Global Change Research [Savonis, M.J., V.R. Burkett, and J.R. Potter (eds.)]. Department of Transportation, Washington, D.C., USA, 445 pp.

## “Taking action now to increase the transportation system’s resilience will reduce long-term costs from climate change.”

*participate in a multiagency, interdisciplinary, climate adaptation research program.* This program would engage both the transportation and climate research communities, with research priorities determined by the information and modeling needs of decision-makers at state and local transportation agencies. This research should include development of advanced climate modeling and integrated climate data and projections, infrastructure and system design standards to improve resilience of transportation in the face of climate change, and risk analysis tools geared towards integrating climate projections with transportation planning needs.

- *Authorize DOT participation in the National Climate Services program.* In parallel with the above recommendation, authorize U.S. DOT funding to support transportation aspects of the National Climate Services data and information clearinghouse recommended by NOAA’s Science Advisory Board.
- *Authorize and fund DOT participation in an interagency infrastructure mapping initiative.* This initiative would develop and make available consistent GIS data for the entire national transportation network and facilities, with a focus on data elements needed for assessing climate vulnerability, such as facility elevation data from LiDAR mapping technology and updates of Federal Emergency Management Agency (FEMA) floodplain maps in light of projected climate change.

### **Revised Planning and Project Development Recommendations**

- *Require climate adaptation to be addressed in the transportation planning and project development processes,* including: Making changes to the transportation planning factors, supporting

longer planning timeframes, providing guidance on the incorporation of quantitative and qualitative climate considerations and how to address uncertainty. In addition, the planning process should require the maintenance of nationally standardized data sources and modeling techniques for transportation climate adaptation planning and for input to project development.

- *Authorize formulation of a national policy and systematic approach to climate adaptation* for the nation’s transportation infrastructure. This should include establishing procedures for transportation risk assessment and adaptation implementation, and developing a process for inventorying and identifying transportation facilities that are vulnerable to climate change. It should authorize the U.S. DOT to lead an ongoing program for reevaluation of design standards for federally-funded infrastructure investments as progress is made in understanding future climate conditions and the options available for addressing them.

### **Program and Funding Recommendations**

- *Authorize capital and planning funding support* to enhance transportation resiliency, including funding states to conduct inventories of their transportation assets and locations that are vulnerable to climate change. Most importantly it should make infrastructure climate adaptation an eligible expense under the core highway and transit programs, based on a comprehensive system inventory and risk assessment.

### **Climate and Energy Legislation**

There is continued support in the Administration and Congress for a combined energy and climate bill. The House of Representatives passed H.R. 2454, the American Clean Energy and Security Act, by a narrow margin in June 2009. Although it contains a “Subtitle E — Adapting to Climate Change,” there is concern that adaptation issues, including transportation components, will get lost in the broader debate about cap-and-trade, carbon pricing, and the potential economic impact of these

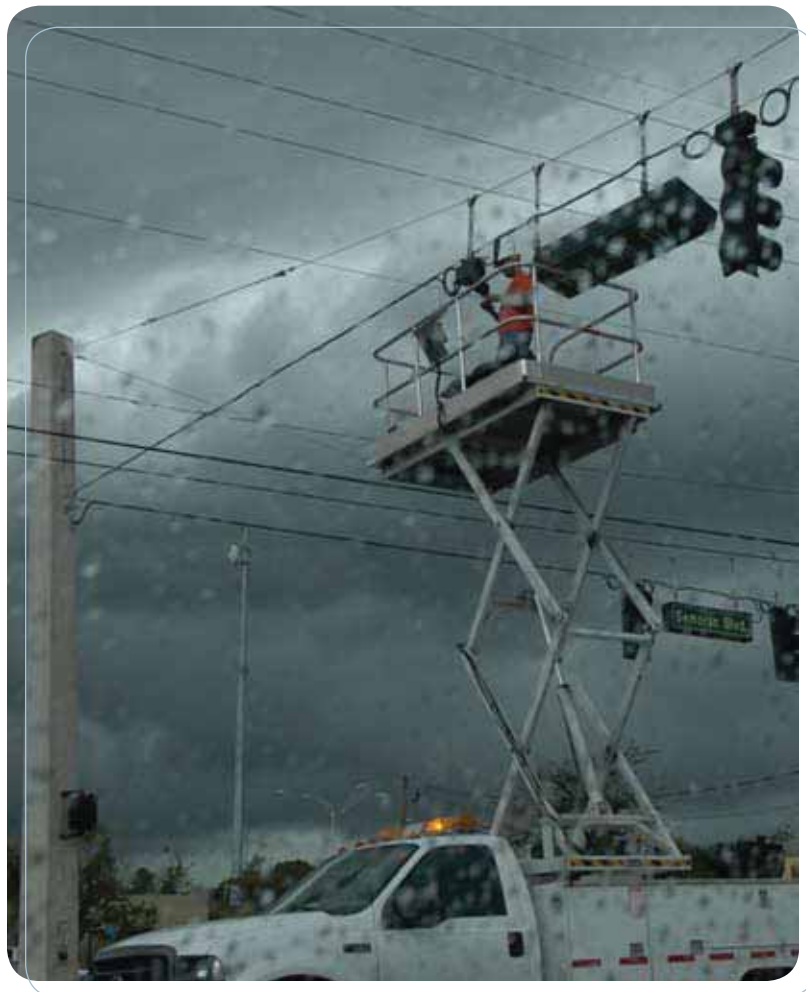
policies. Senators Kerry and Boxer introduced S. 1733, the Clean Energy Jobs and American Power Act, in September 2009, but it remains uncertain whether there is sufficient support in the Senate to pass an energy and cap-and-trade bill in this Congress. In principal, energy and climate legislation should specifically incorporate adaptation provisions directed toward transportation infrastructure into its scope. The bill should also establish and fund an interdisciplinary, long-term, climate-adaptation research and data program that provides climate data, mapping, and projections that can be readily used by planners and practitioners at regional scales, and that develops risk analysis tools, including national vulnerability standards. Importantly, the legislation should dedicate a portion of expected climate program revenues to conduct system inventories and risk analysis, and implement infrastructure adaptation strategies to address climate impacts.

### Executive Policy Action

Some transportation resilience actions can be implemented simply by Executive Order of the President. Some actions particularly suited for executive policy are:

- *Address project development/National Environmental Policy Act (NEPA) considerations.* Adaptation and resiliency considerations can permeate all aspects of the NEPA process, from shaping a project's purpose to its mitigation. Transportation and other planning and resource agencies will require guidance and support in developing feasible and appropriate techniques to incorporate climate information at the project level. This could include developing nationally standardized practice and data sources related to emerging climate impact information (including mapping data needs), developing guidance on the incorporation of climate considerations into project development, and developing guidance on educating stakeholders on climate adaptation considerations.
- *Incorporate climate risk analysis into Federal Infrastructure Investment policies.* Revise Federal

Infrastructure Investment Executive Order(s) to explicitly incorporate climate-related risk analysis into infrastructure investment plans and decision-making. This could include developing inventories of transportation facilities vulnerable to climate change, and developing updated construction standards to address transportation and other infrastructure in vulnerable locations.



- *Conduct a federal interagency assessment to develop and prioritize a climate adaptation research, data, and policy agenda.* This could be an important precursor to funding of a recommended interagency, interdisciplinary, long-term, national climate-adaptation research program in transportation and climate legislation this year.



## 1.0 Introduction

**C**limate change will impact many sectors of the economy, and while required adaptations for some sectors already have been studied in depth, the same cannot be said of transportation infrastructure.

Rising sea levels, greater weather variability, and more extreme weather events, like hurricanes, are just some of the important changes that will impact transportation networks and infrastructure. Transportation Research Board (TRB) Special Report 290 concluded that these impacts “will be widespread and costly in both human and economic terms and will require significant changes in the planning, design, construction, operation, and maintenance of transportation systems.”

Some important preliminary work has been done to identify the ways in which climate change will impact transportation, notably by the Transportation Research Board and the U.S. Department of Transportation, but less attention has been paid to the potential policy options for enabling transportation to successfully adapt in a timely manner. Yet there will be major costs and damages from these climate changes if policies are not implemented immediately to begin increasing the resilience of the transportation system to climate change. Action now will reduce long-term costs and result in a more resilient transportation system.

The National Transportation Policy Project (NTPP) and the National Commission on Energy Policy (NCEP) commissioned this white paper to identify the policy options available to support proactive adaptation measures for transportation. This white paper will serve to inform Congress and other policy-makers about policy options at the federal level to enable the transportation sector to identify risks and take effective action to ensure a robust transportation system in the face of a changing climate.

At the heart of these policy discussions must be the recognition that strong efforts to reduce greenhouse gas (GHG) emissions from the transportation sector will not eliminate the need to prepare for the impacts of climate

**“Rising sea levels, greater weather variability, and more extreme weather events, like hurricanes, are just some of the important changes that will impact transportation networks and infrastructure.”**

change processes that are already underway, and that proactive GHG reduction strategies and adaptation planning need to be undertaken concurrently. Because transportation infrastructure is built to last decades, and represents substantial national investment, it is critical that climate factors

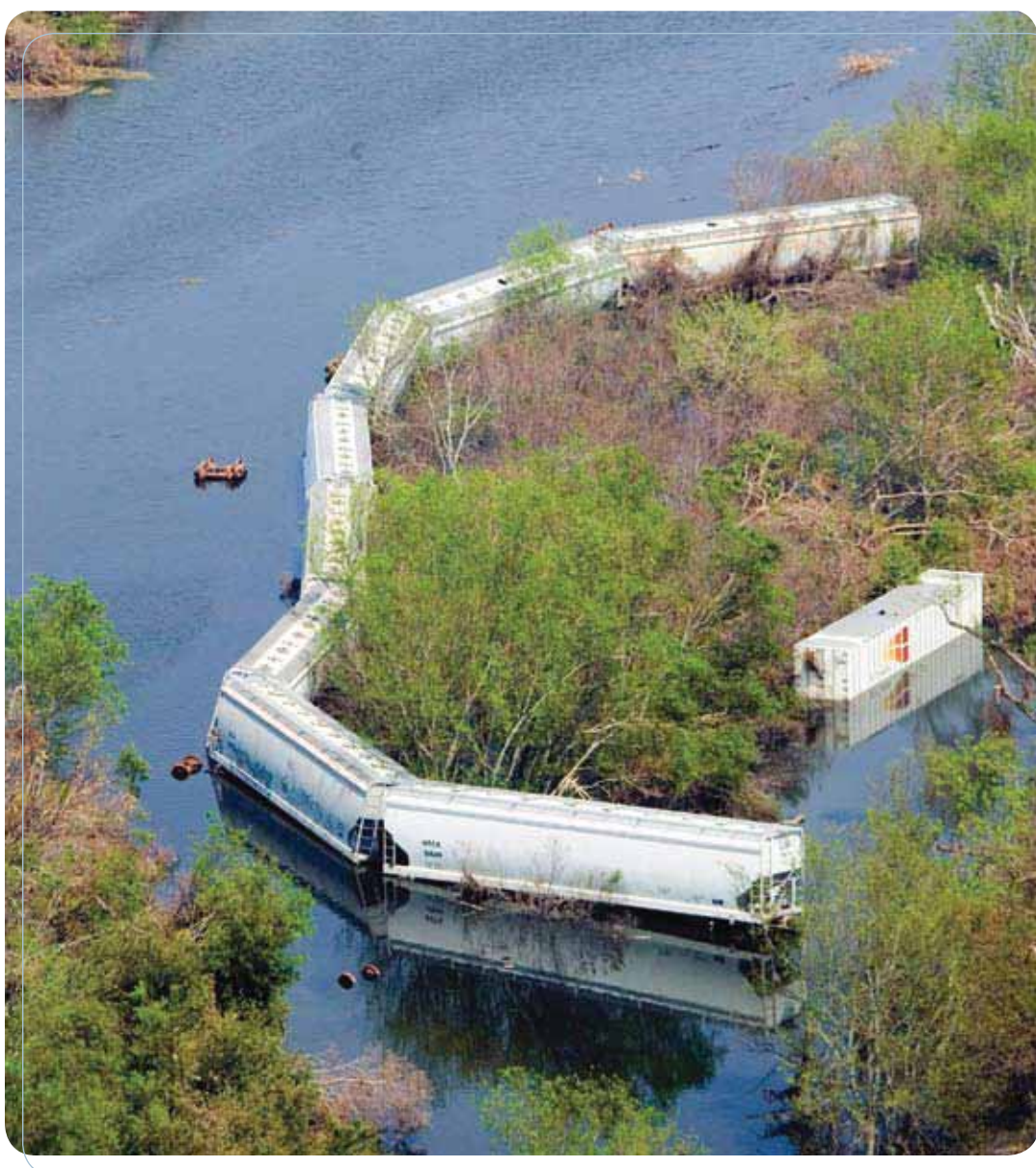


“**The adaptation challenge is further complicated by the range of institutional players at the local, regional, state, and federal levels involved in transportation, land use, and development planning...**”

be incorporated in transportation siting, investment, and design decisions. Figure 1.1 illustrates

the relationship of typical transportation planning processes and infrastructure service life to ongoing climate change impacts.

The adaptation challenge is further complicated by the range of institutional players at the local, regional, state, and federal levels involved in transportation, land use, and development planning — as well as the variety of policy and regulatory frameworks in which they operate. Federal leadership can address the institutional barriers that too often inhibit integrated community and regional



planning and investment, so that issues of equity, economic development, environmental stewardship, and sustainable communities are addressed in concert with infrastructure planning.

The findings and recommendations of this paper are based on a review of research and policy literature, interviews with senior policy-makers and managers of transportation agencies, a review of recent legislative initiatives, and the direct experience of the authors in climate impacts and adaptation work.

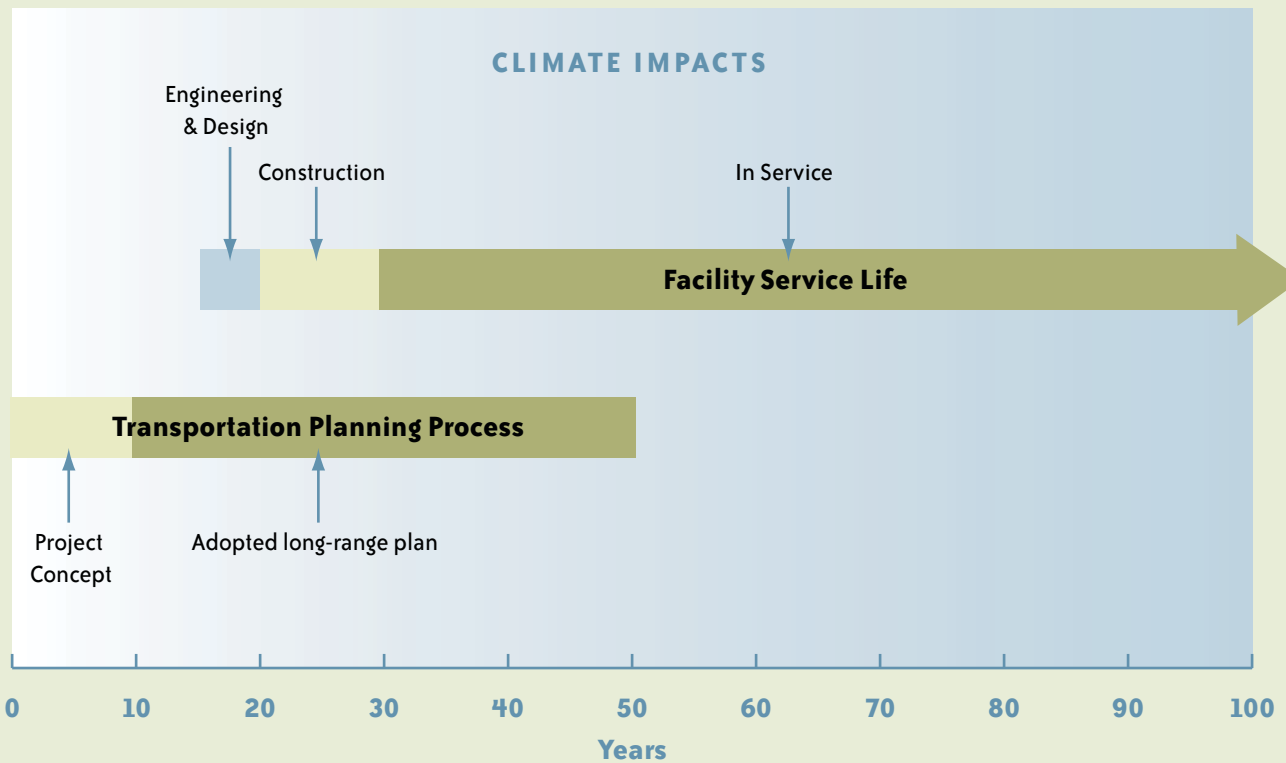
The white paper is organized as follows:

- **Section 2.0** provides an introduction to the potential impacts of climate change, their effects

on transportation, and some of the adaptation strategies and policies that have been recommended in the literature to address these impacts;

- **Section 3.0** summarizes legislative activity that has taken place at the state and federal level regarding adaptation;
- **Section 4.0** discusses recommended short-, medium-, and long-term policies needed to address climate impacts and adaptation for the U.S. transportation system; and
- **Section 5.0** presents near-term recommendations for advancing these policies through Federal legislation and policy.

**Figure 1.1 Relationship of Transportation Planning Timeframe and Infrastructure Service Life to Increasing Climate Change Impacts**



Source: CCSP, 2008: *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I*. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research [Savonis, M. J., V.R. Burkett, and J.R. Potter (eds.)]. Department of Transportation, Washington, D.C., USA.



## 2.0 Background on the Potential Impacts of Climate Change on **Transportation**

### 2.1 OVERVIEW OF THE SCIENCE

**T**he science of climate change has been studied extensively at the national and international levels.

The leading scientific body, the Intergovernmental Panel on Climate Change (IPCC), has been instrumental in documenting the state of knowledge on the extent of climate change, its causes, potential impacts, and levels of emission reductions needed to avoid the most dangerous effects. Global atmospheric concentrations of carbon dioxide (CO<sub>2</sub>), the most abundant greenhouse gas, have increased from 280 parts per million (ppm) in preindustrial times (around 1750) to 379 ppm in 2005.<sup>3</sup> Figure 2.1 illustrates both the increase in CO<sub>2</sub> concentrations (ppm) over this period and the dramatic increase in higher temperature anomalies in recent decades.<sup>4</sup>

Other significant greenhouse gases include water vapor, methane, nitrous oxide, and certain refrigerants. The 2007 IPCC report states that GHG

<sup>3</sup> Intergovernmental Panel on Climate Change (IPCC), 2007. Fourth Assessment Report, Climate Change 2007: Synthesis Report. Valencia, Spain.

<sup>4</sup> TRB, 2008: Potential Impacts of Climate Change on U.S. Transportation. Transportation Research Board (TRB) Special Report 290, Committee on Climate Change and U.S. Transportation, Transportation Research Board, Division on Earth and Life Sciences, National Research Council. Washington, D.C., USA, 280 pp.



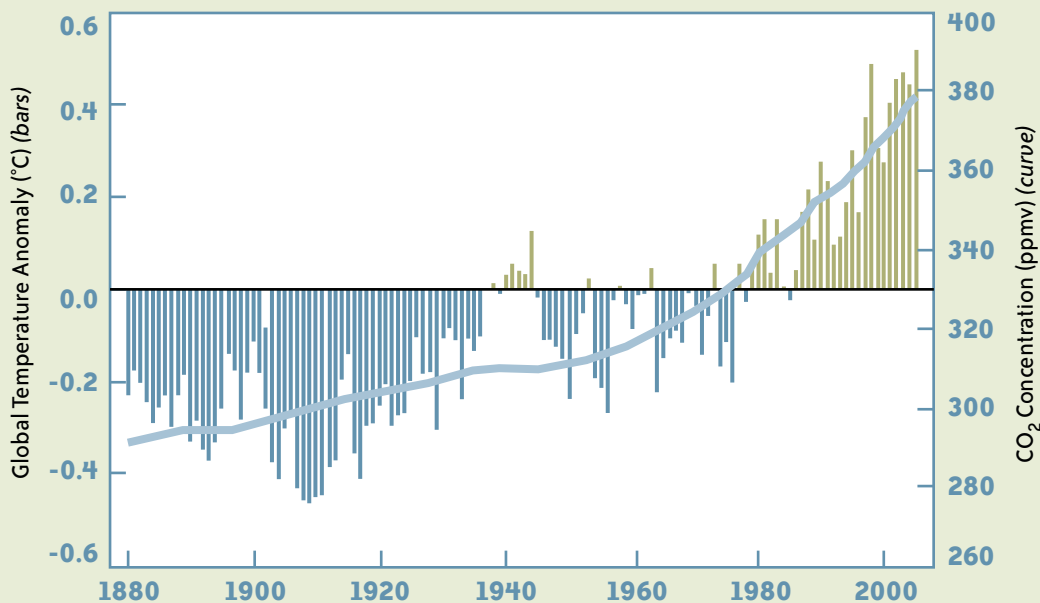
emissions from human activity are unequivocally warming the planet's climate. Further, the IPCC report finds that — even with a stabilization of GHG concentrations at current levels — the impact of climate change will lead to potential irreversible impacts.<sup>5</sup>

The IPCC projects that global temperatures will rise 1.1 to 6.4°C by 2100, and global sea level will rise 18 to 59cm. This warming will have many impacts: on ecosystems, food production, coastlines, human settlements, health, and water availability. Impacts from the changing climate will vary across the globe, and even within North America climate change will have different effects on different regions.

Some of the major impacts projected by the IPCC for North America include:

- Coastal communities and habitats will be increasingly stressed by climate change impacts interacting with development and pollution. Population growth and the rising value of infrastructure in coastal areas increase vulnerability to climate variability and climate change, with losses projected to increase as the intensity of tropical storms increases. Current adaptation efforts are uneven, and readiness for increased exposure is low.
- There is high confidence that many semiarid areas of the western United States will suffer a decrease in water resources due to climate change. Warming in the western mountain states is projected to cause decreased snow pack, more winter flooding, and reduced summer flows in rivers and streams, exacerbating competition for over-allocated water resources. The extent of drought-affected areas is projected to expand.

Figure 2.1 Average Surface Air Temperature and CO<sub>2</sub> Concentrations Since 1880



<sup>5</sup> Intergovernmental Panel on Climate Change (IPCC), 2007. Fourth Assessment Report, Climate Change 2007: Synthesis Report. Valencia, Spain.

- Disturbances from pests, diseases, and fire are projected to have increasing impacts on forests, with an extended period of high fire risk, and large increases in area burned. This will be most pronounced in western states.
- In the early decades of this century, moderate climate change is projected to increase aggregate yields of rain-fed agriculture by five to twenty percent, but with important variability among regions. Major challenges are projected for crops that are grown near the warm end of their suitable range or that depend on irrigation from highly utilized water resources.
- Cities that currently experience heat waves are expected to be further challenged by an increased number, intensity, and duration of heat waves during the course of the century, with

the potential for adverse health impacts. Elderly populations are most at risk.

- In the Arctic region, the main projected biophysical effect is the reduction in thickness and extent of glaciers, ice sheets, and sea ice. Some detrimental impacts to society include those on infrastructure, as well as on traditional indigenous ways of life. Potential beneficial impacts include reduced heating costs and more navigable northern sea routes.

The report also highlighted some specific impacts that are likely to affect transportation in the United States:

- Warmer winters will likely reduce delays, improve ground and air transportation reliability, and decrease the need for winter road maintenance;
- Increased coastal and riverine flooding and landslides will very likely result in negative impacts on transportation;
- Reduced water depth in the Great Lakes would lead to the need for “light loading,” resulting in adverse economic impacts;

“In the Arctic region, the main projected biophysical effect is the reduction in thickness and extent of glaciers, ice sheets, and sea ice.”



- Thawing permafrost caused by warming will likely adversely affect infrastructure for surface transport at high northern latitudes;
- An increase in the frequency, intensity, or duration of heat spells could cause railroad track to buckle or kink, and affect roads through softening and traffic-related rutting.<sup>6</sup>

## 2.2 Known and Potential Impacts to Transportation Infrastructure Previously Identified

A review of the literature indicates that climate change will affect all types of transportation modes (including both infrastructure and operations), and will encompass a range of climate change impacts spread over many geographic areas.

The literature review suggests that climate change impacts can vary considerably by region. Coastal areas in particular face major issues related to sea-level rise and coastal storms. The Arctic region has unique concerns related to rapidly changing conditions and the regionally-specific design and engineering of its transportation infrastructure. All regions face climate impacts of some type, however, such as intense precipitation events and extreme heat events.

The costs of these climate impacts will most likely run into the billions of dollars. Costs will likely be highly variable — extreme events will incur large capital costs in very short periods of time, while other impacts (such as sea level rise) will require investments spread out over long periods and integrated with capital replacement cycles. For instance, the Mississippi DOT spent an estimated \$1 billion on debris removal, highway and bridge repair, and rebuilding the Biloxi and Bay St. Louis bridges in the four years following Hurricane

Katrina, and CSX spent \$250 million rebuilding thirty miles of destroyed rail line. Neither of those figures includes the cost of disrupted or lost service. A study by Associated British Insurers that used insurance catastrophe models to examine the financial implications of climate change through its effects on severe storms estimated that climate change could increase the annual costs of flooding in the United Kingdom almost 15-fold by the 2080s under high-emissions scenarios. Less data is available on the incremental costs of climate change impacts. One study estimated that Boston would experience an 80 percent increase in flooding-induced traveler delay due to climate change; another found that barge shipping on the Mississippi could experience costs ranging from \$1.5 – 41 million per year due to excessively high or low water levels from changing precipitation patterns.<sup>7</sup>

The potential impacts on transportation cover a very wide range of climate change effects. Although these impacts are interactive and, therefore, not always neatly categorized, five groups of climate impacts are likely to be the most significant for transportation systems in the United States. The primary impacts that have been identified in the literature are:

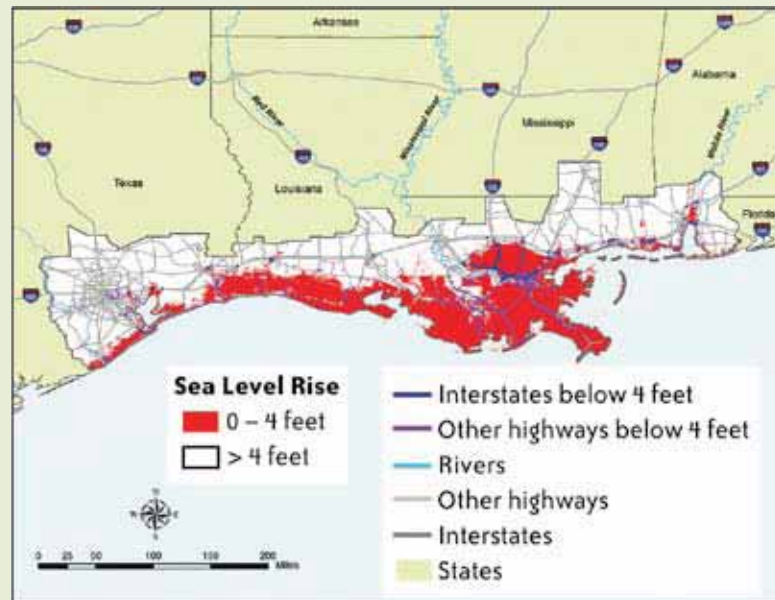
- Sea-level rise;
- Increased storm intensity;
- Changes in precipitation;
- Temperature increases;
- Arctic permafrost thawing and sea ice melt; and
- Other impacts.

These impacts are discussed in greater detail in the following pages.

<sup>6</sup>Field, C.B., L.D. Mortsch,, M. Brklacich, D.L. Forbes, P. Kovacs, J.A. Patz, S.W. Running and M.J. Scott, 2007: North America. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 617-652 pp.

<sup>7</sup>CCSP, 2008: *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I*. A Report by the U.S. Climate Change Science Program and Subcommittee on Global Change Research [Savonis, M.J., V.R. Burkett, and J.R. Potter (eds.)]. Department of Transportation, Washington, D.C., USA, 445 pp.

Figure 2.2 Gulf Coast Study: Highways Vulnerable to Relative Sea-Level Rise (RSLR) of Four Feet



Source: CCSP, 2008: *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I*. A Report by the U.S. Climate Change Science Program and Subcommittee on Global Change Research [Savonis, M.J., V.R. Burkett, and J.R. Potter (eds.)]. Department of Transportation, Washington, D.C., USA, #45 pp.

### 2.2.1 Sea-Level Rise

Rising sea levels can inundate coastal infrastructure and impact coastal areas. While incremental sea-level rise impacts may not be as immediate or severe as storm activity, the effects of sea-level rise could nevertheless seriously affect transportation. More than half of the nation's population lives in the 17 percent of its land area bordering the coastlines,<sup>8</sup> and a large portion of the nation's transportation infrastructure is located in coastal plains. In areas such as the Gulf Coast and North Carolina, rising sea levels are compounded by sinking land (subsidence), due to factors such as compacting sediments or tectonic forces.

The impacts of sea-level rise include increased inundation of coastal infrastructure, affecting all modes of transportation. Many roads and rail lines

were built at the water's edge to take advantage of more level routes or long available rights-of-way. Airports were often built in wetlands and other "undesirable" coastal areas that afforded large level plots of land. Underground transit facilities are particularly vulnerable to flooding where ventilation openings and other access points are not sufficiently elevated — as is the case in many coastal cities, such as New York. Rising sea levels also can affect low bridges, which may not have the clearances needed in the future.

A U.S. DOT study of the Gulf Coast region, for instance, found that a four-foot relative sea-level rise (a plausible scenario over the next century) would threaten 27 percent of major roads in the region (more than 2,400 miles of roadway), three-quarters of the ports, 9 percent of the rail miles

<sup>8</sup> Crosssett, K.M., T.J. Culliton, et al. (2004). *Population trends along the coastal United States: 1980-2008*, NOAA National Ocean Service, Management and Budget Office: 54.

operated, and three major airports;<sup>9</sup> Figure 2.2 illustrates the vulnerability of Gulf Coast highways to sea-level rise. Similarly, a study of Maryland's coastal vulnerability found that 423 km of the roadways are either at-risk or will face regular inundation from sea-level rise (classified by type, this ranges from a low of 3 percent of the State's interstates to a high of 18 percent on non-Interstate principal arterials impacted). In addition, a total of 283 km of the railroads in Maryland are expected to be impacted, representing 11 percent of the State's total.<sup>10</sup>

It is important to recognize that even protected or elevated facilities can be rendered inoperable by sea-level rise if connecting links are inundated, due to the networked nature of the transportation system. Highways lose their functionality if their approach ramps are underwater, even if the highway itself is elevated. For instance, many low-lying airports have protective levees for their airside facilities, but there may not be the same level of protection for off-airport landside links. Similarly, at ports, wharfs are generally built high enough to avoid sea-level rise impacts, but landside facilities (warehouses, container storage areas, etc.) and landside access may not be protected.

### 2.2.2 Increased Storm Intensity

Storms, particularly hurricanes, can cause major damage to transportation infrastructure. Increases in storm intensity will have significant impacts throughout the United States, especially in coastal areas. Transportation infrastructure already experiences storm impacts, but may not be designed to withstand a greater number of high-intensity storm events.

Among the most destructive effects of coastal storms are storm surges, which can cause

temporary disruptions (inundation of facilities that renders them inoperable until the surge subsides) and permanent damage, destroying bridges, pavement, and other structures. Hurricane Katrina storm surges, for instance, destroyed billions of dollars in infrastructure, including miles of coastal roads and rails and several major highway bridges. Storm surges will be exacerbated by further rising sea level, putting a greater range of infrastructure at risk. For instance, a Florida State University (FSU) study found that even if hurricane intensity did not change, sea-level rise of just one foot would triple the frequency of a seven-foot storm surge in coastal Florida from once every 76 years to once every 21 years.<sup>11</sup>

Changes in storm intensity, particularly when coupled with sea-level rise, will have major



<sup>9</sup> CCSP, 2008: *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I*. A Report by the U.S. Climate Change Science Program and Subcommittee on Global Change Research [Savonis, M.J., V.R. Burkett, and J.R. Potter (eds.)]. Department of Transportation, Washington, D.C., USA, 445 pp.

<sup>10</sup> ICF International, 2007: *The Potential Impacts of Global Sea Level Rise on Transportation Infrastructure Phase 1 - Final Report: the District of Columbia, Maryland, North Carolina and Virginia*.

<sup>11</sup> Harrington, J. and T. Watson: *Climate Change in Coastal Florida: Economic Impacts of Sea Level Rise*. Florida State University, 2008.

“Low-lying evacuation routes may not be available in the future, and the increase in frequency of evacuations will call for additional resources devoted to the problem.”



implications for emergency management as well. Low-lying evacuation routes may not be available in the future, and the increase in frequency of evacuations will call for additional resources devoted to the problem. Offshore pipelines are also vulnerable to hurricanes, with wave action and seabed erosion particularly affecting pipelines in shallow waters (as found in the Gulf of Mexico petroleum collection networks). Larger on-shore pipelines also face disruption from storm-induced power outages. For instance, after Hurricane Katrina, gasoline shortages were experienced along the East Coast because pipelines originating in the

storm-damaged region were not operating from lack of power.<sup>12</sup>

Not all impacts are restricted to coastal storms and hurricanes. High storm winds also cause damage to signage and overhead cables, as well as to warehouse facilities at intermodal sites (which tend to be lightly built), and disrupt roadway operations with downed trees and debris. Potentially increased storm activity could include an increase in lightning strikes, which can disrupt electronic transportation infrastructure, such as signaling. On the other hand, decreases in winter snowstorms (e.g., with more winter precipitation falling as rain due to higher temperatures) could reduce winter maintenance needs and costs, reduce use of environmentally damaging winter road maintenance substrates, and positively impact safety.

### 2.2.3 Changes in Precipitation

Projected changes in annual precipitation are not consistent across the United States, with regional models showing increases in some areas and decreases in others. Increasing rates of annual average precipitation can render stormwater facilities inadequate, lead to deteriorating water quality due to run-off and sedimentation, degrade infrastructure, and change soil conditions (with impacts such as subsidence and heave, landslides, and structural instability). Decreasing precipitation rates also can create problems, particularly in drying and shrinking of soils, affecting the base under pavements and other structures. Warming temperatures also will likely result in a shift from snowfall to rainfall, potentially relieving areas that typically see large amounts of snow from some of the cost of maintaining winter roads.

A potentially more significant concern across the nation is a projected increase in the *intensity* of precipitation events. Extreme rainfall events can overwhelm stormwater management systems, lead to more flooding, and increase run-off issues

<sup>12</sup> CCSP, 2008: *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I*. A Report by the U.S. Climate Change Science Program and Subcommittee on Global Change Research [Savonis, M.J., V.R. Burkett, and J.R. Potter (eds.)]. Department of Transportation, Washington, D.C., USA, 445 pp.

throughout the nation. For instance, Tropical Storm Allison caused widespread flooding of Houston’s freeway system in 2001 due not to storm surge, but rather to the intensity, and duration of the rainfall.

Changes in precipitation, coupled with increasing temperatures, also will have important effects on the nation’s inland waterway system. The Great Lakes are projected to experience declining water levels that will impair shipping; for each inch of lost draft a 1,000-foot bulk carrier loses 270 tons of capacity.<sup>13</sup> If lower water levels occur on a regular basis, Great Lakes shippers will be less competitive with other competing modes such as rail or truck.<sup>14</sup> Declining water levels would also result in increased costs and environmental impacts from increased dredging. Projections are less certain for the Mississippi River system, but both drought and flood conditions can stop barge traffic on the river system, greatly affecting the ability to move agricultural products from the interior to market.

#### 2.2.4 Temperature Increases

Increasing temperatures will have a number of effects on both structures and operations. These will result from both increases in average annual temperatures as well as increases in temperature extremes (very hot days). As with precipitation, in many cases the change in the extremes will be more significant than changes in average temperatures.

Pavement damage (such as rutting and shoving) and rail buckling (“sun kinks”) will increase with very hot days. An increase in the frequency of very hot days also may cause delays in the air travel system at airports where runway length is not sufficient to compensate for decreased lift for aircraft on hot days; this will be particularly true at high-altitude airports. Increased energy consump-

tion and costs will be experienced for refrigerated cargo transport, and transit systems also will face increased air conditioning costs.

Shorter winters also will reduce ice cover on the inland waterway system, increasing the shipping season. However, as noted previously, in the Great Lakes this benefit will likely be offset by lower water levels — a robust finding of the climate models. In another freight-related issue, some northern states allow higher trucking weight limits in wintertime, when the frozen ground provides better support for the roadbed. This season will be shortened as winters warm, decreasing load capacity for trucks in those regions.

“A potentially more significant concern across the nation is a projected increase in the intensity of precipitation events.”



<sup>13</sup> CCSP, 2008: *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I*. A Report by the U.S. Climate Change Science Program and Subcommittee on Global Change Research [Savonis, M.J., V.R. Burkett, and J.R. Potter (eds.)]. Department of Transportation, Washington, D.C., USA, 445 pp.

<sup>14</sup> TRB, 2008: Potential Impacts of Climate Change on U.S. Transportation. Transportation Research Board (TRB) Special Report 290, Committee on Climate Change and U.S. Transportation, Transportation Research Board, Division on Earth and Life Sciences, National Research Council. Washington, D.C., USA, 280 pp.



Construction and maintenance also will be affected. Shorter winters will lengthen the construction season in some parts of the country, but an increased number of very hot days will limit construction and maintenance activities in the summertime. In another maintenance-related impact, freeze-thaw cycles will likely shift in location and duration. Although areas that currently experience the most damage from freeze-thaw effects on pavement and infrastructure may benefit from warmer temperatures, it is likely that areas that currently experience consistently below-freezing temperatures will see an increase in maintenance and repair costs as temperatures more often cross the freezing point as part of the daily temperature cycle.

A more difficult to assess secondary effect is changes in production and demographics that will affect transportation demand. Agricultural production in particular will be impacted by a changing climate. This could have major impacts

on use of the inland waterway system, which is the primary outlet for much of the heartland's produce. Demographic shifts could result as populations move to cooler areas or away from vulnerable coastal areas, or as resort and recreation areas change. Potentially, this may result in new infrastructure needs in areas of population growth, while areas that experience population declines may be overserved by existing infrastructure, making it difficult to maintain cost-effectively.

#### **2.2.5 Arctic Permafrost Thawing and Sea Ice Melt**

Arctic transportation systems face a unique set of concerns related to climate change, for two reasons. First, the Arctic already is experiencing more rapid warming than the rest of the United States, and this trend is projected to continue by almost all climate models as the pace of global warming accelerates. Secondly, the Arctic regions have transportation systems and construction



techniques that are not commonly used elsewhere in the United States that will be particularly impacted by warming temperatures. The northern latitudes confront unique issues related to the thawing of permafrost foundations under infrastructure, shorter seasons for ice roads, and significant ecological changes.

A large portion of the region's transportation infrastructure is built on permafrost foundations, which are thawing as winters become shorter and temperatures rise. This already is causing major damage to the regions roads, airports, railways, and other infrastructure. In addition, the region is unique for the network of ice roads that are used every winter (and are the basis for *Ice Road Truckers*, a popular Discovery Channel reality television show). In Alaska, many of these roads are "built" each winter and are the only way to move heavy goods into many rural communities. Shorter winters are cutting into the construction season and greatly reducing the ice road trucking season. On the other hand, longer ice-free seasons on the regions waterways will increase their use for shipping.

The literature indicated that the reduction of waterway ice cover and the eventual opening of an Arctic Northwest Passage may have by far the largest economic consequences of all the impacts, changing sea shipping routes throughout the globe while dramatically altering the region's ecology.<sup>15</sup> The passage could provide an alternative to the Panama Canal and stimulate economic development in the Arctic region. It could also result in a host of new environmental impacts on the region from the influx of shipping, including air and water quality impacts. An additional complication introduced by the opening up of Arctic sea

“Construction and maintenance also will be affected.”

routes is balancing the fragile relationship among countries with competing claims to Arctic territory.<sup>16</sup> Sovereignty issues will need to be resolved to clarify whether the passage will be considered to be international or Canadian waters.<sup>17</sup>

### 2.3 Adaptation Strategies Recommended by Others

Adaptation (as defined by McKeown and Gardner) includes changes in policies and practices designed to deal with climate threats and risks. Adaptation can refer to changes that protect livelihoods, prevent loss of lives, or protect economic assets and the environment.<sup>18</sup> In the context of transportation, adaptation can be thought of as the transportation sector's response to the climate impacts discussed above: what can or should be done to help the transportation system respond to the changing climate?

A range of adaptation and resiliency strategies are necessary to address the various climate change impacts to the transportation system discussed in the preceding section. These include both near-term and longer-range actions, including:

- **Operational.** In the short term, changes in operations and maintenance practices due to changes in the climate and climate extremes are necessary and already are happening in some areas. These responses include incorporating extreme weather events into routine operations, improving collaboration with weather and emergency management as part of agency

<sup>15</sup> TRB, 2008: Potential Impacts of Climate Change on U.S. Transportation. Transportation Research Board (TRB) Special Report 290, Committee on Climate Change and U.S. Transportation, Transportation Research Board, Division on Earth and Life Sciences, National Research Council. Washington, D.C., USA, 280 pp.

<sup>16</sup> [http://hosted.ap.org/dynamic/stories/E/EU\\_ICELAND\\_NATO?SITE=FLPET&SECTION=HOME&TEMPLATE=DEFAULT&CTIME=2009-01-29-16-58-04](http://hosted.ap.org/dynamic/stories/E/EU_ICELAND_NATO?SITE=FLPET&SECTION=HOME&TEMPLATE=DEFAULT&CTIME=2009-01-29-16-58-04).

<sup>17</sup> CCSP, 2008: *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I*. A Report by the U.S. Climate Change Science Program and Subcommittee on Global Change Research [Savonis, M.J., V.R. Burkett, and J.R. Potter (eds.)]. Department of Transportation, Washington, D.C., USA, 445 pp.

<sup>18</sup> State of the World 2009: Climate Change Reference Guide and Glossary. Alice McKeown and Gary Gardner.

operations, and sharing best practices. Maintenance and asset management practices may need to be updated to accommodate changes in environmental factors (changes to freeze/thaw cycles, for instance).

- **Design.** Design changes to new infrastructure to address future climate conditions will mitigate some expected impacts. In the medium term, changes in design and materials (revision of design standards to address climate change impacts, or rehabilitation to meet revised standards) can protect infrastructure from climate changes. In addition, monitoring and use of sensor technology can provide advance warning of potential infrastructure failures due to the effects of weather and climate extremes on transportation systems.
- **Land Use.** Long-term adaptation strategies might include changes in land use management policies in order to reduce risks to people and transportation infrastructure by avoiding areas vulnerable to climate change. Changing conditions may necessitate the relocation of existing infrastructure. Land use also may be utilized to realize the potential of natural systems (such as wetland buffers) to reduce risk to both infrastructure and communities.
- **Planning and Institutional Changes.** Institutional changes to integrate consideration of climate impacts into the transportation planning and investment decision-making process, along with more comprehensively incorporating other planning processes (e.g., economic development and ecological systems), will result in more resilient and cost-effective transportation systems. Possible changes that could be made include: lengthening the planning horizon of the transportation system past its current twenty- to thirty-year outlook, introducing risk assessment and vulnerability analyses, incorporating climate change into NEPA considerations, and forming new institutional arrangements and partnerships. In the short run, these changes may be driven by immediate local concerns about

specific climate factors. For instance, a 2005 study recommended that the Seattle Department of Transportation synchronize sea-level rise assumptions among Seattle's various city agencies (for instance, in the assumptions made for construction of seawalls) (Soo Hoo et al., 2005). In the longer term, a systematic approach is required to incorporate a range of climate information into transportation decisions.

The adaptation responses described above can be thought of as lying on a continuum of planning and investment choices. Each requires different management actions and provides different benefits and costs to the agency. The range of adaptation strategies can be divided into four categories of options:

- 1. Manage/Maintain.** These strategies assume that an increasing cost to repair and maintain infrastructure will be experienced due to increasing stress from severe events. A shorter service life also is possible due to increased climate stress. An incremental approach of absorbing increased damage into annual maintenance cycles may be a reasonable and cost-effective strategy for infrastructure that is at lower risk or is less significant to overall mobility goals.
- 2. Protect/Harden.** These strategies enhance the resilience of infrastructure through techniques such as changing design standards (e.g., higher bridge heights, elevated roadways), building engineered protection (e.g., levees), developing or enhancing natural buffers (e.g., wetlands), etc. Essentially, this approach tries to ensure that existing and future infrastructure withstands projected changes in climate. It is most appropriate for critical infrastructure that is at risk and needs to stay in operation.
- 3. Develop Redundant Services.** These strategies prepare for intermittent loss of service by developing alternate routes or services to maintain continuity of travel when service is disrupted.
- 4. Relocate/Abandon.** These strategies focus on reducing the exposure of infrastructure by

moving service to lower-risk areas. For instance, the increasing vulnerability of some coastal areas may make their continued operation infeasible. In some ways, this is the most radical option; transportation corridors have historically rarely been completely abandoned in the United States. Of course, as communities and businesses themselves relocate, infrastructure needs also will shift.

## 2.4 Policy Option Areas Recommended by Others

The previous sections highlight the need for adaptation planning at the national, state, and local levels to address the potential impacts of climate change on the nation's transportation infra-

**“Long-term adaptation strategies might include changes in land use management policies in order to reduce risks to people and transportation infrastructure by avoiding areas vulnerable to climate change.”**

structure. A wide range of policy options have been presented in the literature regarding adaptation approaches to deal with the impacts of climate change, as shown in Table 2.1 (see page 28). For our purposes, these policy options can be thought of as addressing one of five different areas:





“Climate risks and adaptation options need to be integrated into the transportation planning process.”

- **Research.** A summary of the policy options underscores the need for further research to develop successful approaches to adaptation. Research needs span both the climate science and transportation arenas and include: applied studies — such as the development of methods for transportation practitioners to inventory transportation assets, the development of a climate data clearinghouse for use by transportation agencies, and more advanced climate research to develop more accurate “downscaled” regional models that can provide outputs for the diverse range of geographies across the nation. Another critical research need cited is for improved monitoring technologies to provide transportation officials with advance warning of potential structural failures due to climate change impacts.
- **Planning.** Climate risks and adaptation options need to be integrated into the transportation planning process. Because of the important role of state and local governments in the operations
- and maintenance of the transportation system in the nation, there is an increased need to encourage cross-disciplinary coordination and collaboration among the various government agencies, as well as with the private sector (for example, the private sector railroad operators who own and maintain the majority of the nation’s rail network). Another key policy option is the expansion of planning timeframes that agencies would need for incorporating the impacts of climate change into their long-range vision plans. The timeframes generally used for the federal transportation planning process — 20 to 30 years — are short compared to the multi-decadal period over which climate changes occur. While the current timeframe is realistic for investment planning, agencies need to consider incorporating longer-term climate change effects into their visioning and scenario planning processes that inform their long-range plans. The literature also identified a need for decision support tools to support the planning process, such as risk assessment tools and adaptive management approaches.
- **Design standards.** Development of new design standards also is identified as a need to incorporate the impacts of climate change into design and operations. This includes both infrastructure design standards as well as revision of flood frequency standards to reflect climate projections rather than only historic trend data (e.g., the 100-year flood may now be a 25-year flood). Along with new design standards there is a need to develop ways to share best practices for adaptation design strategies which state and local governments can easily access.
- **Project delivery and the NEPA process.** The fourth category of policy options is the project delivery and the NEPA process. For example, by updating federal agency regulations and procedures pertaining to climate impacts and adaptation strategies, state, and local agencies can better ensure efficiency in adaptation planning and implementation. A collaborative

and flexible approach to the federal permitting process can allow state and local agencies to align their efforts.

- **Funding, performance, and accountability.**

The final category of policy options revolves around funding, performance, and accountability. These policy options range from assessing the long-term costs and benefits of adaptation measures to developing performance measures to determining how to prioritize and fund adaptation projects. The funding mechanisms at the federal and state level can provide incentives for addressing climate change impacts through proactive adaptation planning.

## 2.5 Summary of Key Findings from Existing Studies

The literature reviewed for this paper suggests that potentially the greatest impact of climate change for North America's transportation systems will be flooding of coastal roads, railways, transit systems, and runways because of global rising sea levels, coupled with extreme storm events and storm surges, and exacerbated in some locations by land subsidence. Flooding also will be a concern in non-coastal areas due to an increase in heavy precipitation events. Other impacts include extreme hot days and heat waves. Finally, the Arctic transportation systems face a unique set of concerns related to climate change, including the thawing of permafrost foundations under infrastructure, shorter seasons for ice roads, and significant ecological changes.

One of the important findings of the literature is the need to develop a process for identifying assets and locations that are vulnerable to climate change. The process should use specific local information and knowledge, and incorporate region-specific climate change forecasts and scenarios. The process also would make use of geospatial techniques to better analyze the spatial relationships among topography, development,

and climate. Identifying and prioritizing vulnerable assets is critical to determine which assets require adaptation; identifying vulnerable locations is important to enable communities to proactively minimize future risks.

A fundamental conclusion drawn from the literature is that sound adaptation planning is grounded in a risk-assessment approach. To take effective action, it is essential to understand where transportation services are vulnerable — particularly the most critical points in the system — and how that vulnerability will change over time. This risk can then be assessed alongside other risks to decide what action is appropriate: Is an engineering intervention required immediately? Can intervention wait for the relevant point in the maintenance or reconstruction cycle? Is another management or policy response needed? There is a critical need to develop and refine risk-assessment and management approaches that meet the needs of transportation decision-makers.

One approach that has relevance to climate adaptation and risk analysis is the experience on earthquake retrofitting for bridges. Following the 1994 Northridge earthquake in California, the U.S. Congress passed legislation allowing the use of Federal Highway Bridge Replacement and Rehabilitation Program (HBRR) funds for the seismic retrofit of nondeficient bridges (as defined by the National Bridge Inspection Standards). The seismic retrofit program in California has evolved into a highly sophisticated system. The screening program that began in the early 1990s incorporates a risk algorithm that evaluates the major factors that affect seismic performance, such as structural details, earthquake fault proximity, soil conditions, etc., as well as factors for hazard and risk. While assessing risk due to climate factors is more complex, the experience in assessing seismic risk may help inform the development of approaches to the climate risk assessment challenge.

Table 2.1 Policy Options for Adapting Transportation to Climate Change Identified in Other Sources

Policy Categories	Policy Overview	Policy Description
Research	Develop appropriate model outputs	Develop methods for translating climate change modeling outputs that specifically account for climate change scenarios and different geographies. Integrate climate data and projections, including higher resolution of climate models for regional and sub-regional studies, and more information about the likelihood and extent of extreme events.
Research	Interdisciplinary research	Provide ongoing support for climate research. Conduct interdisciplinary research that engages both the transportation and climate research communities. Climate research should include the needs of transportation decision-makers.
Research	Monitoring technologies	Federal and other research programs should develop monitoring technologies that provide advance warning of impending failures due to weather/climate.
Research	Establish data clearinghouse	NOAA, DOT, and USGS should establish a climate change and transportation clearinghouse on mitigation and adaptation in transportation. FEMA should re-evaluate/update the National Flood Insurance Program and its maps to account for climate impacts.
Research	Inventory assets	Provide guidance and technical assistance on vulnerable infrastructure inventorying, including data collection methods and management. Federal/state/local governments and other infrastructure owners should inventory transportation infrastructure and locations that are vulnerable to climate impacts.
Research	Identify secondary impacts	Conduct research on demographic responses to climate change, land use interactions, and secondary and national economic impacts.
Research/Planning	Educate stakeholders	Understand stakeholder/community response to adaptation. Help citizens, communities, and industries understand the risks of climate change impacts and their role in adaptation efforts.
Planning	Support decision-making	Provide affordable modeling and adaptation planning tools to states and localities to help identify sectors at risk and assess vulnerable systems to support decision-making.
Planning	Coordination and collaboration	Facilitate and support cross-disciplinary coordination and collaboration among state and local agencies, governments, and the private sector, especially for cross-boundary impacts and adaptation plans. Develop policies to mitigate interstate impact and adaptation issues.
Planning	Emergency preparedness planning	Develop climate change strategies to integrate emergency response into operations and build on experience of those places where transportation is well integrated into emergency planning. Update federal emergency preparedness plans to include potential climate change impacts and set guidelines for state preparedness plans.

## Source

FHWA: Peer Workshop on Adaptation to Climate Change Impacts (2008).

Pew Center: Climate Change 101 (2009).

DOT/CCSP: Impacts of Climate Change on Transportation: Gulf Coast Study Phase I Recommendations (2008).

DOT/CCSP: Impacts of Climate Change on Transportation: Gulf Coast Study Phase I Recommendations (2008).

TRB Special Report 290: Potential Impacts of Climate Change on U.S. Transportation (2008).

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Pew Center: Climate Change 101 (2009).

McNeil: Adaptation Research Programs and Funding (Draft 2009).

Table 2.1 Policy Options for Adapting Transportation to Climate Change Identified in Other Sources *(continued)*

Policy Categories	Policy Overview	Policy Description
Planning	Expand planning timeframes	Agencies need to consider incorporating longer-term climate change effects into their visioning and scenario planning processes that inform their long-range plans. Federal planning regulations should recommend including climate change as factor in long-range plans (including longer time horizons, greater coordination with other agencies).
Planning	Refine risk analysis tools	Planners/engineers require support to develop and use probabilistic techniques in risk analysis tools to address the uncertainties that are inherent in projections of climate phenomena.
Planning	Land use	Work with appropriate agencies to influence land use decisions by developing disincentives for inappropriate or high-risk development.
Planning/Design Standards	Develop risk assessment/adaptive management approach	Adopt an iterative risk management approach to provide transportation decision-makers, public officials, and the public a more robust picture of the risks to — and level of resilience of — various components of the transportation network. Provide assistance and guidance on risk management approaches and methodologies.
Planning/Design Standards	Incorporate climate change	Develop strategies for state/local governments and private owners to incorporate climate change into long-range planning, design, and operations.
Planning/Design Standards	Sharing best practices	AASHTO, APTA, and others should develop ways of sharing best practices for climate change adaptation. Catalogue state and global solutions on research and best practices and oversee efficient dissemination to jurisdictions.
Design Standards	Develop new design standards	DOT should lead a federally-funded research program to develop new design standards to incorporate climate change. Develop strategies and tools to change methods, codes and design standards. Infrastructure renewal provides an opportunity to implement adaptation. State/federally-funded rehabilitation projects in vulnerable locations should be rebuilt to higher standards, with better redundancy. Develop flexible design guideline manuals on climate change adaptation for use in different situations and environments.



## Source

DOT/CCSP: Impacts of Climate Change on Transportation: Gulf Coast Study Phase I Recommendations (2008).

TRB Special Report 290: Potential Impacts of Climate Change on U.S. Transportation (2008).

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FHWA: Peer Workshop on Adaptation to Climate Change Impacts (2008).

Table 2.1 Policy Options for Adapting Transportation to Climate Change Identified in Other Sources *(continued)*

Policy Categories	Policy Overview	Policy Description
Project Delivery/ NEPA process	Update federal agency regulations	Require climate change adaptation screening in Environmental Impact Assessments. Review and update federal agency regulations and procedures where climate impacts and adaptation are relevant. Ensure efficiency in adaptation resource planning and implementation. Develop a collaborative and flexible approach to the federal permitting process that is aligned with DOTs regarding data, methods, and processes.
Funding/ Performance/ Accountability	Funding adaptation	Identify strategies to fund climate change adaptation. Incentives in federal/state legislation should be used as a means to address climate impacts through regional and multistate efforts. Require states to include climate impact projections in projects requesting federal funding. Provide resources to states and localities lacking sufficient funding for proactive adaptation planning.
Funding/ Performance/ Accountability	Institutional changes	Make institutional changes to facilitate integration of climate change impacts into the decision-making process for transportation planning and investment. DOT should develop an interagency, adaptation working group.
Funding/ Performance/ Accountability	Prioritization framework	Develop prioritization frameworks for climate change adaptation needs in the context of overall transportation investment, and between adaptation and mitigation-related investments.
Funding/ Performance/ Accountability	Assessment of cost and benefits	Provide guidance to identify opportunities for adaptation and to assess cost estimates and benefits for adaptation initiatives and programs.
Funding/ Performance/ Accountability	Performance measures	Develop performance measures to inform prioritization and decision-making on adaptation approaches and projects.

## Source

Pew Center: Climate Change 101 (2009).

FHWA: Peer Workshop on Adaptation to Climate Change Impacts (2008).

TRB Special Report 290: Potential Impacts of Climate Change on U.S. Transportation (2008).

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## 3.0 Legislative and Executive Vehicles for **Adaptation Policy**

**B**roadly speaking, climate change adaptation is an increasingly important focus of legislative and executive activity, and current momentum appears likely to drive federal legislation in the 111<sup>th</sup> Congress.

However, most adaptation policy is not directed specifically at infrastructure; the same holds true for legislative and executive proposals. Further, efforts reviewed at both the state and federal levels indicate that many difficult decisions are yet to be addressed.

This section first briefly summarizes bills from the 110<sup>th</sup> and 111<sup>th</sup> Congress that in some manner address adaptation with respect to infrastructure, with emphasis on the most promising proposals. To date, most of the legislative initiatives that address adaptation were introduced in the 110<sup>th</sup> Congress.

Next, selected states' legislative and executive actions that are underway are examined. Finally, we provide a brief look at adaptation measures being implemented in other countries, as a point of comparison.

### 3.1 Analysis of 110th Congress Bills

Table 3.1 provides a summary of relevant adaptation bills proposed in the 110<sup>th</sup> Congress. Review of the foregoing bills reveals a broad spectrum of approaches to adaptation policy, both geographically and in terms of

priorities. S. 2211, H.R. 5453, and S. 2191 are focused almost exclusively on ocean and coastal areas. Ecologically focused, the primary intent of these bills is to remediate the effects of climate change and ocean acidification on fish, wildlife, and habitats. Each would involve infrastructure and land use adaptation efforts only in coastal zones, although S. 2211 includes the Great Lakes and major river systems. All three bills would involve state resiliency planning efforts through coastal zone management programs. While these bills do account for sea-level rise impacts on coastal areas, and potentially more intense storm impacts, impacts inland would not be addressed, nor would other effects of climate change.

All of the bills that would require vulnerability assessments broadly address infrastructure. S. 280, H.R. 620, H.R. 4226, H.R. 3221, and H.R. 6186 specifically call for such assessments, and S. 2355 would mandate assessments of “Federally-managed resources.” For recurring infrastructure assessments, H.R. 3221, and S. 2355 require updates every five years, and H.R. 6186 requires updates every four years. S. 2355 and H.R. 6186 would create ongoing national climate programs to handle these requirements, while H.R. 3221 simply assigns the duty to “the President.”

Of the bills reviewed, H.R. 3221 and H.R. 6186 provide the most comprehensive approaches to adaptation in general, and have a sustained focus on impacts to infrastructure. H.R. 3221 and H.R. 6186 provide contrasting approaches, however. H.R. 3221 provides for global change research and contains within that charge the requirement to assess impacts. In terms of specific adaptation policy, the bill is short and straightforward (two pages). H.R. 6186 is much more descriptive and proscriptive with respect to adaptation, treating it more as a stand-alone research and policy area. In general, both would provide fairly comprehensive analyses of expected impacts and guidance for high-level policy for adaptation for infrastructure, as well as other impacted systems. H.R. 3221, and H.R. 6186 also both

“**Ecologically focused, the primary intent of these bills is to remediate the effects of climate change and ocean acidification on fish, wildlife, and habitats.**”

contain provisions dealing with international impacts, although H.R. 6186 is only directed at low-income and developing countries.

Each bill leaves key points open that would require elaboration through regulation or guidance. For example, neither provides a definition of “vulnerable.” Since both bills would make “vulnerability” the cornerstone of planning and decision-making, some working definition of the term will be required to provide direction.

Further, no bill attempts to define the range of climate impacts that the nation may face that may require adaptation responses. This is appropriate, since the scientific understanding of impacts is rapidly advancing, and adaptation action should



Table 3.1 Congressional Bills Related to Climate Change Adaptation (110<sup>th</sup> Congress)

	H.R. 620	S. 280	H.R. 3221	S. 2211
<b>Session</b>	110 <sup>th</sup> , 1 <sup>st</sup>	110 <sup>th</sup> , 1 <sup>st</sup>	110 <sup>th</sup> , 1 <sup>st</sup>	110 <sup>th</sup> , 1 <sup>st</sup>
<b>Name</b>	Climate Stewardship Act of 2007	Climate Stewardship and Innovation Act of 2007	New Direction/Global Change Research and Data Management Act of 2007	Global Warming and Acidification Coastal and Ocean Resiliency Act
<b>Section of Interest</b>	Section 302	Section 401, Section 312	Sections 4601-4618	Section 320
<b>Key Features/ Intent with Relation to Adaptation</b>	<ul style="list-style-type: none"> <li>▪ Six regional and one national infrastructure cost assessments to provide high, medium, low of range of costs;</li> <li>▪ Adaptation plan that prioritizes vulnerable systems, assesses research and technology needs, looks at costs; and</li> <li>▪ \$2 million to conduct research on adverse impact of climate change on low-income populations in the United States and world.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Companion to H.R. 620 (similar components); and</li> <li>▪ Additionally, financial support for government-sponsored technology investment program (unnamed dollar amount).</li> </ul>	<p>Sec. 4617</p> <ul style="list-style-type: none"> <li>▪ Vulnerability assessment every five years which discusses scientific uncertainties, analyzes trends, and summarizes vulnerability of different geographic regions on national security.</li> </ul> <p>Sec. 4618</p> <ul style="list-style-type: none"> <li>▪ Policy assessment every four years to document and evaluate effectiveness of policies to meet mitigation and adaptation goals.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Create national strategy with measures, goals, implementation plan to for planning of ocean/coastal programs and relative sea-level rise in coastal zone planning; and</li> <li>▪ Provide grants (unnamed dollar amount) to resiliency planning adaptation strategies for wildlife on migration corridors, monitor environmental change.</li> </ul>
	S. 2355	H.R. 5453	H.R. 6186	S. 2191
<b>Session</b>	110 <sup>th</sup> , 2 <sup>nd</sup>	110 <sup>th</sup> , 2 <sup>nd</sup>	110 <sup>th</sup> , 2 <sup>nd</sup>	110 <sup>th</sup> , 2 <sup>nd</sup>
<b>Name</b>	Climate Change Adaptation Act	Coastal State Climate Change Planning Act of 2008	Investing in Climate Action and Protection Act	Lieberman-Warner Climate Security Act of 2007
<b>Section of Interest</b>	Section 9, Section 10:		Title III, Subtitle F Title IV, Subtitle.	Title IV, Subtitle G, Subtitle H.
	S. 2235	H.R. 5453	H.R. 6186	S. 2191
<b>Key Features/ Intent with Relation to Adaptation</b>	<ul style="list-style-type: none"> <li>▪ \$25 million each 2009 to 2013 to create national coastal and ocean adaptation plan;</li> <li>▪ \$150 million each 2009 to 2013 for Coastal and Ocean Adaptation Plans, with 75 percent of funds to state plans; and</li> <li>▪ Regional assessments which include federal flood insurance modification, risk assessment, mitigation, education, economic planning.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Amends 1972 Coastal Zone Mgmt Act to look at impacts on public facilities and public services;</li> <li>▪ Authorizes assistance to coastal states to develop coast climate change adaptation plans (financial and technical assistance); and</li> <li>▪ Coastal adaptation project grants awarded to coastal states with adaptation plans that address stress factors.</li> </ul>	<ul style="list-style-type: none"> <li>▪ National climate change adaptation program housed in NOAA (15 percent funding to federal, the remaining for states and local implementation);</li> <li>▪ National synthesis and regional assessments every four years; and</li> <li>▪ International program to provide assistance to vulnerable developing countries administered by USAID, includes foreign aid, community engagement.</li> </ul>	<ul style="list-style-type: none"> <li>▪ An adaptation fund is established to carry out activities (including research and education);</li> <li>▪ Thirty-five percent of funds would go toward State Comprehensive Adaptation Strategies;</li> <li>▪ Ten percent of funds would go toward Department of Commerce to fund adaptation activities to maintain and restore resources aligning with national strategy; and</li> <li>▪ Similar international program to H.R. 6168.</li> </ul>

be guided by the best science as it continues to evolve. H.R. 6186 does provide a series of findings which describe reductions and increases in general terms, and both bills reference existing research by the IPCC (and H.R. 3221 includes other sources) as a potential resource when conducting vulnerability assessments. Along the same line, neither bill sets nor directs the creation of minimum adaptation planning standards.

While both bills have provisions about funding research, it is difficult to judge whether the amounts are adequate. H.R. 3221 requires the President to submit annual budget requests for funding national assessments. H.R. 6186 authorizes expenditures from the National Climate Change Adaptation Fund through 2050, and also provides for state, local, and tribal government adaptation project funding from this same source. The monies in this fund would come from 2 to 2.5 percent of carbon credit auction proceeds.

A final issue relates to the timing and frequency of vulnerability assessments. National assessments on a routine four- or five-year cycle would provide valuable and current data to decision-makers. These assessments will necessarily require considerable resources at both the national and regional level.

## 3.2 111<sup>th</sup> Congress — Existing and Anticipated Bills

### 3.2.1 Surface Transportation Authorization

The next authorization of the surface transportation bill will be particularly significant legislation. The current authorization, SAFETEA-LU, expired September 30, 2009. The next authorization is likely to contain important changes to the structure of transportation funding programs, as well as to the requirements of the transportation planning process. There currently is considerable debate about how climate change — including both greenhouse gas emissions from mobile sources as well as impacts and adaptation issues — will be addressed in the new bill. Adaptation strategies targeted at the federal-aid transportation system

could be incorporated into reauthorization, including planning requirements (such as changes to the planning factors, or scenario planning and visioning), NEPA-related guidelines, researching new design standards, and other DOT research recommendations.

### 3.2.2 Climate and Energy Legislation

Several adaptation bills have been introduced in the 111th Congress. Senators Jeff Bingaman, Sheldon Whitehouse, and Max Baucus introduced S. 1933, the Natural Resources Climate Adaptation Act of 2009, in October 2009. This bill is intended to complement the larger energy and cap-and-trade bill, described below, under consideration in the Senate. As the bill's title suggests, S. 1933 emphasizes ecology above infrastructure, including the impacts of climate change

“National assessments on a routine four- or five-year cycle would provide valuable and current data to decision-makers.”

on forests, coastlines, and wildlife habitats. S. 1933 establishes an integrated program for Federal agency cooperation, coordinated by the Secretaries of Interior and Commerce, including shared scientific and technical expertise through a National Climate Change and Wildlife Center and a periodic survey of climate change impacts on natural resources. The measure creates a federal fund to support existing federal, state, and tribal strategies and adaptation programs. Additional adaptation bills filed in the 111th Congress deal with ocean acidification (S.173. Federal Ocean Acidification Research and Monitoring Act of 2009, H.R. 14 as companion bill) and with water infrastructure (S.22. Omnibus Public Land Management Act of 2009).

In addition, there continues to be support for one large bill containing energy provisions, a cap-and-trade program for greenhouse gas emissions, and



other related policies. The House of Representatives passed H.R. 2454, the American Clean Energy and Security Act, by a vote of 219-212 on June 26, 2009. While the Senate Committee on Energy and Natural Resources reported an independent energy bill on June 17, 2009, Senate leadership has continued to express its intentions to combine this bill with a more comprehensive energy and climate bill, the Clean Energy Jobs and American Power Act, currently under consideration by the Senate Environmental and Public Works Committee.

Energy and climate legislation should include a section on adaptation (as was tried in the Lieberman-Warner Climate Security Act of 2007 described in Table 3.1). This would be particularly appropriate for the research recommendations. It is most likely that a cap-and-trade act will take an “upstream” approach rather than set sector-by-sector targets; therefore, cap-and-trade legislation is not likely to focus on transportation in particular but be more broadly aimed. Some of the research recommendations (such as the establish-

ment of a climate services clearinghouse, and the development of consistent forms of climate data) could be addressed through the appropriation bills for the National Oceanic and Atmospheric Administration (NOAA) or other science agencies. Further, since many of the most costly impacts of climate change are likely to occur in coastal areas due to sea-level rise and storm intensification, some of the planning and inventory recommendations could be implemented through amendments to the Coastal Zone Management Act (as was attempted with the Coastal State Climate Change Planning Act of 2008, see Table 3.1).

### **3.3 Analysis of State-Level Activities**

Future federal policies will need to interact with ongoing state actions, and recognize the geographic diversity that may lead to different policies and levels of involvement among different states. While much adaptation will be focused on coastal states, other issues related to severe weather, including droughts, will occur nationwide.



State and local governments have taken considerable action in the past several years in response to growing public awareness and concern about climate change. Thirty-eight states have developed, or are in the process of developing, state Climate Action Plans.<sup>19</sup> Most of these place much greater emphasis on GHG mitigation than on climate adaptation and resilience concerns, and the focus and level of specificity in these plans varies considerably.

Those states that have addressed adaptation in terms of infrastructure are in the early stages of their policy development on this issue. With the exception of the State of Virginia (see below), most state plans that address adaptation call for research rather than report findings or put forward policy actions to reduce climate risk. Vulnerability assessments are directly or indirectly recommended in each plan. Only in Oregon do the recommendations include prioritization of infrastructure improvement. Similarly, state plans lack specificity in terms of understanding the impacts expected. For example, only Virginia's report made actual recommendations for what levels of climate change planners should anticipate and address. These recommended levels were the most conservative — e.g., lowest level of impacts in the projected range — of the quoted estimates, meaning planning would assume the best case scenario. To date, no state has yet put adaptation recommendations into law or has legislation pending.<sup>20</sup>

Thus, although some states have shown initiative in developing information on adaptation policy for infrastructure, there is much left to do. National guidance in the form of legislation or executive action would be beneficial to support further state-level actions. National leadership also is necessary to promote a uniform, scientifically-sound approach across the country.

“While much adaptation will be focused on coastal states, other issues related to severe weather, including droughts, will occur nationwide.”

At the same time, given the degree of ongoing state activity, it is clear that whatever is legislated by Congress will need to be sensitive to state's priorities and allow states to implement complementary strategies. For instance, Congress may choose to give states the authority to exceed the standards or thresholds set by the federal government in recognition of the priorities already being set by the various states.

For the states to be effective in their roles and responsibilities, it is essential that the federal government give states defensible data, sophisticated planning tools, models to experiment with, and a set of policy objectives that are national in scope and intent. Without the federal government acting as a strong partner in this set of issues, the states will collectively fail.

Table 3.2 provides a summary of activities in a sampling of 12 states to illustrate areas in which states are beginning to take action on climate adaptation, those in which federal leadership is needed to ensure appropriate actions are taken, and areas in which federal coordination will result in more consistent and effective resilience planning and actions.

<sup>19</sup> EPA, accessed March 2009: State and Regional Climate Policy Maps. [http://www.epa.gov/climatechange/wycd/stateandlocalgov/state\\_planning.html#two](http://www.epa.gov/climatechange/wycd/stateandlocalgov/state_planning.html#two).

<sup>20</sup> A survey of each state legislature's online bill web sites produced no results for pending legislation including adaptation (although with many legislatures in session, this could have changed by publication of this report).

Table 3.2 State Activities Related to Climate Change Adaptation

State	Florida	California	Oregon
<b>Authorizing Document</b>	Executive Order 07-128	Executive Order S-13-08	Governor Appointment
<b>Authorized Action and Date</b>	Energy and Climate Change Action Plan October 2008	Climate Adaptation Strategy Report April 2009	A Framework for Addressing Rapid Climate Change December 2007
<b>Section of Interest</b>	Chapter 8 – Adaptation Strategies	Not yet available	Chapter 6 – Recommended Actions
<b>Key Features/ Intent with Relation to Infrastructure Adaptation</b>	Develop long-range goals, objectives, and strategies for adapting to climate change. Identify and evaluate transportation infrastructure at risk. Continue analyzing and updating rainfall statistics and hurricane surge and analyzing the accompanying affects of wave forces and erosion on highways and bridges.	Report is to identify vulnerabilities, provide strategies to promote resiliency to impacts, and develop implementation plans for short- and long-term actions.	Assess and prioritize potential vulnerabilities. Critical infrastructure already at risk should be a priority. Redesign timeframes of planning tools to long-time intervals, 10- to 25- and even 50- to 75-year scales. Use land use codes to discourage occupancy in flood, fire, or landslide hazard areas. Develop new funding options as needed (i.e., a state rainy day fund for extreme events, or carbon emissions penalties for preparation measures). Coordinate research agendas across states and regions to avoid redundancy in data collection.
State	Washington	New Jersey	New York
<b>Authorizing Document</b>	Executive Order 07-02	Global Warming Response Act of 2007	Chapter 613, Laws of New York
<b>Authorized Action and Date</b>	Washington Climate Challenge Report on Preparation and Adaptation Recommendations Undated	Global Warming Response Act Recommendation Report December 2008	Sea-Level Rise Task Force December 2009
State	Washington	New Jersey	New York
<b>Section of Interest</b>	All	Chapter 5 – Adaptation	Not yet available
<b>Key Features/ Intent with Relation to Infrastructure Adaptation</b>	Land use and hazard mitigation planning strategy. Vulnerability characterization and monitoring strategy. Coastal near shore habitat restoration and protection strategy. Coastal facility construction and maintenance strategy.	Comprehensive adaptation policy to be developed as a key component of any long-term climate change action plan. Engage experts from academia, government, nongovernmental organizations, and the business community for policy recommendations on the most pressing adaptation policies. Customize actions to specific regions and municipalities.	Final report which will assess anticipated impacts related to sea-level rise, and make recommendations to provide more protective standards to coastal development, wetlands protection, shoreline armoring, and post-storm recovery, including impacts to infrastructure.

Sources for Table:

Florida: [http://www.dep.state.fl.us/climatechange/files/action\\_plan/app\\_f\\_adaptation.pdf](http://www.dep.state.fl.us/climatechange/files/action_plan/app_f_adaptation.pdf).

California: <http://gov.ca.gov/executive-order/11036/>.

Oregon: <http://www.oregon.gov/ENERGY/GBLWRM/docs/CCIGReport08Web.pdf>.

Washington: <http://www.ecy.wa.gov/pubs/0801008c.pdf>.

New Jersey: [http://www.state.nj.us/globalwarming/home/documents/pdf/final\\_report20081215.pdf](http://www.state.nj.us/globalwarming/home/documents/pdf/final_report20081215.pdf).

New York: <http://www.dec.ny.gov/energy/45202.html>.

Maryland: <http://www.mde.state.md.us/Air/climatechange/index.asp>.

North Carolina: <http://www.ncclimatechange.us/ewebeditpro/items/O120F19992.pdf>.

Virginia: [http://www.deq.virginia.gov/export/sites/default/info/documents/climate/CCC\\_Final\\_Report-Final\\_12152008.pdf](http://www.deq.virginia.gov/export/sites/default/info/documents/climate/CCC_Final_Report-Final_12152008.pdf).

Connecticut: <http://ctclimatechange.com/Adaptation.html>.

Michigan: <http://www.miclimatechange.us/ewebeditpro/items/O46F20826.pdf>.

Kansas: <http://www.ksclimatechange.us/ewebeditpro/items/O1F20411.pdf>.

State	Maryland	North Carolina	Virginia
<b>Authorizing Document</b>	Executive Order 01.01.2007.07	Clean Smokestack Act	Executive Order 59 (2007)
<b>Authorized Action and Date</b>	Climate Action Plan July 2008	Climate Action Plan Advisory Group Recommendations October 2008	Climate Change Action Plan December 2008
<b>Section of Interest</b>	Chapter 5 – Comprehensive Strategy for Reducing Maryland’s Vulnerability to Climate Change	Cross-Cutting Issue 5 – Adaptation	Workgroup on Adaptation and Sequestration
<b>Key Features/Intent with Relation to Infrastructure Adaptation</b>	Require the integration of coastal erosion, coastal storm, and sea-level rise adaptation and response planning strategies into existing state and local policies and programs, develop and implement state and local adaptation policies (i.e., protect, retreat, abandon) for vulnerable public and private sector infrastructure. Strengthen building codes and construction techniques for new infrastructure in vulnerable coastal areas.	Develop a state Climate Change Adaptation Plan that includes identification of: a) potential short-, mid-, and long-term impacts of climate change scenarios likely to affect the State; and b) implementation mechanisms for addressing these impacts. Empanel a state-sanctioned Blue Ribbon Commission on Adaptation to Climate Change as soon as possible to develop a state Climate Change Adaptation Plan within one year of establishment of the Commission.	Work with neighboring states on collaborative adaptation strategies. Develop climate change adaptation plans for critical infrastructure. Climate change impacts, particularly sea-level rise and storm surge vulnerability in coastal areas of Virginia, should be taken into account in all critical infrastructure planning, project design, and prioritization of projects for funding. Plan for a 3.6°F increase in air and water temperatures, and at least a 2.3-foot rise in sea level.
State	Connecticut	Michigan	Kansas
<b>Authorizing Document</b>	Public Act 08-98	Executive Order 2007-42	Executive Order 08-03
<b>Authorized Action and Date</b>	Steering Committee on Climate Change Report Adaptation Subcommittee December 2009	Climate Action Council Recommendations April 2008	Energy and Environmental Policy Advisory Group Recommendations Undated
<b>Section of Interest</b>	Not yet available	Cross Cutting Issue 8 – Adaptation and Vulnerability	Cross-Cutting Issue: Option 10 – Adaptation and Vulnerability
<b>Key Features /Intent with Relation to Infrastructure Adaptation</b>	The Adaptation Subcommittee is required to report on climate impacts by December 31, 2009, addressing impacts on natural resources and habitats, public health, local and state infrastructure, and agriculture. Another report is due to the Governor and General Assembly in July 2010 identifying what should be done to address adaptation in the four topical areas.	Undertake a comprehensive planning effort to assess and address the State’s vulnerability to climate change and adaptation opportunities. Develop a plan for accomplishing a periodic assessment of the ongoing and projected impacts of climate change on Michigan’s natural resources and natural resources-based economic activity.	Undertake a comprehensive planning effort to assess and address the state, local, and regional vulnerability to climate change and adaptation opportunities. All areas of the economy should address climate change impacts and opportunities. Identify sectors of the economy that are most vulnerable to climate impacts, and develop and incorporate adaptation measures into existing emergency plans and other policies. Examples include transportation infrastructure.



## 4.0 Recommendations for Federal Policy Action

**F**ederal policies can significantly promote resilience in the U.S. transportation sector, while more broadly strengthening communities and meeting environmental goals.

After surveying federal, state, and local actions to date on adaptation, it is evident that there is growing awareness and a considerable amount of emerging activity on climate adaptation. However, these efforts suffer from a lack of clear federal policy direction. This section recommends key federal policy actions that we believe are essential to advancing the nation's approach to address climate adaptation implications for transportation infrastructure. Section 5 then lays out a series of legislative action steps to implement the most critical policies discussed here.

### 4.1 Principles for Federal Action

A number of principles should be followed in developing national adaptation policies. In conducting interviews for this white paper, several issues were raised concerning potential federal policies and interactions with state and local actors that suggested the following guiding principles. These principles should be at the core of national policies:

- **National Approach.** There must be a national approach to adaptation for the transportation sector. Increasingly, U.S. transportation infrastructure

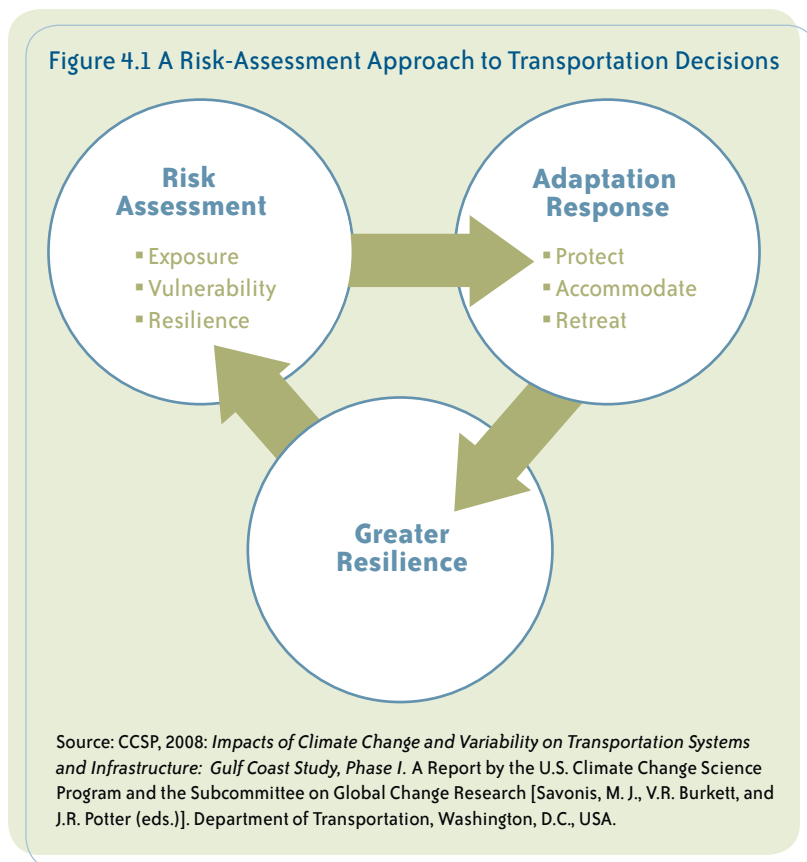
provides the backbone to the nation’s economic and social vitality. No system of infrastructure is as “national” as the Interstate, and indeed the entire federal-aid highway system. Inter-connected rail and aviation networks cross the continent. Further, many of the nation’s key airport, port, rail, and pipeline facilities — essential to domestic and international commerce — are located in vulnerable coastal environments. All aspects of transportation will be impacted by climate change, and accordingly all types of transportation will have to be adapted. A common framework for adaptation planning principles, clear investment guidelines, and asset management is needed, so that states and agencies approach assessing vulnerability and improving resilience with a common overarching framework. The goal is to prevent levels of resilience from varying widely from state to state, so that states facing similar issues (Gulf Coast states, for instance) have a unified approach. However, a national approach cannot mean a one-size-fits-all approach.

- **Recognizes Regional Differences.** Adaptation initiatives and funding need to be designed with the understanding that climate impacts will vary in type and severity across the United States. Adaptation dollars should be directed to the areas that face the most severe climate impacts. Further, risk assessment and adaptation programs and funding should be flexible to allow governments to address the risks that they judge to be most critical. Adaptation requirements or initiatives should not force agencies into policies that do not provide value in their region, or do not focus on their particular concerns.
- **Mobility-based Intermodal Focus.** The focus of adaptation should be on protecting and ensuring *mobility and economic vitality*, rather than on the more narrow focus of protecting structures or modes. Adaptation planning should be intermodal and should look beyond simply armoring existing facilities, i.e., moving the country toward a reliable transportation

“There must be a national approach to adaptation for the transportation sector.”

network that will best serve the nation’s transportation users and our economy, given future climate changes.

- **Addresses System as a Whole.** The linked nature of the transportation network makes it extremely important that adaptation policies address the system as a whole, and do not result in a piecemeal approach. This is particularly true for flood protection, where inconsistent standards can result in varying vulnerability to the same storm — or worse, inadequate protection in one area that directly leads to flooding in adjacent areas with otherwise adequate protection.
- **Adaptive Management Approach.** Effective risk assessment and adaptation will require an ongoing, iterative approach to asset management. (Figure 4.1) As transportation



agencies identify vulnerable components of their network and implement adaptation measures, agencies will need to regularly evaluate the degree of success of these actions — based on appropriate performance measures — and monitor changing climate conditions as new data is received. This assessment will then inform future steps that are needed to ensure the viability of transportation services.

- **Intergovernmental Collaboration.** Addressing adaptation requires knowledge that

crosses disciplines and policies that cross agency jurisdictions. Decisions about transportation infrastructure will reverberate throughout the adaptation planning community, and indeed may be among the most critical decisions made. Successful adaptation frameworks must require interagency and intergovernmental collaboration as an integral element of the planning and investment process.

#### 4.2 Areas for Federal Policy Action

Federal policies are needed in five general areas: 1) research; 2) transportation planning processes; 3) project development/NEPA; 4) design and engineering considerations; and 5) specific programs and funding. These recommendations are summarized below, and identified as short- or medium- to longer-term recommendations. Short-term recommendations are those that should be implemented immediately and are the logical first steps in improving the resilience of our nation's transportation system; specific policy mechanisms for doing so are discussed in

“As transportation agencies identify vulnerable components of their network and implement adaptation measures, agencies will need to regularly evaluate the degree of success of these actions.”



Section 5. Medium- to long-term recommendations are also important but represent steps that will likely be more implementable once the requisite early data, mapping, and tools are available and adaptation planning has been better integrated into transportation decision making.

In addition, an assessment of the lead federal agencies best equipped to implement the recommendations is included with the recommendations. A strong federal partnership of DOT working with science agencies such as NOAA and the U.S. Geological Survey (USGS) will be necessary to implement the research recommendations. DOT is the logical lead agency for transportation planning, project development, transportation design and engineering considerations, and programs and funding. Even among these recommended actions, NOAA and USGS will be essential to the data and mapping recommendations, while FEMA will continue to be the lead agency responsible for flood plain mapping. EPA will also play a critical role in research, data, and tools, as well as in shaping planning and project development guidance.

Our recommendations and prioritization are based on the authors' professional judgment, informed by input received from decision makers and the literature review and analysis conducted for this report.

#### 4.2.1 Climate Impacts and Adaptation Research

A strong, ongoing program of basic and applied research is required in several areas. Sound transportation decisions require reliable, consistent environmental and climate information and modeling outputs. Further, planning agencies need support in developing new decision-making processes and tools in order to incorporate a risk-analysis approach. Federal policy can establish and fund specific research programs to advance the state of science and practice. Policy actions to support research include the following short- and longer-term priority actions.

“A climate change services program is required to generate and provide consistent, high-quality climate information, data, and projections that can be readily used by planners and practitioners.”

#### Short-Term Policy Actions

Immediate action is needed to develop the data and tools necessary for planning and risk assessments of the transportation network, and to conduct the research that will underpin the development of new design standards. These data and tools will enable planners and engineers to begin addressing expected climate changes in new or rehabilitated infrastructure.

- *Authorize an interdisciplinary, long-term, climate adaptation research program* that engages both the transportation and climate research communities. This research should include early development of integrated climate data and modeling; updated flood plain and transportation system elevation mapping, and climate projections, including higher resolution of climate data and models for regional and sub-regional studies; and improved information about the likelihood and extent of extreme events. Research priorities should be informed by and responsive to the information and modeling output needs of decision makers at state and local transportation agencies. **Lead agencies: NOAA, DOT**
- *Establish and fund a National Climate Services clearinghouse.* A climate change services program is required to generate and provide consistent, high-quality climate information, data, and projections that can be readily used by planners and practitioners. This service would provide information to all disciplines at a scale and level of detail relevant to state and regional decision making. Transportation users and researchers — along

with decision makers and users from other sectors — should be included in the design and implementation of this program to ensure that it supports transportation needs.

- NOAA has been pursuing a strategic plan for developing a National Climate Service, and NOAA's Science Advisory Board recommended that NOAA lead, with partners, an evaluation of four options to provide climate services. The options identified by the review board include both government-based and quasi-independent institutional structures to conduct research and

“Development of methods and tools is needed to enable planners and managers to assess the range of potential climate impacts, the vulnerability of infrastructure segments, and the relative risk of components of the transportation network.”

provide climate information to state and local decision makers. These options are: 1) create a national climate service federation that would determine how to deliver climate services to the nation; 2) create a nonprofit corporation with federal sponsorship; 3) create a national climate service with NOAA as the lead agency with specifically defined partners; and 4) expand and improve weather services into weather and climate services within NOAA.<sup>21</sup> Jane Lubchenco, the new director of NOAA, has recently confirmed her intention to move forward with the creation of a National Climate Service. **Lead agency: NOAA**

- *Develop risk-analysis tools* to address the uncertainties that are inherent in projections of

climate phenomena, incorporating probabilistic approaches. Development of methods and tools is needed to enable planners and managers to assess the range of potential climate impacts, the vulnerability of infrastructure segments, and the relative risk of components of the transportation network. **Lead agencies: NOAA, DOT, EPA**

- *Initiate research to evaluate and develop revised design standards.* The U.S. DOT should lead a federally-funded, multi-agency research program for ongoing reevaluation of existing, and development of new, design standards as progress is made in understanding future climate conditions and the options available for addressing them. This process should engage professional organizations in the forefront of civil engineering practice across all modes. **Lead agency: DOT**

#### **Medium- to Long-Term Policy Actions**

In the medium to longer term, research can focus on establishing ongoing, regional, resilience assessment, exploring more nuanced aspects of expected changes, and developing advanced technologies and techniques that will assist adaptation.

- *Continue funding for the long-term, cross disciplinary research program* to develop more sophisticated climate modeling, tools, and data to support regionally-based climate risk analysis and adaptation studies. A regionally focused research program will help advance the state of practice in impacts assessment and adaptation strategy development and implementation by applying research principles in locations confronting different aspects of climate change. Support for regional demonstrations, building on the Gulf Coast study approach, can provide necessary resources to local agencies, build capacity to address climate change issues across the nation, and contribute to a growing knowledge base on impacts and adaptation issues. **Lead agencies: NOAA, DOT, USGS, EPA**

<sup>21</sup> NOAA Science Advisory Board, *A Review of the NOAA Climate Services Strategic Plan, Final Report to the National Oceanic and Atmospheric Administration*, September 2008.





- *Assess secondary responses to climate change impacts and adaptation actions.* Research is needed to assess the demographic responses to climate change, land use interactions, and secondary and national economic impacts. This research should specifically consider the equity implications of shifts in climate, as well as of different adaptation options. **Lead agencies: DOT, EPA**
- *Exploit new technology for climate adaptation planning.* The potential of advanced technologies, including satellite-based data, geospatial tools capable of integrated multiple layers of data and model outputs, and visioning and scenario-planning software, should be further developed to assist both scientific analysis and transportation decision making. **Lead agencies: USGS, NASA, DOT**

- *Develop real-time monitoring capabilities.* Federal and other research programs should develop monitoring technologies that provide advance warning of impending infrastructure failures due to weather/climate. **Lead agencies: DOT, NOAA**

#### 4.2.2 Transportation Planning Processes

Enhanced transportation planning processes and new tools are needed to better address the range of potential climate futures and resulting implications for the built and natural environments. Improvements are needed both in accessing and incorporating climate data and projections into existing scenario planning and decision-making processes, assessing risk, prioritizing investments, and assessing the range of potential options to build resilience. New, integrated metrics are required

to track performance of adaptation responses and proactively manage future investments.

These advancements should not be considered stand-alone processes. Many transportation agencies already are working to integrate a range of important factors into their existing transportation planning processes through expanded consultation and collaboration. Transportation agencies are

“Many transportation agencies already are working to integrate a range of important factors into their existing transportation planning processes.”

engaging resource management and conservation agencies; land use and economic development planners; and a broad set of public, business, and nonprofit stakeholders. This movement toward a more comprehensive approach of integrated planning and visioning should be further expanded to incorporate climate change. Policy strategies to strengthen the planning process include:

#### **Short-Term Policy Actions**

Near-term planning actions focus on the immediate steps needed to integrate climate change into the transportation planning process: revising planning process requirements, establishing long-term scenario planning that looks beyond the current federally-mandated planning horizon, beginning the process of inventorying transportation facilities at risk from climate change, and integrating climate impact considerations into emergency planning.

- *Revise planning process requirements in the next surface transportation authorization bill to address climate considerations.* Legislative action or guidance should address the incorporation of climate change considerations — both emissions mitiga-

tion and adaptation — in the planning process. This may be accomplished by adding climate change as a distinct planning factor, requiring and supporting cross-agency consultation among climate science agencies, transportation agencies, resource agencies and local governments; and/or specifying that climate measures be included as part of a performance-based planning and program approach. **Lead agency: DOT**

- *Establish and support longer-range scenario planning timeframes and approaches.* The timeframes generally used for the federal transportation planning process — twenty to thirty years — are short compared to the multi-decadal period over which climate changes occur. While the current timeframe is realistic for investment planning, agencies need to consider incorporating longer-term climate change effects into their visioning and scenario planning processes that inform their long-range plans. This long-range planning should include risk analysis and probabilistic approaches to decision making, to support a more informed and robust approach to transportation planning. **Lead agency: DOT**
- *Develop processes for inventorying and identifying assets and locations* that are vulnerable to climate change. Federal, state, and local governments, in collaboration with owners and operators of infrastructure, such as ports and airports and private railroad and pipeline companies, should inventory critical transportation infrastructure in light of climate change scenarios to determine whether, when, and where projected climate changes in their regions might be consequential. The process should use specific local information and knowledge, and climate change projections for a specific region. The process also would make use of geospatial techniques to analyze the spatial relationships among topography, infrastructure and other land use development, and climate. Identifying vulnerable assets is important to prioritize existing assets that require adaptation, as well as to inform the location of future infrastructure and

development to proactively minimize future risks. It is especially important to have national resources available to deal with high-vulnerability locations like New York City, where subways, ports, airports, and highways are all potentially subject to severe climate change impacts. **Lead agency: DOT**

- *Develop improved quantitative analytical planning methodologies.* Improved quantitative tools and analyses are needed to support more sophisticated approaches to decision making utilizing data developed through the research program discussed above. These tools will help practitioners shift from a deterministic decision-making process to a more probabilistic approach



“Programs are needed that will promote best practices, provide technical support, and enable agencies to build capacity in adaptation planning.”

designed to develop robust adaptation strategies that will be effective under a range of climate futures. **Lead agencies: NOAA, DOT**

- *Provide technical assistance and capacity-development support.* Programs are needed that will promote best practices, provide technical support, and enable agencies to build capacity in adaptation planning. Actions such as workshops, creation of a web-based adaptation clearinghouse, funding for technical tools, and development of other technical resources will support agencies as they work to incorporate new climate information in their decisions.

**Lead agency: DOT**

- *Integrate climate considerations into emergency planning.* Support and direction is required to promote the integration of climate impact considerations into emergency planning, especially for at-risk populations. This will require strong interagency collaboration that engages FEMA and other federal agencies; state, regional, and local organizations; first responders; climate science agencies; and transportation and planning agencies. **Lead agencies: DOT, FEMA**

#### **Medium- to Long-Term Policy Actions**

Over the longer term, planning capabilities should be enhanced by:

- *Developing more comprehensive climate models, data, and infrastructure planning tools.* Once short term-tool and data needs are met and state and local planning agencies have better incorporated climate adaptation into transportation planning and project development processes, there will almost certainly be a growing demand for more sophisticated analysis capabilities. The longer-term research program discussed in

section 4.2.1 should be providing these tools by that time. **Lead agencies: DOT, NOAA**

#### **4.2.3 Project Development/NEPA**

Transportation and planning agencies require guidance and support in developing feasible and appropriate techniques to incorporate climate information, not only during the planning process, but at the project level as well. These strategies should be developed in parallel with planning approaches to ensure efficient links across the long-range planning to project development continuum. Policy strategies to support this include:

##### **Short-Term Policy Actions**

Standardizing climate data for project development and providing guidance on how to use it are immediate first steps needed before climate change can be incorporated into the project development/NEPA process.

- *Develop and maintain nationally-standardized practice and data sources for climate information.* Ultimately, agencies need credible ranges of potential climate effects that can be applied at the project level. Development of a feasible and realistic approach to project-level siting and design in consideration of longer-range climate implications is a critical need for transportation agencies. **Lead agencies: NOAA, DOT**
- *Develop and provide federal guidance on the incorporation of quantitative and qualitative climate adaptation considerations into project development.* Transportation agencies currently are attempting to incorporate climate information into project development decisions without sufficient guidance. This is particularly challenging given the level of uncertainty inherent in climate models and projections. Federal guidance is needed to assist agencies in navigating this new area of analysis. **Lead agency: DOT**
- *Support stakeholder education and involvement.* Guidance and federal support is needed to educate stakeholders on climate adaptation considerations. Incorporating adaptation into project development will have a variety of

consequences, and public involvement will be vitally important in reviewing the impacts for context and severity. **Lead agencies: DOT, EPA, NOAA**

#### 4.2.4 Design and Engineering Considerations

Transportation agencies need to address climate information in infrastructure design. This will require ready access to the climate information and data generated from research, coupled with federal guidance and best practices in developing cost-effective designs that support infrastructure resilience. It is equally important that local decision makers retain the flexibility to determine the levels of service performance of individual segments of their network, and to make investment judgments at the local level. Of particular importance is updated information on flood plans and associated risk.

##### Short-Term Policy Actions

Higher accuracy mapping and updates of flood plain assumptions are near-term actions that will enable more appropriate and cost-effective infrastructure design and engineering.

- *Conduct an update of flood plain maps.* FEMA should reevaluate and update the National Flood Insurance Program and its maps to account for climate impacts. **Lead agency: FEMA**
- *Update transportation geospatial mapping.* Building on emerging LiDAR mapping technology, systematically update transportation infrastructure geospatial databases to include accurate elevation information for climate adaptation vulnerability analysis. This effort needs to be funded as quickly as possible by the federal government. It is fundamental to the planning and investment process. **Lead agencies: DOT, USGS**

##### Medium- to Long-Term Policy Actions

In the longer-term, as research is completed, this information should be used to inform revised standards:

- *Establish a process to evaluate and revise construction and design standards.* Based on design

standard research described in section 4.2.1, initiate a multi-agency process for the development of revised design standards to address infrastructure in vulnerable locations, particularly for federally-funded projects. **Lead agencies: DOT, FEMA, USGS**

#### 4.2.5 Programs and Funding

Federal support is required to raise awareness, develop the capacity to adequately plan for adaptation, and to implement climate adaptation strategies. Each of the strategies described above will require funding.

##### Short-Term Policy Actions

Specific policy actions to fund these strategies in the short term include:

- *Dedicate cap-and-trade revenue to impacts assessment and adaptation.* Through climate cap-and-trade legislation, direct a portion of revenues from credit auctions to transportation to conduct risk analysis and implement adaptation strategies to climate impacts. **Lead agency: DOT**
- *Make highway and transit core programs eligible for climate adaptation activities.* Through transportation reauthorization, make core transportation programs eligible for implementation of adaptation strategies when based on a comprehensive system inventory and risk assessment. **Lead agency: DOT**

##### Medium- to Long-Term

- *Fund climate adaptation demonstration project(s).* Funding is needed for demonstration projects that illustrate regional or mega-region analysis of risk to infrastructure, development of adaptation strategies, and implementation of adaptation plans as part of an integrated regional development plan. **Lead agencies: DOT, NOAA, USGS**



## 5.0 Federal Mechanisms to **Implement Climate Adaptation** Policies in the Short Term

**T**hese following two subsections contain recommendations for near-term federal transportation and related climate legislation and policy direction, based on the key policies recommended in Section 4.

Many of these policies will need to be implemented via legislation, but some also can be advanced through Executive Order, regulation, or policy guidance as discussed below. In some cases, policies will need to be implemented through multiple mechanisms. For instance, DOT participation in and support of a National Climate Service likely would be implemented through reauthorization, but the National Climate Service would need to be implemented by other legislation. Where this is the case, we have included recommendations under both mechanisms.

### 5.1 Federal Legislation

Federal legislative recommendations focus first and foremost on surface transportation reauthorization due this year, but also include consideration of likely emerging climate and energy legislation.

#### 5.1.1 Surface Transportation Authorization

New surface transportation authorization (or an extension of current legislation) is needed by October 1, 2009. Climate adaptation strategies targeted

at the federal-aid transportation system should be incorporated into the next authorization, including funding of a comprehensive U.S. DOT climate research program and data clearinghouse linked to the interagency U.S. Climate Change Science Program (CCSP), new transportation planning and project development requirements to accommodate climate considerations, and formulation of a national policy and systematic approach to incorporation of climate adaptation considerations into investment decision-making for the nation's transportation infrastructure. The next authorization bill should contain the following key components:

#### **Support for Research Recommendations**

- *Fund Climate Research.* Authorize funding for the U.S. Department of Transportation (DOT) and its Climate Center to fully participate in a multiagency, interdisciplinary, climate adaptation research program. This program would engage both the transportation and climate research communities, with research priorities determined by the information and modeling needs of decision-makers at state and local transportation agencies. This research should include development of:
  - Advanced climate modeling and integrated climate data and projections, including higher resolution of climate data and models for regional and subregional studies, and more information about the likelihood and extent of extreme events.
  - New infrastructure and system design standards to improve resilience of transportation in the face of climate change.
  - New risk analysis tools geared towards integrating climate projections with transportation planning needs.
- *Authorize DOT participation in the National Climate Services program.* In parallel with the above recommendation, authorize U.S. DOT funding to support transportation aspects of the

“**Federal legislative recommendations focus first and foremost on surface transportation reauthorization due this year.**”

National Climate Services data and information clearinghouse recommended by NOAA's Science Advisory Board. This service would provide consistent, high-quality, climate information data and projections at a scale and level of detail relevant to state and regional decision making. DOT should participate in the design and implementation of this program to ensure that it supports transportation needs.

- *Authorize and fund DOT participation in an interagency infrastructure mapping initiative.* One of the key parts of this initiative would be to develop and make available consistent GIS data for the entire national transportation network and facilities. It would include:
  - A particular focus on data elements needed for assessing climate vulnerability, such as facility elevation data from LiDAR mapping technology,
  - Updates of FEMA floodplain maps in light of projected climate change.

#### **Revised Planning and Project Development Recommendations**

Specific changes to the transportation planning and project development can be implemented through authorization:

- *Require climate adaptation to be addressed in the transportation planning and project development processes.* This should include at least the following:
  - Revise the transportation planning factors to explicitly consider climate adaptation,
  - Support longer planning timeframes (50 years or more) for scenario planning, visioning, and risk analysis that better in-



“Sources indicate growing support for **one large bill** relating to energy, cap and trade, and other climate issues related to climate change to be filed in 2009.”

forms long-range plans regarding incorporation of climate change implications,

- Provide federal guidance to transportation agencies on the incorporation of quantitative and qualitative climate considerations into planning and project development processes. This should

explicitly provide guidance on addressing the level of uncertainty inherent in climate models and projections.

- Develop and maintain nationally-standardized data sources and modeling techniques for transportation climate adaptation planning and for input to project development.
- Strengthened interagency consultation with relevant natural resource or science agencies.
- *Authorize formulation of a national policy and systematic approach to climate adaptation for the nation's transportation infrastructure. This should include but not be limited to:*



- Establishing policies and procedures for transportation risk assessment and adaptation implementation.
- Developing a framework and process for inventorying and identifying transportation assets and locations that are vulnerable to climate change to proactively minimize future risks.
- Authorizing U.S. DOT to lead a federally-funded, multi-agency research program for ongoing reevaluation of existing and development of new design standards for federally-funded infrastructure investments as progress is made in understanding future climate conditions and the options available for addressing them.

#### **Program and Funding Recommendations**

- *Authorize capital and planning funding support.* Provide funding to enhance transportation resiliency. This should include:
  - Require and fund states to conduct inventories of their transportation assets and locations that are vulnerable to climate change.
  - Making infrastructure climate adaptation an eligible expense under the core highway and transit programs, where based on a comprehensive system inventory and risk assessment.

#### **5.1.2 Potential Climate Change and Energy Legislation**

##### **Combined Energy and Climate Change Legislation**

There continues to be support for one large bill containing energy provisions, a cap-and-trade program for greenhouse gas emissions, and other policies. The House of Representatives passed H.R. 2454, the American Clean Energy and Security Act, by a vote of 219-212 on June 26, 2009. While the Senate Committee on Energy and Natural Resources reported an independent

energy bill on June 17, 2009, Senate leadership has continued to express its intentions to combine this bill with a more comprehensive energy and climate bill, the Clean Energy Jobs and American Power Act, under consideration by the Senate Environmental and Public Works Committee. It remains to be seen whether a combined energy and climate bill will be passed by the Senate or the full body during the 111th Congress.

However, we recommend that future climate legislation contain adaptation provisions that consider the following recommendations:

- *Incorporate specifically transportation infrastructure effects in the scope of climate impacts.* Introductory language similar to that in H.R. 6186 will serve to introduce the purpose of the provisions being enacted. That bill contains a litany of ten types of predicted future impacts on water systems, water quality, wildfire, flooding, erosion, storms, infectious disease, and coastal and Alaskan infrastructure. This list should be included in emerging climate legislation, and should be expanded to include impacts on transportation and other infrastructure, property and insurance, and the economy.
- *Dedicate a portion of climate revenues to fund core transportation adaptation needs,* specifically:
  - An interdisciplinary, long-term, climate adaptation research program. A cross disciplinary research program should be authorized and funded that engages both the transportation and climate research communities.
  - A National Climate Services program that 1) generates and provides consistent, high-quality, climate information; data; and projections that can be readily used by planners and practitioners, including higher resolution of climate data and models for regional and sub regional studies, and more information about the likelihood and extent of extreme events; and 2) de-

velops risk analysis tools to address the uncertainties that are inherent in projections of climate phenomena, incorporating probabilistic approaches.

- Conducting transportation system inventories, risk analysis, and implementing infrastructure adaptation strategies to address climate impacts.
- *Establish an extensive public education and outreach program.* The discussion draft contains language directing NOAA, as part of the National Climate Service, to undertake education and outreach initiatives related to impacts, vulnerabilities, and how adaptation is applied in decision making.
- *Direct federal agencies to establish guidelines and national standards for vulnerability and adaptation actions.* An interdisciplinary working group of climate scientists and practitioners — including all levels of government, the private sector, and advocacy groups — should be established



to develop standards for impact assessment and adaptation. This would include developing standard definitions for what the term “vulnerable” means in the adaptation context. The process should recognize ongoing efforts in some states under Cooperative Federalism where the federal government sets minimum standards, while allowing individual states to set standards which are higher. In terms of adaptation, this would allow states to plan more practically and allocate resources along different timelines. For example, Florida and California are states with long coastlines, but they will likely have very different impacts from climate change.<sup>22</sup>

### 5.1.3 Climate Adaptation Legislation

If a cap-and-trade program does not pass in the 111th Congress, another avenue would be to introduce a stand-alone adaptation bill that can begin to address the impacts of climate change currently experienced in the U.S. Again, referring to H.R. 6186, Subtitle F was entitled the National Climate Change Adaptation Program, and (other than funding) this part of that bill essentially stands alone. Debate on such legislation may be more constructive and less controversial if not tied to other potentially more politically-contentious issues associated with cap-and-trade and carbon taxation. Also, because cap-and-trade revenue may not materialize in the absence of a successful climate bill, it may be better to seek an independent funding source for adaptation activities in the near term.

## 5.2 Executive Policy Actions

By Executive Order (EO) the President can require all federal action to take adaptation considerations into account, such as was done in regard to Environmental Justice in a previous EO.<sup>23</sup> He also can direct federal agencies to develop guidance or amend existing regulations to further

<sup>22</sup> Of course, the linchpin to Cooperative Federalism is setting minimum standards. Of all federal and state materials surveyed, to date only Virginia has attempted to recommend minimum threshold assumptions for adaptation planning – 3.6°F increase in air and water temperatures, and at least a 2.3 foot rise in sea level. Even in Virginia, though, this is expressed as occurring by the year 2100. The closest federal bill provision is in H.R. 6186 which dictates that “scientific uncertainties” should be resolved by following either the IPCC Fourth Assessment Report guidance or “similar uniform guidelines” established by NOAA.

develop policy implementation. Some actions particularly suited for executive policy are:

- *Address project development/NEPA considerations.* Climate impacts and adaptation certainly fall within the NEPA scope of considerations. The basic goal of adaptation planning as part of NEPA should be to prepare for the projected impacts of climate change in order that infrastructure investment decisions can meet the desired outcome to “create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and future generations of Americans.”<sup>24</sup> Adaptation considerations can permeate all aspects of the NEPA process, from shaping a project’s purpose and need to its mitigation. Transportation and other planning and resource agencies will require guidance and support in developing feasible and appropriate techniques to incorporate climate information at the project level. Guidance would likely include:
  - *Quality climate data.* Developing and maintaining nationally-standardized practice and data sources related to emerging climate impact information. This should include consistent GIS mapping of the transportation network as related to climate variables (particularly elevation) and updated FEMA flood plain mapping.
  - *Project-level guidance.* Developing federal guidance for transportation and other planning and resource agencies on the incorporation of quantitative and qualitative climate considerations into project development. This guidance should explicitly address the uncertainty inherent in climate models and projections.
  - *Public involvement.* Developing guidance on educating stakeholders on climate adapta-

“Florida and California are states with long coastlines, but they will likely have very different impacts from climate change.”

tion considerations. Incorporating adaptation into project development will have a variety of consequences, and public involvement will be vitally important in reviewing the impacts for context and severity.

- *Incorporate climate risk analysis into federal infrastructure investment policies.* Revise Federal Infrastructure Investment Executive Order(s) to explicitly incorporate climate-related risk analysis into infrastructure investment plans and decision making. To proactively minimize future risks, it should include a framework and process for inventorying and identifying transportation assets and locations that are vulnerable to climate change. Finally, it should implement processes to develop updated construction standards to address transportation and other infrastructure in vulnerable locations.
- *Conduct a federal interagency assessment to develop and prioritize a climate adaptation research, data, and policy agenda.* This could be an important precursor to funding of a recommended interagency, interdisciplinary, long-term, national, climate adaptation research program in transportation and climate legislation this year. It would help set the research agenda and, in particular, the priorities for early action to support infrastructure and other adaptation planning.

### 5.3 Conclusion

Federal action on climate change impacts and adaptation is urgently needed and should be a priority for legislative and policy action. Climate change processes already are underway; strong ef-

<sup>23</sup> In many respects, the approach to Environmental Justice provides a roadmap for this approach. See FHWA’s web site at <http://www.fhwa.dot.gov/environment/ej2000.htm>.

<sup>24</sup> 42 USC 4321

**“Federal action on climate change impacts and adaptation is urgently needed and should be a priority for legislative and policy action.”**

forts to reduce greenhouse gas (GHG) emissions will not eliminate the need to prepare for these impacts. Therefore proactive GHG reduction strategies and adaptation planning need to be undertaken concurrently.

Climate change will have tremendous impacts on the human and natural environment, including significant effects on the United States’ transportation networks. The nation’s transportation systems represent huge national investments that are critical to the strength of the country’s economy and the vitality of its communities. Further, these networks, once designed and constructed, are in

place for decades. Given the strategic importance of transportation to the future of the country, and the substantial funding that is invested, it is both prudent and essential to consider the potential risks of climate change and to develop sound adaptation strategies that will ensure the long-term viability of our infrastructure.

To date, government leadership and action on the issue of understanding and preparing for the effects of climate changes has occurred primarily at the state level. While these efforts are valuable, the complexities and magnitude involved in researching, planning for, and adapting to climate change require a national-level approach. A national approach will provide a consistent policy and data framework and ensure effective coordination of efforts across agencies and disciplines. Only the federal government can do the necessary supportive interdisciplinary climate impact research, data



gathering, modeling and forecasting, mapping, and structuring of the comprehensive planning and risk-analysis framework necessary to ensure the resilience of our nation's multimodal transportation systems, and the communities and businesses they serve.

The next surface transportation authorization will provide opportunities to focus transportation planning and investment on strategies to advance understanding of climate impacts and address adaptation. Secondly, as energy and climate legislation is debated, it is critical that impacts and adaptation issues not be overshadowed in the broader debate about cap-and-trade, carbon pricing, and its potential impact on the economy. Development of adaptation and resiliency measures should be guided by a system-level, intermodal approach that focuses on mobility and economic vitality, rather than on protecting specific structures or modes. Further, policies should be designed to encourage an adaptive management approach: An ongoing, iterative process through which transportation agencies continually assess and improve the resilience of their networks and services. Given the complexity of the climate change challenge, effective adaptation efforts will require strong interdisciplinary collaboration and partnerships across all levels of government.

Congress and the Administration can address critical impacts and adaptation concerns, building on rapidly-emerging climate science research and expanding data analysis, including infrastructure impact assessments. Through the next authorization bill and upcoming climate legislation, as well as through policy development, the following near-term policy actions are recommended:

#### 5.3.1 Surface Transportation Authorization

- Fund advanced climate research
- Authorize DOT participation in the National Climate Services program
- Authorize and fund DOT participation in an interagency infrastructure mapping initiative

- Require climate adaptation to be addressed in the transportation planning and project development processes
- Authorize formulation of a national policy and systematic approach to climate adaptation for the nation's transportation infrastructure
- Authorize capital and planning funding support to enhance transportation resiliency

“Development of adaptation and resiliency measures should be guided by a system-level, intermodal approach that focuses on mobility and economic vitality.”

#### 5.3.2 Climate and Energy Legislation

- Incorporate, specifically, transportation infrastructure effects in the scope of climate impacts
- Dedicate a portion of climate program revenues — including cap-and-trade revenues — to fund core transportation adaptation needs
- Establish an extensive public education and outreach program
- Direct federal agencies to establish guidelines and national standards for vulnerability and adaptation actions

#### 5.3.3 Executive Policy Actions

- Address project development and NEPA considerations by developing quality climate data and by providing project-level guidance on incorporation of climate considerations and public involvement in project development.
- Incorporate climate risk analysis into federal infrastructure investment policies.
- Conduct a Federal interagency assessment to develop and prioritize a climate adaptation research, data, and policy agenda.



These policy actions would significantly advance the country's capability to understand and plan for the effects of climate change. The resilience of transportation infrastructure — a vital component of the U.S.' economic and social

wellbeing — warrants strong consideration as the nation develops its priorities and funding commitments in coming surface transportation and climate legislation.

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