TRB SPECIAL REPORT

Potential Impacts of Climate Change on U.S. Transportation

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Transportation professionals should acknowledge the challenges that will result from climate change and should incorporate current scientific knowledge about climate change into the planning, design, construction, operation, and maintenance of transportation systems. Climate change will affect every mode of transportation and every region in the United States, and the challenges to infrastructure providers will be new and often unfamiliar.

TRB Special Report 290: Potential Impacts of Climate Change on U.S. Transportation presents the findings and recommendations of a study conducted by a committee of experts under the auspices of the Transportation Research Board and the Division on Earth and Life Studies of the National Research Council (see box, page 24). According to the study committee's report, focusing on the problem now should help avoid future costly infrastructure investments and disruptions to transportation operations.

Challenges of Climate Change

Climate change will affect transportation primarily through increases in several types of weather and climate extremes, such as very hot days and heat waves; warming Arctic temperatures; rising sea levels coupled with storm surges and land subsidence; intense precipitation events; and intense hurricanes. The impacts will vary by mode of transportation and by region of the country but will be widespread and costly in human and economic terms and will require significant changes in the way that transportation professionals do business.

The historical regional climate patterns of the past several decades, commonly used by transportation planners to guide operations and investments, may no longer be a reliable guide. In particular, the future climate will include new classes of weather and will reach extremes in terms of magnitude and frequency—for example, with record rainfalls and record heat waves—as human-induced environmen-

A Joplin, Missouri, police car travels through a flooded intersection.

Focusing on the Consequences for Transportation

Although many studies have examined the potential impacts of climate change on broad sectors of the economy, such as agriculture and forestry, few have studied the impacts on transportation. The primary focus of this study is on the consequences of climate change for U.S. transportation infrastructure and operations.

The report provides transportation professionals with an overview of the scientific consensus on the current and future climate changes relevant to U.S. transportation, including the limits of scientific understanding about the timing, magnitude, and geographic location; identifies the potential impacts on U.S. transportation and the options for adaptation; and offers recommendations for research and for actions to prepare for climate change. The report also summarizes research and work on strategies for reducing transportation-related emissions of carbon dioxide (CO_2), the primary greenhouse gas and a contributor to climate change.

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tal changes are superimposed on the natural variability of the climate.

The decisions that transportation professionals make today—particularly for the redesign and retrofitting of transportation infrastructure or for the location and design of new infrastructure—will affect how well the system will adapt to climate change.

Addressing the Impacts

◆ **Inventory critical infrastructure.**

The flooding of coastal roads, railways, transit systems, and runways will be a likely result of a projected global rise in sea level coupled with storm surges and exacerbated by land subsidence in some locations. This flooding represents the greatest potential impact of climate change on North America's transportation system.

The vulnerability of transportation infrastructure to climate change, however, will extend beyond coastal areas. Federal, state, and local governments, in collaboration with owners and operators of infrastructure—such as ports, airports, and private railroads and pipelines—should inventory critical transportation infrastructure, identifying whether, when, and where the projected climate changes may be consequential.

In a possible preview of coastal area transportation problems that may become routine with projected climate changes, torrential rainwater rushes down the commuter steps onto the platform and tunnel at New York City's Times Square station, August 8, 2007.

◆ **Incorporate climate change into investment decisions.**

Every day, public officials at various levels of government and executives of private companies make short- and long-term investment decisions that have implications for how the transportation system will respond to climate change. Transportation decision makers, therefore, should be preparing now for the projected climate changes.

State and local governments and private infrastructure providers should incorporate adjustments for climate change into long-term capital improvement plans, facility designs, maintenance practices, operations, and emergency response plans. A six-step approach for determining appropriate investment priorities is presented in the box on page 23.

◆ **Adopt strategic, risk-based approaches to decision making.**

The costs of redesigning and retrofitting transportation infrastructure to adapt to the potential impacts of climate change are likely to be significant. More strategic, risk-based approaches to investment decisions are needed.

Transportation planners and engineers should incorporate more probabilistic investment analyses and design approaches that trade off the costs of making the infrastructure more robust against the economic costs of failure. Moreover, they should communicate these trade-offs to the policy makers who are responsible for investment decisions and for the authorization of funds.

The California Seismic Retrofit Program offers a model. The program uses a risk-based approach to analyze a highway bridge's vulnerability to earthquakes and its criticality to the road network, to determine priorities for retrofitting and replacement.

◆ **Improve communication.**

For transportation decision makers, one of the most difficult aspects of addressing climate change is obtaining the relevant information in the form they need for planning and design. Transportation professionals often lack sufficient information about the details and timing of expected climate changes to take appropriate action. The National Oceanic and Atmospheric Administration, the U.S. Department of Transportation (DOT), the U.S. Geological Survey, and other agencies should work together to institute a process to improve communication among transportation professionals,

climate scientists, and those in other relevant scientific disciplines, and to establish a clearinghouse for climate change information related to transportation.

In addition, better decision support tools are needed to assist transportation decision makers. Ongoing and planned research at federal and state agencies and universities that provide climate data and decision support tools should include the needs of transportation decision makers.

◆ **Integrate evacuation planning and emergency response into transportation operations.**

Projected increases in weather and climate extremes underscore the importance of emergency response plans for vulnerable locations. Transportation providers must work more closely with weather forecasters and emergency planners and assume a greater role in evacuation planning and emergency response.

Climate extremes—such as more intense storms and more intense precipitation—will require near-term operational responses from transportation providers and greater attention to emergency response in transportation operations and budgets. Transportation agencies and service providers should build on the experience of jurisdictions that have integrated transportation into emergency response and evacuation plans.

◆ **Develop and implement monitoring technologies.**

Monitoring the condition of the transportation infrastructure, particularly the impacts of weather and climate extremes, offers an alternative to the preventive retrofitting or reconstruction of some facilities in advance of climate change. Greater use of sensors and other "smart" technologies would enable infrastructure providers to receive advance warnings of potential failure caused by water levels and currents, wave action, winds, and temperatures exceeding what the infrastructure was designed to withstand. Federal and academic research programs should encourage the development and implementation of these technologies.

◆ **Share best practices.**

As the climate changes, many areas of the United States will experience new weather patterns. The geographic extent of the United States—from Alaska to Florida and from Maine to Hawaii—and its diversity of weather and climate conditions can provide a laboratory for best practices and information sharing as the climate changes. Drawing on technology transfer mechanisms, transportation professional and research organizations should develop a mechanism to encourage the sharing of best practices to address the potential impacts of climate change.

◆ **Reevaluate design standards.**

Environmental factors are integral to transportation infrastructure design. Engineers have not addressed the sufficiency of current design standards, however, for accommodating climate change. Climate change projections, for example, indicate that today's 100-year precipitation event is likely to occur every 50 years or perhaps even every 20 years by the end of this century.

Reevaluating, developing, and regularly updating design standards for transportation infrastructure to withstand the impacts of climate change will require a broad-based research and testing program and a substantial implementation effort. U.S. DOT should take the lead, working with professional organizations in the forefront of civil engineering practice, to initiate immediately a federally funded, multiagency research program for all modes. The program should reevaluate design standards and develop new standards as progress is made in understanding future climate conditions and the options for addressing them.

A research plan and cost proposal should be developed and submitted to Congress for authorization and funding. Until new standards are developed, infrastructure rehabilitation projects in highly vulnerable locations should be rebuilt to higher standards.

The development of appropriate design standards to accommodate climate change is only one of several possible adaptation strategies that may require federal leadership, research, and funding. Federal agencies have not focused on adaptation in addressing climate change. Better collaboration could direct attention to

TRB Special Report 290, Potential Impacts of Climate Change on U.S. Transportation*, is available from the TRB online bookstore, www.trb.org/bookstore; to view the book online, go to http://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf. The background papers commissioned by the study committee are also available online at www.trb.org/news/blurb_detail.asp?id=8808.*

Decision Framework for Addressing the Impacts of Climate Change on U.S. Transportation Infrastructure

1. Assess how climate changes are likely to affect various regions of the country and modes of transportation.
2. Inventory transportation infrastructure essential to maintaining network performance in light of climate change projections to determine whether, when, and where their impacts could be consequential.
3. Analyze adaptation options to assess the trade-offs between making the infrastructure more robust and the costs involved. Consider monitoring as an option.
4. Determine investment priorities, taking into consideration criticality of the infrastructure components as well as opportunities for multiple benefits (for example, congestion relief or the removal of evacuation route bottlenecks).
5. Develop and implement a program of adaptation strategies for the near and long terms.
6. Periodically assess the effectiveness of adaptation strategies, and repeat Steps 1 through 5.

PHOTO: WASHINGTON STATE DOT

Floods from the surging Chehalis River in southwestern Washington State overwhelm Interstate 5, December 4, 2007. Climate change may trigger more intense storms and extend the scope of special flood hazard areas.

these issues and shape research programs. U.S. DOT should take the lead in developing an interagency working group focused on adaptation.

◆ **Include climate change in transportation and land use planning.**

One of the most effective strategies for reducing the risks of climate change is to avoid placing people and infrastructure in vulnerable locations. Transportation planners are not currently required to consider climate change and its effects on infrastructure investments. Land use decisions are made primarily by local governments, which have too limited a perspective to account for the broadly shared risks of climate change. Integration between transportation and land use planning is uncommon.

Federal planning regulations should require that public-sector, long-range transportation plans include the consideration of climate change. In addition, regulations should eliminate any perception that such plans only need to address the next 20 to 30 years. The regulations also should require collaboration in plan development among the agencies responsible for land use, environmental protection, and natural resources management, to foster more integrated transportation–land use decision making.

◆ **Evaluate the National Flood Insurance Program and flood insurance rate maps.**

The federal government is the insurer of last resort for homeowners in specially designated flood hazard areas. The National Flood Insurance Program, administered by the Federal Emergency Management Agency (FEMA), and the flood insurance rate maps (FIRMs), which determine program eligibility, do not take climate change into account.

FEMA should reevaluate the effectiveness of the National Flood Insurance Program and the FIRMs in risk reduction, particularly because climate change may trigger more intense storms and because the rise in sea level will extend the scope of flood damage in some special flood hazard areas. At a minimum, updated FIRMs that account for sea level rise—as well as for land subsidence—should be a priority in coastal areas.

◆ **Develop new organizational arrangements.**

The impacts of climate change do not follow the modal, corporate, or jurisdictional boundaries that define decision making in the transportation sector. The institutional arrangements for transportation planning and operations were not organized to address climate change and may not be adequate to the task.

Models of cross-jurisdictional cooperation include regional authorities for specific facilities, such as Southern California's Alameda Corridor; regional and multistate emergency response agreements; and state-mandated regional authorities responsible for air quality improvement. Similar arrangements could emerge to address the effects of sea level rise on coastal real estate and infrastructure, of drought on shipping along inland waterways, and of hurricanes in the Gulf Coast. State or federal incentives, however, may be necessary to ensure the development of such organizational arrangements at the regional or multistate level.

Leadership and Commitment

Actions to prepare for climate change can be taken immediately. Local governments and private infrastructure providers can undertake some steps, but others depend on federal and state action. In all cases, leadership and continuing commitment are essential.

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