TRANSPORTATION RESEARCH BOARD

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Potential Impacts of Climate Change on U.S. Transportation

Transportation professionals should acknowledge the challenges posed by climate change and incorporate current scientific knowledge into the planning, design, construction, operation, and maintenance of transportation systems. Every mode of transportation and every region in the United States will be affected as climate change poses new and often unfamiliar challenges to infrastructure providers. *Special Report 290: Potential Impacts of Climate Change on U.S. Transportation*—the report 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—makes the case that focusing on the problem now should help avoid costly future investments and disruptions to operations.

Challenges of Climate Change

Climate change will affect transportation primarily through increases in several types of weather and climate extremes. Climate warming over the next 50 to 100 years will be manifested by increases in very hot days and heat waves, increases in Arctic temperatures, rising sea levels coupled with storm surges and land subsidence, more frequent intense precipitation events, and increases in the intensity of strong hurricanes. The impacts will vary by mode of transportation and region of the country, but they 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.

The past several decades of historical regional climate patterns commonly used by transportation planners to guide their operations and investments may no longer be a reliable guide for future plans. In particular, future climate will include new classes (in terms of magnitude and frequency) of weather and climate extremes, such as record rainfall and record heat waves, not experienced in modern times as human-induced changes are superimposed on the natural variability of the climate.

Decisions transportation professionals take today, particularly those related to the redesign and retrofitting of existing transportation infrastructure or the location and design of new infrastructure, will affect how well the system adapts to climate change far into the future.

Addressing the Impacts of Climate Change on Transportation

Inventory Critical Infrastructure

Potentially, the greatest impact of climate change on North America's transportation system will be flooding of coastal roads, railways, transit systems, and runways because of a global rise in sea level coupled with storm surge and exacerbated in some locations by land subsidence. The vulnerability of transportation infrastructure to climate change, however, will extend well beyond coastal areas. Therefore, 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 to identify whether, when, and where projected climate changes in particular regions might be consequential.

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The Study's Primary Focus

Many studies have examined the potential impacts of climate change on broad sectors of the economy, such as agriculture and forestry, but 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 of particular relevance to U.S. transportation, including the limits of present scientific understanding as to their precise timing, magnitude, and geographic location; identifies potential impacts on U.S. transportation and adaptation options; and offers recommendations for both research and actions that can be taken to prepare for climate change. The report also summarizes previous work on strategies for reducing transportation-related emissions of carbon dioxide (CO_2)—the primary greenhouse gas—that contribute to climate change, an area in which more research has been done. The study was funded by the Transportation Research Board, the National Cooperative Highway Research Program, the U.S. Department of Transportation, the Transit Cooperative Research Program, the U.S. Environmental Protection Agency, and the U.S. Army Corps of Engineers.

Incorporate Climate Change into Investment Decisions

Public authorities and officials at various governmental levels and executives of private companies are making short- and long-term investment decisions every day that have implications for how the transportation system will respond to climate change in the near and long terms. Transportation decision makers have an opportunity now to prepare for projected climate changes. State and local governments and private infrastructure providers should incorporate climate change into their long-term capital improvement plans, facility designs, maintenance practices, operations, and emergency response plans. See the box on the next page, which lays out a six-step approach for determining appropriate investment priorities.

Adopt Strategic, Risk-Based Approaches to Decision Making

The significant costs of redesigning and retrofitting transportation infrastructure to adapt to the potential impacts of climate change suggest the need for more strategic, risk-based approaches to investment decisions. Transportation planners and engineers should incorporate more probabilistic investment analyses and design approaches that apply techniques for trading off the costs of making the infrastructure more robust against the economic costs of failure and should communicate these trade-offs to policy makers who make investment decisions and authorize funding. One model is the California Seismic Retrofit Program, which uses a risk-based approach to analyze vulnerability to earthquakes and criticality of highway bridges to determine priorities for retrofitting and replacement.

Improve Communication

Transportation decision makers note that one of the most difficult aspects of addressing climate change is obtaining the relevant information in the form they need to plan and design. Transportation professionals often lack sufficiently detailed information about expected climate changes and their timing to take appropriate action. The National Oceanic and Atmospheric Administration, the U.S. Department of Transportation (USDOT), the U.S. Geological Survey, and other relevant agencies should work together to institute a process for better communication among transportation professionals, climate scientists, and those in other relevant scientific disciplines, and establish a clearinghouse for transportation-relevant climate change information. 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 provides 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 in vulnerable locations and require that transportation providers 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 in locations where transportation is well integrated into emergency response and evacuation plans.

Develop and Implement Monitoring Technologies

Monitoring transportation infrastructure conditions, particularly the impacts of weather and climate extremes, offers an alternative to 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 warning of potential failure due to 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.

Decision Framework for Transportation Professionals to Use in 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 (e.g., congestion relief, 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.

Share Best Practices

As the climate changes, many U.S. locations will experience new climate-induced 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 existing technology transfer mechanisms, relevant transportation professional and research organizations should develop a mechanism to encourage sharing of best practices to address the potential impacts of climate change.

Reevaluate Design Standards

Environmental factors are integral to transportation infrastructure design. However, engineers have not given much thought to whether current design standards are sufficient to accommodate climate change. Climate change projections 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 address the impacts of climate change will require a broad-based research and testing program and a substantial implementation effort. USDOT should take a leadership role along with professional organizations in the forefront of civil engineering practice across all modes to initiate immediately a federally funded, multiagency research program. The program should focus on the reevaluation of existing design standards and the development of new standards as progress is made in understanding future climate conditions and the options available for addressing them. A research plan and cost proposal should be developed for submission 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 generally on adaptation in addressing climate change. Better collaboration could help focus attention on these issues and shape existing research programs. USDOT 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 climate change be included as a factor in the development of public-sector, long-range transportation plans; eliminate any perception that such plans be limited to 20 to 30 years; and require collaboration in plan development with agencies responsible for land use, environmental protection, and natural resource 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) that determine program eligibility do not take climate change into account. FEMA should reevaluate the risk reduction

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

Develop New Organizational Arrangements

The impacts of climate change do not follow modal, corporate, or jurisdictional boundaries, yet decision making in the transportation sector is based on these boundaries. Current institutional arrangements for transportation planning and operations were not organized to address climate change and may not be adequate for the purpose. Some models of cross-jurisdictional cooperation exist. Among them are regional authorities for specific facilities (e.g., the Alameda Corridor); regional and multistate emergency response agreements; and state-mandated regional authorities, such as those responsible for air quality improvement. Similar arrangements could emerge to address the effects of sea level rise on coastal real estate and infrastructure, drought on shipping along inland waterways, and hurricanes in the Gulf Coast region. However, state or federal incentives may be required to ensure the development of such organizational arrangements at the regional or multistate level.

Actions to prepare for climate change can be taken almost immediately. Some steps can be undertaken by local governments and private infrastructure providers. Others depend on federal and state action. In all cases, leadership and continuing commitment are essential.

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This report was prepared by the National Research Council on the basis of the committee's report. Permission granted to reproduce this brief in its entirety with no additions or alterations. *Potential Impacts of Climate Change on U.S. Transportation* is available from the Transportation Research Board, 500 Fifth Street, NW, Washington, DC 20001 (telephone 202-334-3213; fax 202-334-2519; or e-mail TRBsales@nas.edu).

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