

FEDERAL HIGHWAY ADMINISTRATION'S DEVELOPMENT OF A STRATEGY TO ADDRESS ADAPTATION TO CLIMATE CHANGE

M. Culp & P. Pisano
USDOT Federal Highway Administration, Washington, D.C. USA
michael.culp@dot.gov & paul.pisano@dot.gov

F. Klein
Noblis, Inc., Falls Church, Virginia, USA
fred.klein@noblis.org

ABSTRACT

With the changing climate comes the need for the transportation community to understand and take action. Much work is being done to pursue mitigation strategies; i.e., actions that will reduce greenhouse gas emissions. However, limited work has been done with respect to adaptation; i.e., actions that will ensure that the transportation system is able to adapt to the impending changes in the natural environment caused by global climate change. The Federal Highway Administration (FHWA) has taken a leadership position within the United States to address the growing gap surrounding adaptation. Specifically, an internal working group was established in 2008 to create a strategy that addresses adaptation to the impacts of climate change. The purpose of the strategy is to solidify FHWA position on adaptation given the emerging understanding of the impending climate change impacts. The strategic ideas and activities for adaptation provide a means of communicating a policy direction for FHWA to all our stakeholders, especially state and local transportation agencies, as well as the public. The third objective of ideas and activities for adaptation is to serve as a strategic foundation for future actions to be taken by FHWA.

The scope of the adaptation activities and ideas focuses on the Administration's roles and responsibilities, particularly with respect to the Federal Aid Highway Program; the umbrella program defined by Federal statute that provides highway funds to the States. It addresses the different stages of life-cycle decision making in the Program, from planning and design, through construction to operations and preventive maintenance. It includes discussions of why impacts due to climate change are relevant to each of the program areas, focusing on significant system vulnerabilities to global climate change impacts. It covers options to address these vulnerabilities, as well as anticipated future activities to be taken by the Administration. One key aspect of the strategy is that it will encourage probabilistic and risk-based approaches to decision making, due to the significant uncertainties surrounding regional and local environmental changes. That is, we know that changes are occurring at the global scale, and know that these changes will translate differently at regional and local levels, we just don't yet know how with much certainty. Such uncertainty makes it difficult, but not impossible, to develop guidance. Incorporating risk-based approaches provides a sound means of addressing the uncertainties.

KEYWORDS

CLIMATE CHANGE / USDOT / ADAPTATION / GLOBAL CLIMATE / IMPACTS

1. INTRODUCTION

Global climate change (GCC) is one of the most significant issues humankind faces today. Although there is some uncertainty regarding the scope and magnitude of climate change effects and impacts, there is consensus among the scientific community that climate change is occurring and will continue to occur. While the complex task of reducing greenhouse gas (GHG) emissions is a central component in worldwide efforts to alleviate or minimize climate change effects, it is critical to also prepare to adapt to climate impacts. GHG mitigation efforts can help reduce the effects and impacts of climate change over the long term, but will have little effect on expected impacts over the next twenty or thirty years.

The U.S. Department of Transportation (USDOT) Federal Highway Administration's (FHWA) responsibility to address climate change adaptation is to take the appropriate actions to preserve and enhance the Interstate System to meet the needs of the 21st Century [1] and adequately serve the existing and planned future traffic of the highway in a manner that is conducive to safety, durability, and economy of maintenance [2]. Therefore, the FHWA has the duty to provide national leadership in assuring that state and local transportation agencies adapt current and existing transportation system to the impacts of climate change. The underlying economic, social, and environmental concerns relating to transportation decisions only strengthen this objective.

This paper conveys climate change adaptation key areas of focus, and ideas and activities the USDOT, Federal Highway Administration (FHWA) considers important enough to be included in a strategy to mitigate impacts of climate change. This paper is taken from a draft strategy document where a diverse array of perspectives and resources were sought and used as input for these adaptation ideas and activities. A climate change adaptation working group consisting of five FHWA offices was assembled to discuss adaptation considerations in the highway context and to inform the strategy development process. FHWA conducted a series of interviews with staff in a variety of the agency's disciplines, and considered the recommendations from reports such as the U.S. Climate Change Science Program's *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I (Gulf Coast Study)* [3] and the Transportation Research Board (TRB) *Special Report 290*. [4]

The FHWA's purposes are to provide a foundation and a plan for future FHWA activities, and communicate FHWA's planned approach for addressing climate change effects and impacts across a variety of transportation decision-making areas to FHWA staff, its stakeholders and the public.

This purpose will be achieved through:

- Synthesizing data scaled for State DOT and Metropolitan Planning Organization use;
- Assessing vulnerability to climate change effects – evaluating the probability and consequences of climate change impacts to vulnerable transportation infrastructure;
- Developing methodologies, policy, and guidance – encouraging states to incorporate adaptation strategies into long-term planning activities and infrastructure investment decision-making; and
- Conducting research, outreach, and education – raising the awareness of climate change among transportation professionals, improving their capacity to respond to recognized risks, and monitoring the adaptation strategies of other federal agencies to ensure adaptation actions are compatible and integrated.

Planning and implementing adaptation initiatives are long-term processes that will demand continued attention. The experience and learning gained from developing and implementing ideas and activities will enable leveraging by other USDOT modal administrations, and state and local governments as they also consider the effects and impacts of climate change on their programs

2. THE CHANGING CLIMATE

Our climate has already begun changing, and this change is expected to accelerate in future decades. Global mean surface temperature has increased 0.74°C over the past 100 years. The snow cover in the Northern Hemisphere and floating ice in the Arctic Ocean have decreased. Over the past century, sea level has risen 4–10 inches globally. Worldwide precipitation over land has increased by about one percent, and the frequency of extreme rainfall events has increased throughout much of the United States.

In climate change terms, *adaptation* consists of the actions of individuals or systems to avoid, withstand, or take advantage of current and projected climate changes and impacts [5]. Adaptation is a dynamic process that decreases a system's vulnerability or increases its resilience to impacts. As the focus of adaptation, the infrastructure consists not only of the roads, bridges, and other structures of our highway systems but also the operations in maintaining them for use by the public.

2.1. What Changes in Climate Can Be Reasonably Expected.

Though sustained global reductions in emissions can reduce climate change - and the need to adapt over the long term, it is still a complex issue. While climate change forecasts become less certain as the time horizon grows, the likely effects of climate change become larger, introducing greater risk of impacts on the transportation system. FHWA recognizes that transportation agencies should make decisions that acknowledge uncertainty regarding GCC effects. Doing so will ultimately ensure a more resilient and robust transportation system.

Current science and evidence suggest climate change's most likely effects include the following;

- Sea level rise
- Increased frequency, intensity, and duration of extreme weather events [this overlaps with the next effect]
- Change in precipitation levels, average and peak
- Change in temperature, average and highs

For example, sea-level rise, coastal erosion, tropical storms/hurricanes, storm surges, and subsidence are all major—and difficult to predict—concerns in coastal areas. Potential impacts on coastal infrastructure include increased risk of bridge scour and bridge failure during storms, periodic or permanent inundation of coastal roads, increased frequency of infrastructure repair after events, and emergency evacuation concerns. Also, increased variability in (short-term) temperature extremes and more severe precipitation events, will impact transportation infrastructure with increased pavement deterioration, an inability to implement or maintain mitigation commitments, short-term flooding and/or compromised safety, among many others.

3. POTENTIAL IMPACTS TO HIGHWAY INFRASTRUCTURE

Several research studies regarding climate change's potential impacts to highway infrastructure have been conducted to date. In particular, the TRB's Special Report 290 and the U.S. DOT's Gulf Coast Study outline some of the wide range of impacts on highways that are forecast (see Table 1 on next page and Figure 1 below). The Gulf Coast Study includes a comprehensive review of the literature related to the numerous, potential impacts of climate change on transportation. U.S. DOT has also used GIS to map areas and transportation infrastructure that could be affected by multiple scenarios of sea level rise along the Atlantic coast. According to the resources cited there, the possible impacts are expected to be geographically widespread, modally diverse, and affecting both transportation infrastructure and operations. In each case, the climate change effects that stress transportation systems in ways beyond which they were designed are likely to be the most challenging to address.



Figure 1- Impacts: Hydraulic Failure (left) and Highway (NC12) Washout, 2003 (right)

4. FHWA OBJECTIVES IN ADDRESSING CLIMATE CHANGE ADAPTATION

4.1. Transportation Planning

Given the goals, objectives, and context of a metropolitan region or state, the transportation planning process helps determine what transportation problems exist and what mix of transportation investments can help solve those problems. Since projected climate change effects and impacts have significant implications for where and how transportation infrastructure is built—and may ultimately determine its lifespan, FHWA has a critical role in helping state DOTs and MPOs integrate climate change adaptation considerations early in the transportation planning process.

An early objective is to increase consideration of climate change adaptation in state and local transportation decision-making. This includes developing guidance and best practices on the consideration of climate change adaptation in transportation planning, and identifying and assessing ways to make climate change effects, impacts, and adaptation more prominent in the transportation planning process.

Geographic areas associated with watersheds and floodplains may be more appropriate scales of analysis in areas susceptible to projected climate change impacts, as opposed to limiting analysis to political or jurisdictional boundaries. The timeframes associated with many large infrastructure projects, and associated climate change effects, may be from 20-25 to 50 or more years in some cases. Consequently, another objective is ensuring that planning analysis geographic and temporal scales are appropriate to address climate change effects.

Table 1- Some Effects and the Potential Infrastructure and Operations Impacts [6]

Climate Change Effect	Changes in Environmental Condition	Potential Highway Infrastructure and Operations Impacts
Sea level rise	Rising water levels in coastal areas and rivers; increases in severe coastal flooding	Greater coastal area inundation and erosion of coastal highways Need for more stringent design standards for flooding and building in saturated soils Greater protection of infrastructure when higher sea levels combine with storm surges Greater stress on Coastal Zone Management and increased need for planned resilience for public roads and structures.
Increased storm frequency and severity	More severe precipitation, wind, lightning, wave action	Damage to road infrastructure Closures or major disruptions of roads; emergency evacuations, travel delays Disruption to electronic transportation infrastructure
Greater storm surges and wave heights	Larger and more frequent storm surges; more powerful wave action	Increased coastal flooding necessitating changes to bridge design in vulnerable areas; need for more probabilistic approach to predicting storm surges Changes in materials specifications and more protective strategies for critical components Increased Vehicles Miles Travelled (VMT) and Vehicle Hours Travelled (VHT), number of road accidents, evacuation route delays, and stranded motorists
Changing precipitation levels	More precipitation; higher water tables; greater levels of flooding; higher moisture content in soils; also potential for decreased precipitation	Pavement , foundation, drainage, culvert, and materials design impacts Increased frequency and magnitude of flooding Need for greater attention to foundation conditions, more probabilistic approaches to design floods, more targeted maintenance Concrete deterioration and bridge scour Increased landslide prevalence Loss of visibility from drifting snow, lane obstruction (debris) Travel and schedule delays Less rain could dilute surface salt causing steel reinforcing in concrete structures to corrode
Temperature change	Rising maximum temperature; lower minimum temperature; wider temperature range; possible significant impact on permafrost	Highway asphalt rutting and more rapid breakdown of asphalt seal binders, resulting in cracking, potholing, and bleeding, which could damage the structural integrity of the road and/or cause pavement to become more slippery when wet Need for pavement and structural design changes, new materials and better maintenance strategies, milling out ruts, and overlay with more rut-resistant asphalt Thermal expansion of bridges causing more frequent detours and traffic disruptions Changes to biodiversity requiring increased pest management, impacting wetlands commitments, and increasing slipperiness on roads and visual obstructions (due to trees having leaves for longer time periods) Longer construction seasons and/or drier and warmer days Failing road embankments and settling of shallow pile foundations
Wind loads	Stronger wind speeds and thus loads on bridge structures; more turbulence	Changes to testing of and design factors for wind speed Need for materials of greater strength

To encourage planners to address issues strategically and systematically, the federal and state partners plan to implement vulnerability and risk assessment tools to support system-level investment decisions, and also improve understanding of how climate change can affect asset management investment cycles.

Improved linkages among FWHA program offices and other agencies can be achieved by supporting integrated planning among agencies, identifying and communicating the implications for other laws and regulations—such as those for air quality, floodplains, the Clean Air Act (air quality), or the Endangered Species Act (ESA).

4.2. Preliminary Engineering and Project Development

In areas where climate change effects are likely to be substantial, assumptions regarding potential changes to the context of a project should be adequately considered. This information is essential in determining preliminary engineering design parameters, screening alternatives, and addressing constructability, maintenance, and life-cycle cost concerns.

In order to reduce transportation project delivery delays resulting from GCC impacts, an objective will be to encourage the engagement of appropriate climate change experts and the use of national, regional, and local (if available) climate change data in the project scoping process. Also, the FHWA intends to help identify best practices and provide assistance to improve the choice and use of appropriate data, methodologies, and tools for forecasting future conditions. By monitoring the changing environmental conditions for a project, modifications to project design and implementation addressing these changes can be facilitated.

Another objective is to enhance inclusion of climate change and adaptation in environmental documentation. To do this the FHWA believes it is important to develop guidance on how climate change will be addressed in National Environmental Policy Act (NEPA) documents [7] and work to implement project-based risk assessment tools to be utilized during project development. An approach by the U.S. Army Corps of Engineers provides regulatory decision-making that couples traditional risk assessment and planning with multi-criteria decision analysis (MCDA) [8].

The last objective of project development calls for strengthening environmental stewardship. This may be accomplished by evaluating the potential effects of climate change impacts on other environmental requirements. For example, transportation agencies will need to understand how climate change may affect mitigation commitments and/or the project approval process. Also, agencies will need to determine the value of ecosystem services [9] with regard to asset management and life-cycle cost analyses.

4.3. Project Design and Construction

The effects of climate change may impact project design parameters, potentially necessitating different or additional analyses, and changes in how standards are applied in the future. Many transportation investments have long design lives.

Bridge design must approach wave force, storm surge, and scour vulnerabilities in existing and new bridge structures. Mitigation ideas are working with relevant stakeholders to revise and enhance bridge design specifications, as necessary, assessing whether changes to bridge guidance are necessary, encouraging State DOTs to make type, size,

and location considerations in advance of or during the NEPA process, and continuing to engage in research and technology transfer activities.

Pavement design must consider improved methodologies for assessing pavement damage due to prolonged inundation, rising water tables, and increased freeze/thaw cycle frequency. Mitigation ideas are researching damage done to pavements under various extreme water stresses, and promoting the use of American Association of State Highway and Transportation Officials' (AASHTO) Mechanistic-Empirical Design Guide (MEPDG).

Hydraulics design must incorporate climate change considerations into hydraulic modeling and design in existing and new structures. Predicted climate changes will stress existing hydraulic structures and may lead to unanticipated failures. Also, floodplain regulations will be examined to determine if climate change considerations can be incorporated in a potential update.

Construction design must maximize schedule efficiency and staff safety to include assessing how climate change effects will potentially change construction schedules and/or methods.

Emergency relief design must consider continued continuity of operations for emergency relief programs given projected climate change effects and assess whether programs need additional resources. FHWA will explore the clarification of eligibility requirements for emergency relief program funding.

4.4. Asset management

Asset management focuses on business and engineering practices for resource allocation and utilization, with the objective of better decision making based upon quality information and well-defined objectives. To maximize performance and minimize life-cycle costs of transportation systems, the work will be conducted to investigate how these systems will be altered by climate change effects such as increased frequency of maintenance cycles and earlier intervention of capital costs. Other initiatives may include encouraging development of performance standards for how highways should perform under different weather events, and promoting green asset management approaches to help minimize mitigation costs and to allow highway projects to receive the benefits of ecosystem services (research and pilot programs). Another idea includes promoting state and local efforts to identify areas where restoration or maintenance of ecosystems may be able to reduce highway maintenance or repair costs.

FHWA will explore improving linkages between asset management and transportation planning activities by assuring the engagement of asset management professionals in conducting system-level vulnerability and risk assessments. Data collection standards will be developed where needed since maintenance staff members are being asked to track more data than ever before and standards will help ensure that information, including GIS, coming from where events are occurring can be effectively linked back to the planning process.

4.5. Operations

FHWA's Office of Operations provides national leadership for the operation of the surface transportation system. Good operations practices will be flexible to adapt to climate change impacts by improving system-wide management strategies and/or advanced

decision-support systems and enhancing capacity of highway infrastructure to respond to emergencies.

Adaptation focuses on developing appropriate guidance to State and local agencies to establish and deploy sound, system-wide management strategies that are effective under varying weather conditions, regardless of climate change. These strategies rely heavily on technology deployed on the roadway; consequently, there is a concerted effort to develop guidance on conducting inventories of hardware to assess its vulnerabilities to projected climate changes, which includes guidelines for collecting metadata from Intelligent Transportation Systems hardware.

For highway infrastructures, mitigation ideas will consider contingencies for at-risk infrastructure and their role in emergency evacuation operations, and include building State DOT's capacities to deliver emergency response programs.

4.6. Safety

FHWA is also responsible for reducing highway fatalities by seeing that safe roads are designed. The likelihood of weather-related incidents may increase when considering climate change effects; necessitating new design considerations. Safety objectives include an improved ability to respond to new safety concerns that projected climate change impacts may cause. Ideas in support of this objective are monitoring on-going research to consider how projected climate change impacts may affect safety design standards, conduct research on how projected climate change impacts may be factored into safety predictive models, assess possible implications of climate change on the safety planning process and the development of Strategic Highway Safety Plans, and evaluate how projected climate change impacts could affect contra-flow safety on evacuation routes.

4.7. Technical Assistance on Climate Change Effects

FHWA will consider a variety of technical assistance options to state DOTs seeking to develop, expand, and improve their transportation programs in planning for climate change and its impacts to transportation infrastructure. Mitigation objectives include many ideas in support of communicating current and relevant climate change adaptation information to transportation practitioners. Activities include working to enhance FHWA's outreach and communication activities through the continued support of the FHWA Climate Change website and the Transportation and Climate Change Clearinghouse website. Additional work includes promoting and/or providing training on topics with adaptation overlap, continuing to contribute to the U.S. Climate Change Research Program, and facilitating contact between FHWA division offices, states, and/or MPOs and those with expertise in climate change adaptation as it relates to transportation decision making.

5. FHWA'S KEY CLIMATE CHANGE ADAPTATION FOCUS AREAS

FHWA recognizes that the challenge of adapting existing and planned infrastructure to potential climate change effects is moving beyond the consideration of weather-related consequences that have been and are currently being experienced to, instead, account for forecasted changes in climate patterns that the transportation system is likely to face within its design life.

5.1. Collect, Synthesize, and Disseminate Data Scaled for Practitioner Application

Consulting with other agencies and research organizations, work will be conducted to provide information on climate change effects and potential impacts that are

understandable and usable by planners, designers, and asset managers, among others. In addition, further efforts will encourage transportation agencies to collaborate with climatologists and other experts (such as hydraulics and coastal engineers and specialists) in their respective states to define and refine projected climate changes and resulting impacts in their areas of expertise. Data availability, technical capability, and assumptions about how climate change may affect at-risk transportation infrastructure vary across the country, and efforts to promote interdisciplinary coordination can help ensure maximum benefit from on-going research.

Global climate models (GCMs) outputs used to estimate GCC affects will likely need to be “downscaled.” State- or regional-scale information needs to be derived from the larger-scale models and data analyses in order to make better assumptions about what, where, and when changes can be expected, and to be usable by transportation practitioners [10].

5.2. Assessing Vulnerability and Risk to Climate Change Effects

In order to reduce the likelihood of transportation system failure or significant damage as a result of climate change impacts, it is necessary to identify impacts in a given region. This is followed by and establishing a weather baseline against which shifting risks and susceptibility can be determined. To help accomplish this, FHWA will explore working with relevant stakeholders to develop a non-prescriptive, risk-based methodology for conducting vulnerability and risk assessments. Considering GCC effects and their potential impacts will be especially important in current high-risk areas.

5.3. Developing Decision-making Methodologies, Policy, and Guidance

Relying on traditional planning, design, and operational methods and assumptions may no longer be adequate in high-risk areas. FHWA’s regulations, technical advisories, guidance memoranda, and policies will be reviewed, evaluated, and, where appropriate, revised to ensure that adequate consideration and accounting is given to climate change concerns from system and project planning to operations, maintenance, and emergency management. Design standards or inputs will need to be researched to determine whether they adequately consider GCC effects. Methods and principles for conducting vulnerability assessments will also need to be periodically reviewed and revised.

5.4. Conducting Research, Outreach, and Education

For many states, the climate change impacts do not yet seem as imminent or as threatening as they are in Alaska or other especially vulnerable regions, while other states may not yet attribute these impacts to climate change. Only a collaborative approach between planning, resource, emergency management, and transportation agencies at the federal, state, and local levels will ultimately make adaptation activities successful. The FHWA is contributing to and helping advance various research efforts through the USDOT’s Climate Center, the US Climate Change Science Program, and the National Academies of Science. Synthesizing and communicating downscaled data for transportation applications, providing the data in transportation language and context, and sponsoring peer exchanges and best practice studies on climate change adaptation will also contribute to a collaborative approach.

6. CONCLUSION

Scientific consensus is that the effects of climate change are occurring and will likely continue. Transportation decisions from planning to maintenance often have long-term

implications, and, thus, their outcomes stand to be affected more by climate change—more extreme weather events will likely be encountered during the lifecycle of transportation infrastructure. For this reason, a better understanding of how climate change may affect the transportation system is needed in order to stimulate better, and adaptive, decisions.

FHWA has a responsibility to provide an effective highway network. Given that the climate directly affects or influences many transportation decisions, this review of possible actions and ideas to mitigate the impacts of climate change provides a foundation for FHWA to assess how a changing climate will likely affect its transportation activities and to identify associated risks and ways to manage them.

FHWA intends to help identify the data needed to analyze climate change effects and impacts at regional scales. FHWA also aims to develop methodologies, policy, and guidance that will aid in integrating GCC effects, impacts, and adaptation considerations into transportation decision-making, including conducting vulnerability and risk assessments. With a corresponding emphasis on research, outreach, and education, FHWA expects to strengthen state and local transportation agencies' capacity to adapt transportation decisions to respond to and address climate change concerns.

REFERENCES

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- [5] Pew Center on Global Climate Change. Adaptation Fact Sheet. Available at: www.pewclimate.org/global-warming-basics/climate_change_101
- [6] Adapted from TRB Special Report 290 Table 5–1 and Gulf Coast Study, Phase 1, Table 1.1.
- [7] The National Environmental Policy Act (NEPA) is a United States environmental law signed into law on January 1, 1970 and established a U.S. National policy promoting the enhancement of the environment, and set up procedural requirements for all federal government agencies to prepare Environmental Assessments (EAs) and Environmental Impact Statements (EISs). EAs and EISs contain statements of the environmental effects of proposed federal agency actions.
- [8] The MCDA process, which allows multiple streams of dissimilar information to be analysed, requires setting a stated goal or decision statement that is linked to measurable and logical criteria. The approach provides a means to define and gauge the most important information, improving the quality and defensibility of risk decision-making.
- [9] Ecosystem services are functions that ecosystems provide to society at no cost. If these services are impaired or destroyed, their functions become scarce, and society must pay to restore the natural ecosystem function or replace the function with technological solutions. State DOTs efforts to develop regional ecosystem frameworks are encouraged—as described in FHWA's Eco-Logical document—to recognize climate change effects and use probabilistic scenario approaches to design conservation areas. FHWA believes it is important to conduct pilot projects to quantify the value of ecosystem services for protection of transportation infrastructure.
- [10] IPCC. *Climate Change 2007: Synthesis Report, Chapter 8*. www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter8.pdf