Sustainability

Publications

Resilience

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Overview

- Building Resilient Transportation **(January 2019)** - Three-page graphic summary of how FHWA, states, and regions are responding to climate change and what transportation agencies can do. (PDF 1.45 MB)
- Climate Change and Transportation Infographic **(January 2016)** - This infographic shows the importance of taking action early to plan for infrastructure resilience and to cut transportation greenhouse gas emissions. It summarizes actions that state and regional transportation agencies can take. (PDF 1 MB)

Multi-Discipline

- Coastal Nature-Based Solutions: Lessons Learned , August 2024. This fact-sheet summarizes emerging practices and lessons learned for planning, designing, and implementing Coastal Nature-Based Solutions.
- Nature-Based Solutions for Coastal Highway Resilience: An Implementation Guide **(September, 2019)** The Implementation Guide is designed to help transportation practitioners understand how and where nature-based solutions can be used to improve the resilience of coastal roads and bridges. Upfront, it summarizes the potential flood-reduction benefits and co-benefits of these strategies. From there, the guide follows the steps in the project delivery process, providing guidance on how to consider nature-based solutions in the planning process, how to conduct a site assessment to determine whether nature-based solutions are appropriate, key engineering and ecological design considerations, permitting approaches, construction considerations, and monitoring and maintenance strategies. (PDF , 5.5MB)
- White Paper: Nature-based Solutions for Coastal Highway Resilience **(March 2018)** - Briefly describes the current state of practice regarding the use of natural and nature-based features to protect coastal roads from flooding. Provides an overview of available tools for design, implementation challenges, and knowledge gaps. (PDF , 754 KB)
- Vulnerability Assessment and Adaptation Framework, Third Edition **(December 2017)** - This document is a guide for transportation agencies interested in assessing their vulnerability to climate change and extreme weather events. It gives and overview of key steps in conducting vulnerability assessments and uses in-practice examples to demonstrate a variety of ways to gather and process information. (PDF , 17.7MB)
- Post-Hurricane Sandy Transportation Resilience Study of NY, NJ, and CT **(July 2017)** - The objective of this study was to assess the impacts of October 2012's Hurricane Sandy, (and to a lesser extent, Hurricane Irene, Tropical Storm Lee, and the Halloween Nor'easter in 2011) on the transportation

assets within the greater NY-NJ-CT metropolitan region, assess the vulnerability of those assets to the impacts of extreme weather events and the possible future impacts of a changing climate, and identify adaptation strategies to increase the resilience of the transportation system.

- 2013-2015 Climate Resilience Pilot Program: Outcomes, Lessons Learned, and Recommendations **(July 2016)** - From 2013 to 2015, nineteen pilot teams partnered with FHWA to assess transportation vulnerability and evaluate options for improving resilience. This report synthesizes lessons learned, identified needs, and recommended next steps from the pilot program. It includes illustrative project findings, outcomes, and examples throughout. (PDF 2.5 MB)
- Climate Change Resilience Pilots Reports and Information **(2018)** - In multiple groups of pilot projects, FHWA partnered with states and metropolitan areas to conduct climate change and extreme weather vulnerability assessments of transportation infrastructure and to analyze options for adapting and improving resiliency.
- Gulf Coast Study Reports **(January 2015)** - This groundbreaking U.S. DOT study produced tools and lessons learned that transportation agencies across the country are using to assess vulnerabilities and build resilience to climate change. Reports include 1) synthesis of lessons learned and methods applied; 2) criticality assessment; 3) climate projections and sensitivity assessment; 4) vulnerability assessment; 5) engineering assessment of adaptation options. Summaries and multi-media materials also available.

Engineering

- Pavement Resilience: State of the Practice **(March 2023)** - This document examines pavement resilience, a subset of transportation resilience, and describes the state of knowledge, practice, and future needs based on (1) key national and international climate documents, (2) a FHWA approach to resilience, (3) the results of an unpublished literature review, and (4) the findings from two FHWAsponsored Peer Exchanges on pavement resilience held in late 2020.
- Geohazards, Extreme Weather Events and Climate Change Resilience Manual **(February 2023)** - This manual supports transportation agencies in adopting a proactive Geohazards and Climate Change Resilience approach.
- Emerging Issues Associated with Sea Level Rise: Findings from FHWA Peer Exchanges **(August 2022)** – This report summarizes the results of peer exchanges FHWA convened in four States focused on transportation infrastructure's vulnerability to sea level rise, both now and in the future as climate change worsens. Issues addressed included sunny day flooding (nuisance flooding) and other sea level rise impacts, responses to sea level rise, and resource and data needs.
- Infrastructure Resilience to Extreme Events and Climate Change - Federal Lands Sensitivity Case Studies **(June 2022)** – This report presents case studies that examine the resilience of infrastructure to extreme events and includes assessments of sensitivity of a range of transportation projects recently built in national parks to (mostly) higher design flows. Projects include two bridge structures, a small culvert, a curb and paved ditch, an aquatic organism passage (AOP) structure, a large culvert, bank stabilization, and a storm water drainage system.
- Synthesis of Approaches for Addressing Resilience in Project Development **(July 2017)** - This report synthesizes lessons learned and innovations from a variety of recent FHWA studies and pilots to help transportation agencies address resilience concerns at the asset level in engineering-informed adaptation studies. (PDF 4.9 MB)
- Transportation Engineering Approaches to Climate Resiliency TEACR **(October 2015)** The objective of this project is to develop recommended engineering practices for identifying and evaluating project-level vulnerabilities from future extreme weather events and climate change, and designing solutions to respond and adapt to those vulnerabilities. Engineering analyses of a diverse set of transportation assets around the country were performed in order to identify best practices for improving the resiliency of the transportation system to extreme weather and climate change. The result will be a cross-cutting set of recommendations for engineering practice to cover a wide range of facility types and locations.
- Engineering Assessment of Adaptation Options, Gulf Coast Study **(November 2014)** - Presents an 11-step process for analyzing climate change adaptation measures during the engineering of transportation facilities. Provides case studies from a variety of asset types, including culvert, bridge, tunnel, rail, shipping pier, and pavement. Full Report (PDF 16.8 MB). Summaries (HTML).
- Hydraulic Engineering Circular 17: Highways in the River Environment - Floodplains, Extreme Events, Risk, and Resilience, 2nd Edition **(June 2016)** - Provides technical guidance and methods for assessing the vulnerability of transportation facilities to extreme events and climate change in riverine environments. (PDF 6 MB)

- Highways in the Coastal Environment: Hydraulic Engineering Circular Number 25 – 3rd edition **(January 2020)** – This coastal engineering reference manual for highway engineers includes technical guidance and methods for assessing the vulnerability of roads and bridges to extreme events and climate change, focusing on sea level rise, storm surge, and waves. It also addresses the science behind coastal processes including sediment transport, waves and tides; introduces a range of common threats to coastal highways (including waves, erosion, sea level rise, overwashing, storm surge and scour); and, discusses methods to analyze and resolve those threats and develop potential solutions.
- TechBrief: Climate Change Adaptation for Pavements **(August 2015)** - This TechBrief from FHWA's Office of Infrastructure describes climate change impacts on pavement systems along with specific pavement adaptation strategies that can be implemented now and in the future.
- Culvert Management Case Studies: Vermont, Oregon, Ohio and Los Angeles County **(June 2014)** - This report describes how four agencies are managing maintenance and increasing the resilience of their culvert systems.
- Assessment of the Body of Knowledge on Incorporating Climate Change Adaptation Measures into Transportation Projects **(December 2013)** - This report highlights adaptation actions that transportation agencies are pursuing and articulates a growing set of best practices for implementing adaptation. The report also discusses strategies, examples, and best practices for evaluating the costs and benefits of adaptation. The purpose of the report is to provide transportation practitioners with a guide to the current "state of practice" in this field. (PDF 1.2 MB)

Planning

- Integrating Natural Hazard Resilience into the Transportation Planning Process **(September 2024)** - This handbook provides information on integrating climate change resilience into transportation agencies' transportation planning processes. It is primarily focused on long-range plans and transportation improvement plans, but many of the approaches are applicable to other plans, such as transportation asset management plans and corridor plans, which are also discussed briefly in this handbook. The handbook provides approaches to build resilience to natural disasters, extreme weather events, climate change, mitigation of stormwater, and other natural hazards for each step in the transportation planning process.
- Freight Resilience Planning in the Face of Climate-Related Disruption (June 2022) - The purpose of this research is to summarize the state of the practice for freight resiliency planning. Freight planning by public sector agencies is still a relatively new discipline. Given that climate change is causing more frequent and more severe extreme weather events and that these events are increasingly disrupting the movement of goods and services across the United States, this research provides a summary of current practices, methods, and gaps in freight resiliency planning to inform the development and improvement of freight resiliency planning to address climate change and extreme weather risks.Climate Resilience and Planning Peer Exchange:Atlanta Regional Commission **(January 2017)** - This report summarizes a peer exchange on climate change resilience that was held October 4-5, 2016 in Atlanta, Georgia and hosted by the Atlanta Regional Commission (ARC). The peer exchange was co-organized by the Federal Highway Administration (FHWA) and ARC. (PDF 664 KB)
- Resilience and Transportation Planning **(January 2017)** - This fact sheet outlines updates to the metropolitan and statewide transportation planning regulations to reflect new FAST Act requirements to address resilience and natural disaster risks. (PDF 223 KB)
- Climate Change and Environmental Justice: Considerations for Transportation Decision-making **(June 2016)** - This fact sheet explores the impacts of climate change on low income and minority communities, as well as actions transportation agencies can take to minimize negative impacts. (PDF 352 KB)
- Integrating Climate Change in Transportation and Land Use Scenario Planning - An Example from Central New Mexico **(April 2015)** - This project used scenario planning to analyze strategies to reduce greenhouse gas emissions and adapt to climate change impacts, alongside other community goals, in the greater Albuquerque area of central New Mexico. The project demonstrated how climate change considerations can be incorporated into transportation and land use scenario planning and provided analysis that was incorporated into the region's long range transportation plan. (PDF 4 MB) Additional Project Information.
- A Framework for Considering Climate Change in Transportation and Land Use Scenario Planning: Lessons Learned from an Interagency Pilot Project on Cape Cod **(July 2011)** - FHWA and the Volpe Center have developed a guidebook that discusses the steps taken during the pilot project and presents lessons learned and recommendations that will guide other areas in pursuing a similar multi-

agency approach to reduce greenhouse gas emissions and plan for climate change impacts through integrated transportation and land use scenario planning. (PDF 2.2 MB)

- Assessing Criticality in Transportation Adaptation Planning **(June 13, 2011)** - This memo discusses approaches for narrowing the universe of transportation assets to study in a climate change vulnerability and risk assessment by assessing their "criticality" and otherwise narrowing study scope. It identifies common challenges, and draws on examples from the FHWA Adaptation Conceptual Model Pilots and the ongoing USDOT Gulf Coast Phase 2 study. (PDF 113 KB)
- Literature Review: Climate Change Vulnerability Assessment, Risk Assessment, and Adaptation Approaches **(July 2009)** - This document details how vulnerability, risk, and adaptation assessments have been or could be used to integrate climate change impacts into transportation decisions and ultimately increase the adaptive capacity of the highway system.

Emergency Relief and Emergency Response

- Trails and Resilience: Review of the Role of Trails in Climate Resilience and Emergency Response **(February 2023)** - This white paper explores existing research, highlights project examples, and identifies research gaps for trails in connection to climate resilience, emergency response, and public health emergencies.
- FAQ: Emergency Relief Program and Resilience **(January 2017)** - Explains that FHWA emergency relief funds may be used to rebuild damaged highways to be more resilient to future extreme weather events if cost effective or consistent with current design standards. (PDF 300 KB)

Operations

- Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance: A Primer **(November 2015)** - This guide provides information and resources to help transportation management, operations, and maintenance staff incorporate climate change into their planning and ongoing activities. Adjustments to transportation system management and operations (TSMO) and maintenance programs-ranging from minor to major changes-can help to minimize the current and future risks to effective TSMO and maintenance. (PDF 5.5 MB) Summary materials: Briefing for Technical Staff and Briefing for Executives
- Planning for Systems Management and Operations as Part of Climate Adaptation **(March 2013)** - This white paper presents various effects of climate change, and how those effects will impact transportation system management and operations. Also presented are presents various options for agencies to assess the vulnerabilities of transportation systems and proposed changes to make transportation operations more resilient to climate change.

Asset Management

- Addressing Resilience to Climate Change and Extreme Weather in Transportation Asset Management (April 2023) - This handbook is designed to help transportation practitioners incorporate natural hazard resilience into asset management.
- Federal Lands Southeast Region Climate Change Transportation Project **(November 2014)** - FHWA partnered with the U.S. National Park Service, and the U.S. Fish and Wildlife Service on a project to develop a tool to help agencies manage their transportation assets in the face of climate change. Major project components include: (1) a synthesis report of federal lands climate change efforts and current best practices; (2) a Southeast Region Climate Change and Transportation Tool to help National Parks and National Wildlife Refuges assess climate vulnerabilities and develop adaptation strategies; and (3) workshops at four pilot units (two parks and two refuges) to test best practices and tool components. (PDF 1.3 MB)
- Managing External Threats through Risk-Based Asset Management **(March 2013)** - explains how risk-based asset management serves as a climate adaptation strategy.

International Practices

- Resilient and Sustainable Transport – Dutch Style: An interim report on bilateral cooperation between FHWA and Rijkwaterstaat **(August 2017)** - This interim report summarizes information and perspectives gained to date from collaboratively testing US and Dutch climate resilience tools on highway projects in both countries. (PDF 2.2 MB)
- A Review of Practices in Denmark, the Netherlands, and Norway. Executive Summary **(June 2017)** - Information gleaned through an FHWA Global Benchmarking Study on climate resilience practices used by transportation agencies in each of the three countries. Includes international practices on

integrating climate projections into highway planning and design procedures, managing uncertainty, and emergency management.

- International Practices on Climate Adaptation in Transportation **(January 2015)** - Presents leading practices in climate adaptation from abroad that may be useful to US transportation agencies. Includes information on practices in Australia, New Zealand, Korea, United Kingdom, Canada, Denmark, Netherlands, and Norway. (PDF 2.2 MB)

Climate Change Projections

- The Use of Climate Information in Vulnerability Assessments **(January 2011)** - This memorandum focuses on the use of climate information when performing a vulnerability assessment. The memorandum describes several sources of precipitation and temperature information, and provides some recommendations on how this information can be used by transportation planners as they consider their climate-related risks. The memorandum has an Appendix which outlines some of the methods employed by pilots to estimate the impacts of sea-level rise. (PDF 400 KB)
- Regional Climate Change Effects: Useful Information for Transportation Agencies **(May 2010)** - This document provides basic information on projected future climate change effects (changes in temperature, precipitation, storm activity and sea level rise) over the near term, mid-century and end-of-century. The report includes two appendices: maps for some of the climate change effects, and a "typology" of projected climate change information gleaned from recent reports. **Also in PDF**: Report & Appendix A (1.3 MB), Appendix B (17.5 MB), Appendix C (463 KB).
- The Potential Impacts of Global Sea Level Rise on Transportation Infrastructure - Atlantic Coast Study **(October 2008)** - This study assesses the potential net effects of sea level rise, and associated increases in storm surges, on transportation infrastructure coastal states and low-lying regions on the Atlantic coast from New York to Florida. Using statistics from the United Nations Intergovernmental Panel on Climate Change, the report describes several scenarios for sea level rise and provides a series of statewide and county maps that visualize the potential impacts of sea level rise on transportation infrastructure.

Archives

- FHWA Climate Change & Extreme Weather Vulnerability Assessment Framework **(December 2012)**
- 10 Simple Steps to Reducing Climate Change
- Highways and Climate Change Brochure