Climate Change Adaptation Support for Transportation Practitioners

2013 Volpe Center Innovation Challenge Project

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13. ABSTRACT (Maximum 200 words)

The nature of the U.S. transportation system requires that actions to adapt to climate change impacts occur primarily at the State and local levels. Federal agencies support State, regional, and local agencies and they work hard to provide frameworks, data, tools, and research and to fund pilot projects as well. Experience has shown that advanced planning to anticipate, prepare for, and respond to the impacts of climate change has the potential to save money and prevent economic disruptions. However, even proactive State and local governments that have begun evaluating climate- and extreme weather-related risks to their resources have not yet fully integrated consideration of changing conditions into existing planning and operational practices, and others are in the early stages of identifying the climate risks and vulnerabilities they face. In December 2013, the Volpe Center's Innovation Challenge judges selected as the winning idea a project focused on helping transportation practitioners at all levels better understand, access, and use Federal climate change adaptation resources. This report summarizes the project and presents the resulting "Expert System" concept.

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List of Abbreviations

Abbreviation	Term
CCSP	Climate Change Scenario Planning
CDC	Centers for Disease Control
DHS	Department of Human Services
DOD	Department of Defense
DOT	Department of Transportation
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIRM	Flood Insurance Rate Map
FTA	Federal Transit Administration
GIS	Geographic Information Systems
IPCC	Intergovernmental Panel on Climate Change
LRTP	Long-Range Transportation Plan
MPO	Metropolitan Planning Organization
MRCOG	Mid-Region Council of Governments
OST-P	Office of Assistant Secretary for Transportation Policy
OST-R	Office of Assistant Secretary of Transportation for Research and Technology
RPO	Rural Planning Organization
STACC Team	Sustainable Transportation and Climate Change Team
USDOT	United States Department of Transportation
USDOT Climate Center	USDOT Center for Climate Change and Environmental Forecasting

Foreword/Preface

The Volpe Center established the Volpe Innovation Challenge in 2012 with the purpose of promoting innovation and interdisciplinary collaboration within the Center to encourage thought leadership at the Center and advance transportation innovation for the public good. The Challenge involves the development of novel project ideas that teams of Volpe staff present to a judging panel of high ranking U.S. Department of Transportation (USDOT) officials from the modal agencies. In 2013, the panel selected this project on Climate Change Adaptation and Resilience for seed funding to develop the team's ideas further. Additional funding for interagency coordination was provided by the Office of the Assistant Secretary of Transportation for Research and Technology (OST-R) through Dr. Kevin Womack. The project team has been grateful for the opportunity to further research this topic, identify existing resources, and flesh out its concept for an "Expert System" to navigate these resources. The project team looks forward to assisting in the development and implementation of such a system in collaboration with its sponsors in the future.

Executive Summary

The nature of the U.S. transportation system requires that actions to adapt to climate change impacts occur primarily at the State and local levels. Federal agencies support State, regional, and local agencies and they work hard to provide frameworks, data, tools, and research and to fund pilot projects as well. However, there exists an apparent mismatch between the scale of the challenge and perceived actions to adapt transportation systems to climate change. Experience has shown that advanced planning to anticipate, prepare for, and respond to the impacts of climate change has the potential to save money and prevent economic disruptions. However, even proactive State and local governments that have begun evaluating climate- and extreme weather-related risks to their resources have not yet fully integrated consideration of changing conditions into existing planning and operational practices, and others are in the early stages of identifying the climate risks and vulnerabilities they face. In December 2013, the Volpe Center's Innovation Challenge judges selected as the winning idea a project focused on helping transportation practitioners at all levels better understand, access, and use Federal climate change adaptation resources. This report summarizes the project and presents the resulting "Expert System" concept.

The project's goal was to lay the groundwork to support State and local practitioners as they proactively (or reactively) adapt to climate change impacts by:

- Developing a comprehensive database of relevant resources
- Categorizing and tagging those resources to make them more searchable
- Developing an "Expert System" concept to help practitioners quickly identify the resources most relevant to them, through a step-by-step guided approach
- Gathering feedback from USDOT agencies and practitioners to help refine the concept
- Presenting the concept to USDOT agencies and assisting with implementation

The Volpe project team began by conducting a scan for all climate change adaptation resources relevant to transportation. This scan resulted in an extensive matrix of 272 resources, including 72 USDOT resources. This exercise confirmed that the universe of potential resources is large and potentially confusing to practitioners. The exercise also produced a prototype database of resources which could be used to help practitioners quickly locate and navigate to the resources most relevant to them.

To help practitioners more easily find the resources they need to take action on climate change, the project team developed a concept for an "Expert System," which would provide users with step-by-step guidance through a series of questions and quickly lead them to resources relevant to their agency or project. The concept was reviewed with USDOT agencies and practitioners through a series of workshops, informal conversations, and meetings. During some of these interactions, the project team also gathered information about potential opportunities to improve Federal agency support to transportation practitioners, with something like the Expert System, and through other means. The team encouraged participants in these events to prioritize the list of opportunities/ideas. Participants' highest ranked idea was for USDOT to support agencies with tools to conduct cost/benefit analysis related to climate change and for those analyses to consider the economic costs of disruption to the regional economy.

The results of these outreach meetings were generally supportive of the Expert System concept. These meetings also informed refinements to the Expert System concept, adding the idea for a potential project scoping component and keyword search function, which would provide multiple ways for users

to access the climate change tools and resources.

The Expert System is a concept that would need to be implemented and maintained by sponsor agencies. This report presents the concept, but it is not an implementation plan. The project team plans to present the final Expert System concept to potential sponsor agencies and looks forward to working with interested parties to implement the ideas presented in this report.

1. Introduction

The world's climate science community has long warned of the dangers of climate change and its implications for nearly all human settlements and systems (IPCC 2014). In the U.S., climate change is already generating measurable impacts, which are expected to increase over the current century and beyond (Melillo et al. 2014). Although there is considerable uncertainty about the precise timing, scale, frequency, and intensity of these impacts, there is little doubt that in order to protect the safety of the American public and for the economy to continue to grow and prosper the U.S. transportation system must adapt to a changing climate.

The U.S. transportation network links goods, services, and people throughout the nation and connects the U.S. to the rest of the world via an interconnected system of over four million miles of roads, over two million miles of pipelines, over 100,000 miles of rail, and 25,000 miles of navigable waterways. The country's transportation infrastructure also includes over 500 commercial and nearly 20,000 general aviation airports, over 600,000 bridges, thousands of rail stations, docks, and nearly 200 ports (Bureau of Transportation Statistics 2015). In recent years, this complex system has been repeatedly damaged by extreme weather events such as Hurricane Sandy as well as day-to-day variability and long-term changes in climate and weather. Thus, the transportation system in the U.S. is challenged by today's conditions and is likely to be further challenged by future conditions, which experts predict to progressively change and become more variable.

Research shows that investment in resiliency planning to prepare for extreme and changing conditions pays off. One resource estimates that at least $4 are saved for every $1 invested in reducing vulnerability to such hazards (Multihazard Mitigation Council 2005). The insurance industry has also recognized the need for increased emphasis on preparing for the impacts of climate change and extreme weather. In 2015, the SmarterSafer coalition, which includes major insurance companies, issued a report titled *Bracing for the Storm* with recommendations for how to reform U.S. disaster policy. The report details the rising costs to the Government of disaster recovery and recommends a shift in emphasis to pre-disaster preparedness, mitigation, and actions to reduce the risk of damage to infrastructure and communities(SmarterSafer 2015).

Transportation practitioners at the regional, State, and local levels are working to assess vulnerability, identify risks, and implement solutions and are looking for tools and resources with which to do this work. Federal agencies, as well as States, academic researchers, non-governmental organizations, and private entities are working to develop analytical tools, data, and resources to aid in these efforts. Yet transportation practitioners often are adding, or are trying to add, climate change adaptation analyses and efforts to already full workloads, and finding, selecting, and using available resources can therefore be overwhelming.

The focus of this project was to help enhance Federal agency efforts to provide support to transportation practitioners at the State, regional, and local levels working on climate change adaptation and resilience. The project included three key elements:

- Identify the existing Federal tools, resources, and data that are available to transportation practitioners and clarify the uses, audience, and requirements of transportation-related resources in particular;
- Identify outstanding needs and issues perceived by transportation practitioners; and

- Develop a conceptual framework for an "Expert System" that, if implemented, would aid someone starting out with a climate change adaptation analysis for transportation to identify resources particularly relevant to their project goals and needs.

Over the course of the project, the Project Team undertook extensive coordination and consultation with DOT agencies and other agencies involved in climate change adaptation and resilience to facilitate collaboration and information sharing (see Appendix A: Coordination and Collaboration).

2. The Matrix: Available Resources and Their Uses

The project team wanted to understand the range of resources available from Federal agencies to support transportation practitioners (and others) and how the resources are intended to be used. The team therefore compiled a spreadsheet matrix identifying current tools, guidance, data, and references from across all agencies within the Federal government. This matrix is a multimodal compilation of resources that provides the basis for developing the Expert System concept and could provide the underlying resource catalog that the Expert System would reference.

2.1 Data Collection and Resource Categorization

The initial matrix was compiled from a thorough web-based search, which included websites of approximately 40 Federal agencies. The matrix was limited to tools and resources of which the Federal agencies had some ownership, rather than links to external resources (e.g., at an academic institution or non-governmental organization). This research resulted in 272 resources identified (see Appendix C: Federal Climate Change Resources (as of April 2015). The project team then categorized resources as tools, data, references/case studies, funding opportunities, frameworks, or web portals to aid in quickly filtering the database to particular resources of interest for specific use. The project team shared a draft matrix with the USDOT modal agencies, resulting in additional updates on their respective tools.

Of the 272 resources identified, 72 were from USDOT and its modal agencies. The project team further categorized USDOT tools to aid in filtering the database. The categories are shown in Table 1.

Table 1: Categorizations used to organize entries in the matrix of available Federal transportation-related resources on climate change adaptation and resilience. Note: some resources fall into multiple categories.

Categorization Type	Categories Used	Number of Resources Identified
Resource Type	Data	2
	Tool	6
	Reference	60
	Funding	1
	Framework	2
	Web Portal	6
Modal Relevance	Highway/ALL	59
	Transit	21
	Rail	5
	Aviation	1

2.1.1 Summary of USDOT Resources

USDOT agencies have been actively producing frameworks, tools, guidance, and reference reports (e.g., case studies) for transportation practitioners at state and local levels for several years. The Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA) have produced the greatest volume of resources (sometimes in collaboration with the USDOT Climate Center) and have the most active programs oriented to State, regional, and local practitioners. Descriptions of a small sample of notable highlights of some of these resources follow.

The FHWA Vulnerability Assessment Framework provides a general guide for State and local agencies to help them conceptualize how to assess the vulnerability of their infrastructure to climate change and extreme weather. This framework is the foundation for several of FHWA's climate change resources.

FHWA and the USDOT Climate Center undertook an extensive study of climate change and transportation vulnerability and adaptation in the U.S. Gulf Coast. The study produced research reports on lessons learned, vulnerability assessments, criticality assessments, climate projections, sensitivity assessments, and engineering assessments and adaptation options. The study also produced tools designed for use by State and local agencies that the FHWA promotes the usage of widely, including:

- **Sensitivity Matrix**, a spreadsheet tool that documents the sensitivity of transportation infrastructure (roads, bridges, airports, ports, pipelines, and rail) to 11 climate impacts.
- **CMIP Climate Data Processing Tool**, a spreadsheet tool that processes raw climate model outputs at the local level from the World Climate Research Programme's Couple Model Intercomparison Project CMIP3 and CMIP5 databases into relevant statistics for transportation planners. (CMIP3 Tool; CMIP5 Tool)
- **Vulnerability Assessment Scoring Tool (VAST)**, a spreadsheet tool that guides the user through a quantitative, indicator-based vulnerability screen. Intended for agencies assessing how components of their transportation system may be vulnerable to climate stressors.

Both FHWA and FTA have funded a number of pilot projects that focus on transportation climate change adaptation. These pilot projects resulted in dozens of case studies, which provide a significant knowledge base about how transportation agencies are implementing the FHWA framework and similar concepts to increase system resiliency. (FHWA Pilot Projects, FTA Pilot Projects)

FHWA has also been active in updating engineering guidance relevant to climate change, such as the recently updated Hydraulic Engineering Circular (HEC) 25: Highways in the Coastal Environment, which now includes guidance on estimating future sea levels and storm surges along with designing protection measures.

The Federal Motor Carrier Safety Administration (FMCSA) produced a study on Weather and Climate Impacts on Commercial Motor Vehicle Safety examining how existing weather conditions may affect the safe operation of commercial motor vehicles and how climate change may affect this issue.

USDOT agencies continue working to expand and improve the resources available to State, regional, and local agencies working on climate change resilience. To help inform this ongoing resource development work, the project team focused next on the experiences of hands-on transportation practitioners to learn more about their perceived opportunities for future support.

3. A Gap Analysis: Opportunities and Feedback from Transportation Practitioners

3.1 Background and Methodology

After researching and documenting the universe of Federal climate change adaptation tools and resources currently available, the project team contacted practitioners and reviewed available materials to identify and understand what on-the-ground practitioners perceive as gaps in these resources. During January and February 2015, the Volpe Center held informal conversations with practitioners at seven State, regional, and local government transportation agencies (shown in red stars in Figure 1) and reviewed five final and 10 draft FHWA climate change adaptation pilot project reports (shown in yellow stars in Figure 1) (AECOM et al. 2011, Oahu Metropolitan Planning Organization 2011, WSDOT 2011, Cambridge Systematics et al. 2014a, Cambridge Systematics et al. 2014b, Climate Change Adaptation Research Partnership 2014, ConnDOT 2014, Hampton Roads PDC et al. 2014, Maine DOT 2014, MD State Highway Administration 2014, MnDOT 2014, ODOT 2014, ADOT 2015, WSDOT 2015, MDOT n.d.). Based on these conversations and this review, the project team compiled a summary of perceived gaps in the existing resources as well as opportunities to develop new resources. These findings are summarized in Section 3.2 below.

Figure 1: Locations of practitioners contacted (in red) and locations of FHWA pilots reviewed (in yellow).

The team noted gaps and opportunities that were discussed in each conversation or report. After completing the conversations and reviews, the project team combined and organized its notes to categorize every gap and opportunity mentioned under the following general themes the team identified within the comments received:

1. General
2. Data and Research
3. Vulnerability and Risk Assessments
4. Implementation
5. Modeling and Mapping
6. Evacuation and Disaster Planning
7. Asset Management
8. Outreach and Communication
9. Cost/Benefit Analysis

The project team identified over 40 potential gaps and opportunities expressed by practitioners under these headings. In late February 2015, the Volpe Center presented its results at a USDOT Climate Center "Climate Change Adaptation Workshop." Over 75 individuals attended this workshop, representing the USDOT modal administrations, other Federal agencies, and State, regional and local transportation agencies, as well as other relevant agencies and organizations. At the end of its presentation, the team asked attendees to place up to three adhesive dots next any of the gaps or opportunities printed out on several posters around the room to denote the gaps and opportunities they felt the USDOT should prioritize addressing. The results of this "dots exercise" are shown below. Participants also identified additional gaps and opportunities, which are listed under "Ideas Suggested by Workshop Attendees" in Section 3.2.

In May 2015, the project team hosted a working group at the National Adaptation Forum in St. Louis, Missouri, to discuss the Expert System concept and gather additional input from practitioners. Approximately 20 practitioners from local governments, metropolitan planning organizations, federal agencies, university researchers, non-governmental advocacy organizations, and foundations attended the working group. The team distributed a worksheet containing the list of needs and gaps presented at the February workshop and asked participants to identify their top three priorities. The worksheets were handed in after the working group and the results of this exercise were added to the summary of the February workshop.

Votes submitted by workshop attendees are presented after each idea below in the following format: (# of dots voted for overall category; X/Y/**Z** where X = dots from the February workshop, Y = votes from the May workshop, and **Z** = the total of both workshops.

Note: The ideas denoted with a "*" were suggested during the May 2015 workshop and thus were not included as options for others to select during the February workshop or when filling out the May 2015 prioritization worksheet.

3.2 Results: Needs and Gaps Identified by Transportation Practitioners

1. General (0 dots for overall category; 5/4/**9** total in this category)
   - **1.1.** A handbook, resource guide, or user-friendly clearinghouse highlighting case studies and best practices for an agency just starting a climate adaptation/resilience planning project which clearly lays out the data and tools needed and how to obtain them (3/4/**7**)
   - **1.2.** Continue exploring an integrated approach to climate change adaptation planning and scenario planning, as has been piloted by FHWA and others (2/0/**2**)

2. Data and Research (0 for overall category; 12/1/**13** total in this category)
   - **2.1.** More coordination, especially regarding data availability and quality, across sectors, States, and other levels of government on research and data collection (5/0/**5**)
   - **2.2.** Greater data availability, e.g., data on historic extreme events difficult to obtain, same with estimating future extreme events; elevation and floodplain data inconsistent; data/projections for less common variables like wind, wildfire, erosion, and landslide potential not always available (1/1/**2**)
   - **2.3.** Transportation agencies have limited data on their own facilities; progress on national standards is needed (e.g., how to easily get asset data where none may exist and then put it in a useable GIS format) (5/0/**5**)
   - **2.4.** Research needed on specific vulnerabilities such as pavement design for extended high-heat conditions (110+ F) and effects of temporary salt-water inundation on infrastructure (1/0/**1**)

3. Vulnerability and Risk Assessments (4 for overall category; 16/4/**20** total in this category)
   - **3.1.** Robust modeling of multiple, complex systems (e.g., hydrology, wildfires) on granular scale to assess overall vulnerability to extreme weather (0/0/**0**)
   - **3.2.** Guidance on how to approach different scales of vulnerability assessment (e.g., statewide, local, asset-specific); different scales are suited to different goals and outputs (2/0/**2**)
   - **3.3.** Resources and tools to help agencies go beyond infrastructure vulnerability to the *implications* of that vulnerability such as economic impacts, effects on environmental-justice and transit-dependent populations, and disruption to regional and local health systems (4/4/**8**)
   - **3.4.** Better integrate infrastructure vulnerability planning with multi-hazard mitigation planning (3/0/**3**)
   - **3.5.** Tools and guidance on how to consider land cover and biotic communities in vulnerability assessment (0/0/**0**)
   - **3.6.** Guidance on how to incorporate replacement cost factor into criticality assessment (0/0/**0**)
   - **3.7.** Guidance on how to set risk tolerance levels and how to tie those thresholds to stakeholder priorities (3/0/**3**)

4. Implementation (5 dots for overall category; 14/7/**21** total in this category)
   - **4.1.** Guidance on how to integrate vulnerability/risk into long-range planning and investment programming processes (4/0/**4**)
   - **4.2.** A decision-making tool to help evaluate trade-offs and probability of impact/damage across all modes and at multiple scales (regional, corridor, asset-level) (2/2/**4**)

4.3. Resources on how agencies can increase resiliency incrementally, through "low-cost climate countermeasures" (0/0/**0**)

4.4. Updated inputs to design processes which account for future climate "norms" and extremes (2/2/**4**)
4.5. GIS-based vulnerability and criticality screening tool for use in project development (1/1/**2**)
4.6. Guidance and incentives for enhanced coordination between State and local infrastructure owners (0/0/**0**)
4.7. Handbook on "add-on adaptation measures" that can be added on to construction projects at relatively low cost for longer-term cost (and potentially life) savings (0/2/**2**)

5. Modeling and Mapping (0 dots for overall category; 8/5/**13** total in this category)
5.1. Update FEMA Flood Insurance Rate Maps (FIRMs) to account for projected sea-level rise (1/1/**2**)
5.2. Predictive tools to show the expected increase in frequency and intensity of extreme events regionally (6/2/**8**)
5.3. Improved modeling tools for projecting changes to non-oceanic water bodies (e.g., rivers, lakes) (0/1/**2**)
5.4. Tools for estimating future erosion locations and rates that account for sea-level rise and increases in extreme events (0/0/**0**)
5.5. Tools tailored to transportation agencies that can focus on fine-grained geographies (0/0/**0**)
5.6. Enhanced tools for modeling the impacts of changes in precipitation patterns in inland areas needed (0/0/**0**)
5.7. Enhanced visualization tools for viewing potential impacts at multiple scales = high outreach and communication potential (1/1/**2**)

6. Evacuation and Disaster Planning (0 dots for overall category; 0/1/**1** total in this category)
6.1. Tool to help identify the impacts of major storms, critical links that should be prioritized, and opportunities to make the system generally more resilient
6.2. Guidebook on how to use a range of downscaled projections for emergency/evacuation planning (0/1/**1**)

7. Asset Management (0 dots for overall category; 2/0/**2** total in this category)
7.1. Guidelines for how to incorporate climate projections into asset condition and deterioration models (0/0/**0**)
7.2. Dissemination of best practices for collecting data needed for vulnerability assessment during the asset management process as an opportunity to improve assessment over time (2/0/**2**)

8. Outreach and Communication (0 dots for overall category; 3/6/**9** total in this category)
8.1. Central location/clearinghouse for information on transportation sector approaches to climate change adaptation (1/2/**3**)
8.2. Support in building a community of climate adaptation professionals in the transportation sector, through regular webinars, peer exchanges, and conferences (1/1/**2**)
8.3. Early outreach to agencies about data challenges and requirements (0/0/**0**)
8.4. Visualization tools to better inform the public and decision-makers about potential impacts (0/1/**2**)
8.5. Outreach and training to help engineers adopt climate projections as inputs to design processes (1/2/**3**)

9. Cost/Benefit Analysis (3 dots for overall category; 22/4/**26** total in this category)

9.1. Guidance on how to model the economic and other impacts of particular assets or sets of assets being out of service, at the city/regional scale (6/0/**6**)

9.2. A tool to help evaluate the costs/benefits of certain investments; ideally considers not only costs of infrastructure replacement, but also costs of disruption to regional economy and other systems (13/4/**17**)

10. Ideas Suggested by Workshop Attendees

10.1. Performance measures for climate adaptation (3/0/**3**)

10.2. Improved guidance on criticality assessment (1/0/**1**)

10.3. Policies that improve integration of programs and requirements across Federal agencies (4/0/**4**)

10.4. Research on strategies that address adaptation and mitigation together (4/2/**6**)

10.5. Increased understanding of interdependencies between transportation and other sectors (0/2/**2**)

10.6. Funding source for adaptation planning projects (a bridge to integration of climate change in the long-range transportation planning process) (1/1/**2**)

10.7. Guidance on how to prioritize infrastructure improvements (0/0/**0**)

10.8. Tools related to use of green and nature-based approaches to climate adaptation for transportation (0/1/**1**)*

10.9. Visualization tools that show potential benefits of adaptation options (as opposed to just climate change impacts (0/1/**1**)*

10.10. Outreach to tribes; integration of climate science with traditional knowledge and concerns (0/1/**1**)*

3.3 Summary of Results

The top items receiving votes in both the February and March workshops are listed below. Together these items represent 40 percent of all dots/votes provided by the workshop participants:

9.2. A tool to help evaluate the costs/benefits of certain investments; ideally considers not only costs of infrastructure replacement, but also costs of disruption to regional economy and other systems (13/4/**17** –13 percent of all dots/votes)

5.2. Predictive tools to show the expected increase in frequency and intensity of extreme events regionally (6/2/**8** – 6 percent of all dots/votes)

3.3. Resources and tools to help agencies go beyond infrastructure vulnerability to the *implications* of that vulnerability such as economic impacts, effects on environmental-justice and transit-dependent populations, and disruption to regional and local health systems (4/4/**8** – 6 percent of all dots/votes)

1.1. A handbook, resource guide, or user-friendly clearinghouse highlighting case studies and best practices for an agency just starting a climate adaptation/resilience planning project which clearly lays out the data and tools needed and how to obtain them (3/4/**7** – 5 percent of all dots/votes)

9.1. Guidance on how to model the economic and other impacts of a particular assets or set of assets being out of service, at the city/regional scale (**6** – 5 percent of all dots/votes)

10.4. Research on strategies that address adaptation and mitigation together (4/2/**6** – 5 percent of all dotes/votes)

The top five categories of gaps and opportunities receiving votes (as measured by the average number of votes per gap/opportunity, shown in parentheses) are:

9. Cost/Benefit Analysis (13.0)
1. General (4.5)
2. Data and Research (3.3)
4. Implementation (3.0)
3. Vulnerability and Risk Assessments (2.9)

A key theme of the overall results was the concept of integrating adaptation and resilience into existing and routine analyses and planning efforts. The results of this work and the practitioner feedback informed the project team's development of the Expert System concept and will inform other Federal entities' work as they continue to develop and promote climate change adaptation resources for transportation planning practitioners.

4. A Climate Change Adaptation "Expert System" Concept for Transportation Practitioners

4.1 Federal, State, Regional, and Local Roles in Transportation Climate Change Adaptation

In the U.S., transportation systems are built and maintained through multi-level partnerships between Federal, State, regional, local, and special purpose governments. The specifics vary significantly by region and by transportation mode, but the vast majority of transportation infrastructure is planned, built, and maintained by State, regional, and local agencies. Federal agencies typically provide funding, oversight, guidance, and technical support. Therefore, it is largely the actions of State, regional, and local transportation practitioners that will prepare for and respond to the challenges of climate change. However, despite some notable examples of State, regional, and local agencies actively working on climate change in the transportation sector, many agencies are struggling with getting started in transportation climate change adaptation planning or with taking the next steps into implementation.

4.2 Climate Information Overload

As evidenced by the matrix of resources presented in Chapter 2, Federal agencies have developed a wealth of research, data, tools, and other resources to support State, regional, and local agencies in preparing for and adapting to climate change. Increasingly, agencies make these resources available both through agency websites and through departmental and government-wide clearinghouses (e.g., USDOT Transportation and Climate Change Clearinghouse, U.S. Climate Resilience Toolkit), expanding easy access to them. However, it may be difficult for practitioners to efficiently identify which of the numerous resources are best-suited to the context of the climate change adaptation or resiliency projects they are considering. In fact, the project team noted in its conversations that some practitioners felt overwhelmed by the large number of resources and rapidly-changing research landscape, leading to "climate information overload."

The project team theorized that this overload may be in part responsible for a perceived mismatch between the seriousness of the climate change challenge and the level of action and funding being allocated at State, regional, and local levels in recent years. The team theorized that a comprehensive, step-by-step system could help users overcome climate information overload and help guide them quickly to a set of tools, data, and case studies that would help them find a clear path to action. The team developed the Climate Change Adaptation Expert System for Transportation Practitioners concept to demonstrate how such a system might work.

4.3 Expert System Concept Overview

The concept of the Transportation Climate Change Adaptation Expert System is for a tool that provides step-by-step guidance to transportation practitioners to help users cut through the complexity of knowing how to take action and instead focus on important decisions, identify tools and resources that are applicable to them, and help document those decisions in a customized project map. The Expert

System could be designed to sit on top of and draw from centralized clearinghouses of information such as the U.S. Climate Resilience Toolkit, providing different ways to quickly navigate through and access the information. By providing practitioners with not only access to the wealth of research, data, and tools that Federal agencies have developed, but also with assistance in figuring out which of these are likely good fits for their agency, region, or project, barriers to taking action would be reduced and more State and local governments would feel confident in moving forward.

4.3.1 A user-focused approach

In order to identify the most relevant resources, the system would gather information about the user's agency and context. The project team's concept for the Expert System would begin by asking users a series of simple questions in the same manner as familiar tax preparation software, such as TurboTax®[1]. The answers to these questions would be documented and used for filtering searches of resources and could also be useful in helping identify potential peer agencies and case study references.

The system would start by asking the user what they would like to do. In many ways, this is the most significant characteristic of an Expert System user and one that can enable the system to bypass questions that may be irrelevant or of lower priority to the user. The answer to the first question can therefore help guide the user down one of many "paths." However, users should be encouraged to explore multiple paths, save progress, or modify previous work. Some examples of potential initial paths are listed below and illustrated in Figure 2:

- Understand how climate change can impact transportation infrastructure and facilities, generally
- Estimate how climate change will affect transportation facilities in my State or region, specifically
- Explore the implications of climate change for my transportation system and prioritize potential actions
- Find strategies on how to integrate the consideration of climate change in my agency's practices and decision-making
- Learn about how my peers are increasing resiliency to climate change and extreme weather events
- Learn about training and technical assistance resources to help advance climate change adaptation in my State or region

[1] https://turbotax.intuit.com/

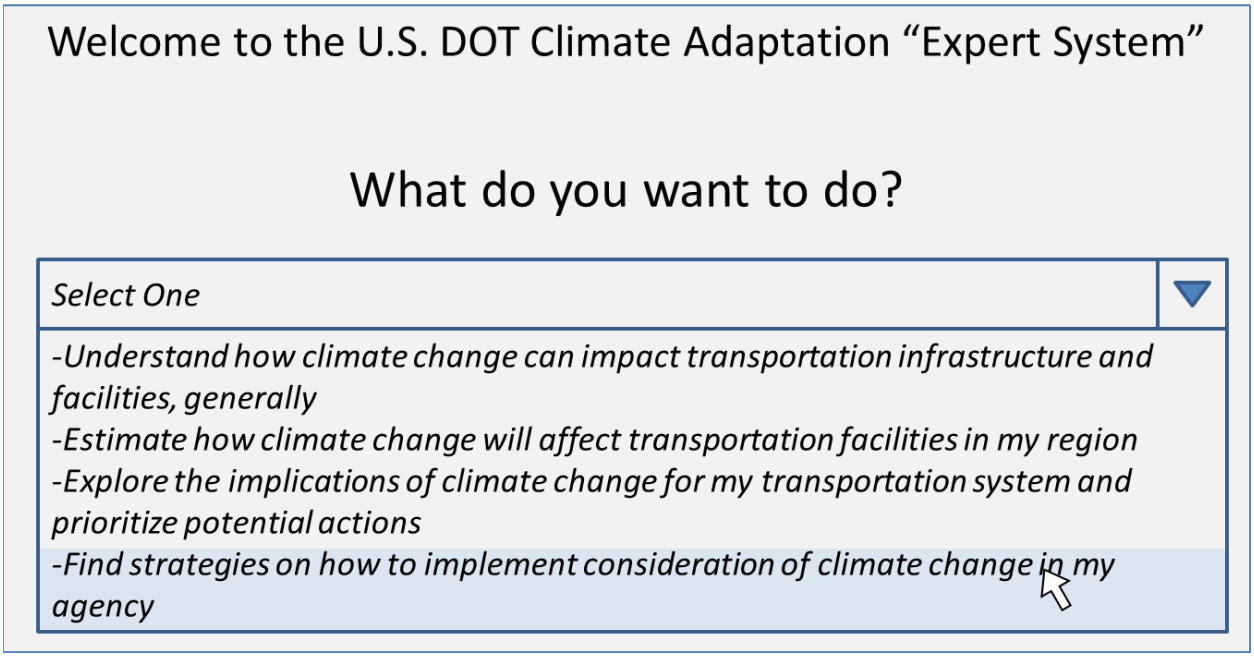


Figure 2: Illustration of Expert System Opening Path Selection

4.3.2 Step-by-step resource filtering

One of several Expert System functions could be the step-by-step filtering of tools, data, case studies, and other resources. After the user selects what they want to do, the system would ask the user more detailed questions about their agency. It would begin by listing all potentially relevant resources, but as the user answered questions, the list of resources would be refined. Users could choose to stop answering questions and explore the results at any time. Figure 3 and Figure 4 below illustrate how this filtering might look.

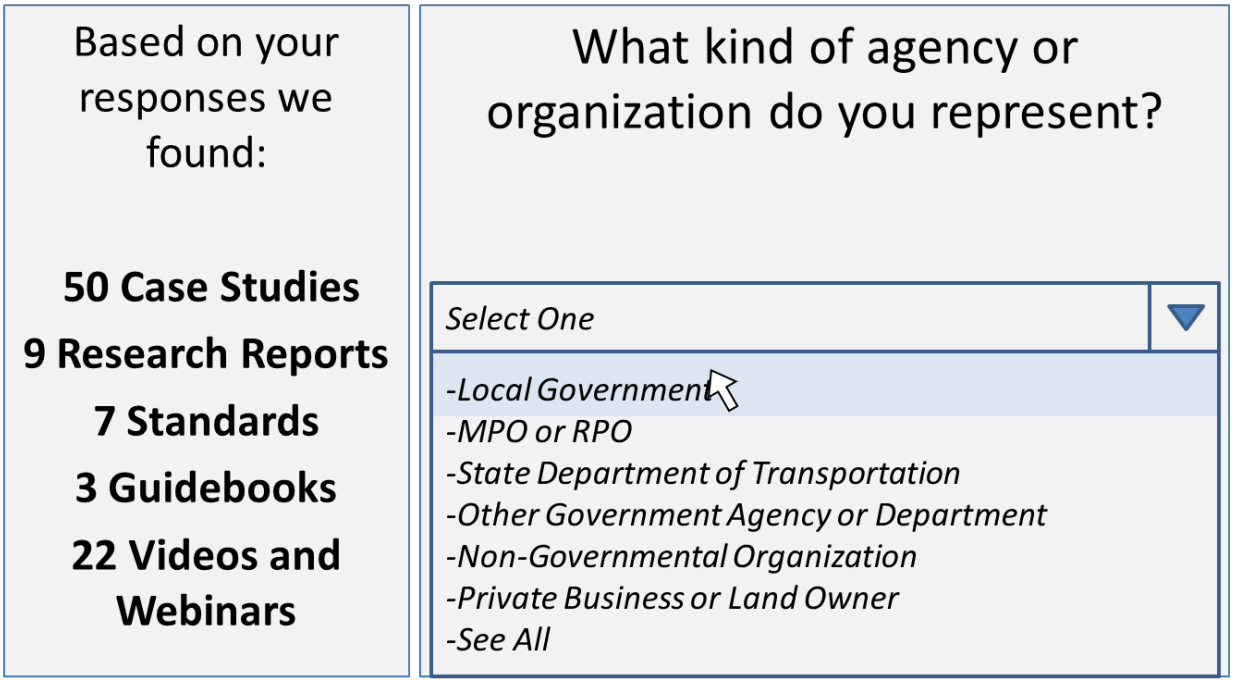


Figure 3: Illustration of Expert System resource filtering based on agency type

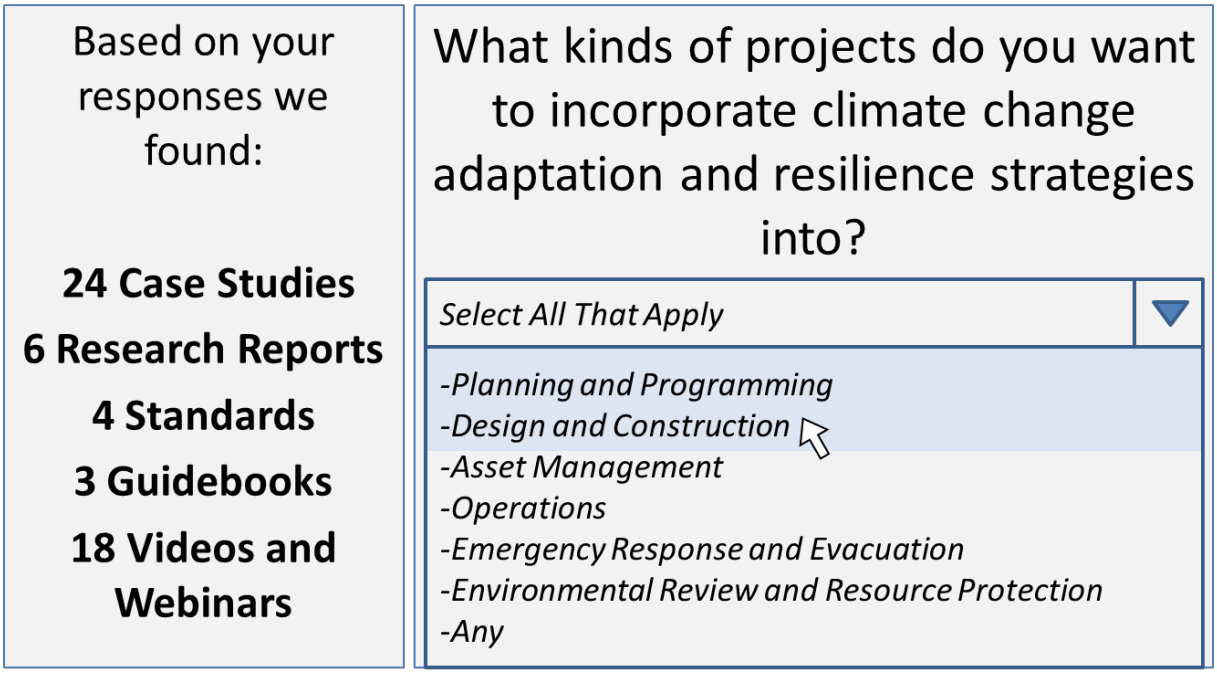


Figure 4: Illustration of further Expert System resource filtering based on project type

Users could also perhaps filter resources by geographic characters (e.g., such as costal, inland), or potentially by U.S. region (Figure 5). Users familiar with climate change impacts in their State or region could filter along these lines (Figure 6) and users could filter by mode, project life, or any number of other factors (Figure 7) as well.

Figure 5: Illustration of further Expert System resource filtering based on geography

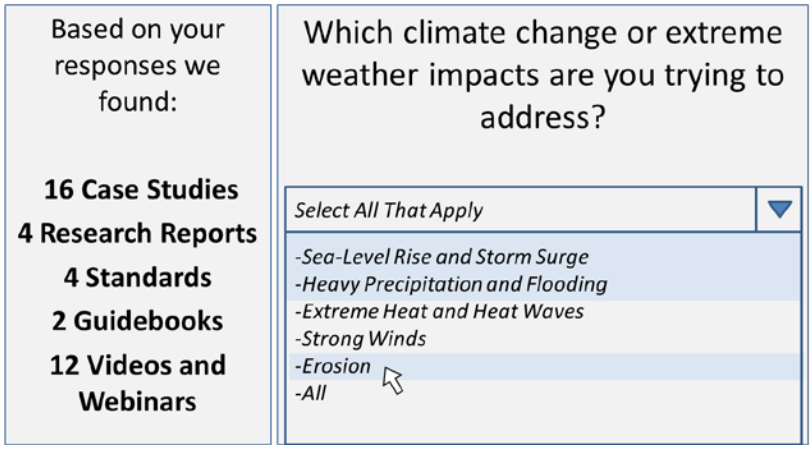


Figure 6: Illustration of further Expert System resource filtering based on climate change impacts

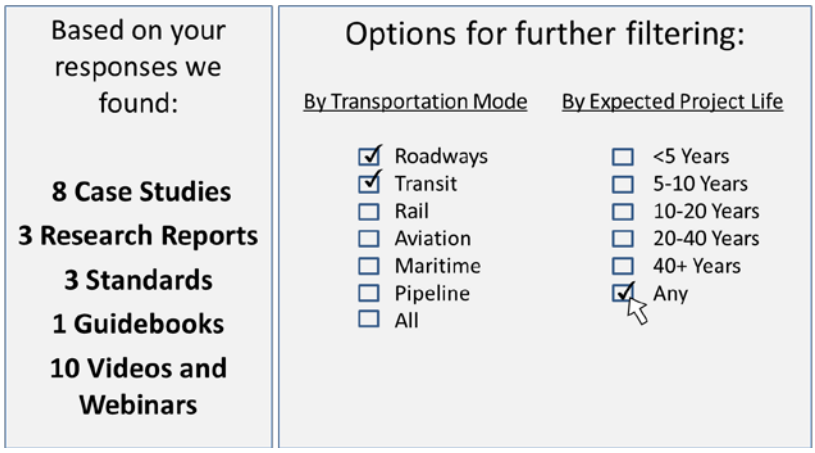


Figure 7: Illustration of further Expert System resource filtering based on other factors

4.3.3 Guided project scoping

In addition to helping users navigate the complex landscape of climate adaptation tools and resources, the Expert System could be built to help users through difficult stages in the transportation climate adaptation planning process. For example, the system could help users in scoping an infrastructure vulnerability assessment using the FHWA Climate Change Vulnerability Assessment Framework. By helping users navigate complex processes like this, the Expert System could reduce the barriers to State, regional, and local agencies moving forward with key actions that will enable them to more confidently initiate and proceed with climate adaptation and resilience projects.

Using the example of the FHWA Climate Change Vulnerability Assessment Framework, the system could guide users through each step in the scoping process. In this example, users would begin by articulating their objectives for the vulnerability assessment. The system could be designed to allow users to choose common objectives from a list of pre-defined options or to write-in their own user-defined objectives (Figure 8).

When the user chooses pre-defined objectives, the Expert System could automatically match them up with relevant case studies or other resources that may be relevant (Figure 9). User-defined objectives would not link to resource but would be documented and stored for later reference. The system could be setup so that users could save their progress, providing them with the option of skipping steps to come back to later or to modify past choices.

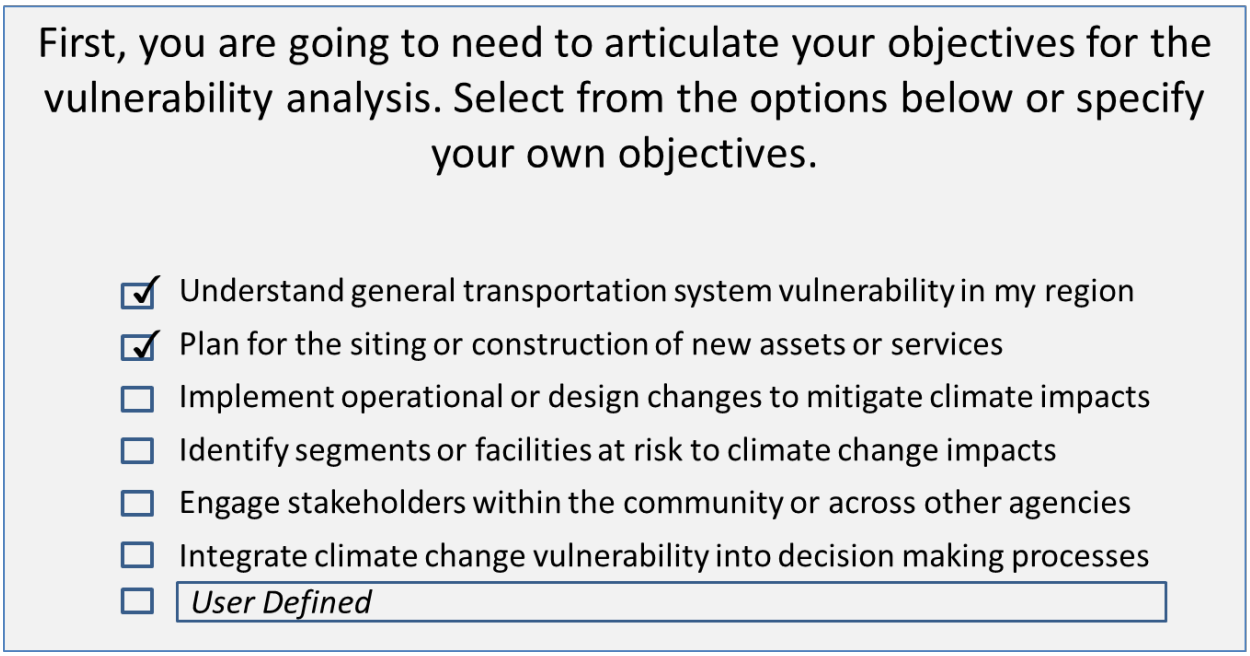


Figure 8: Illustration of possible Expert System project scoping assistance for selecting and documenting objectives

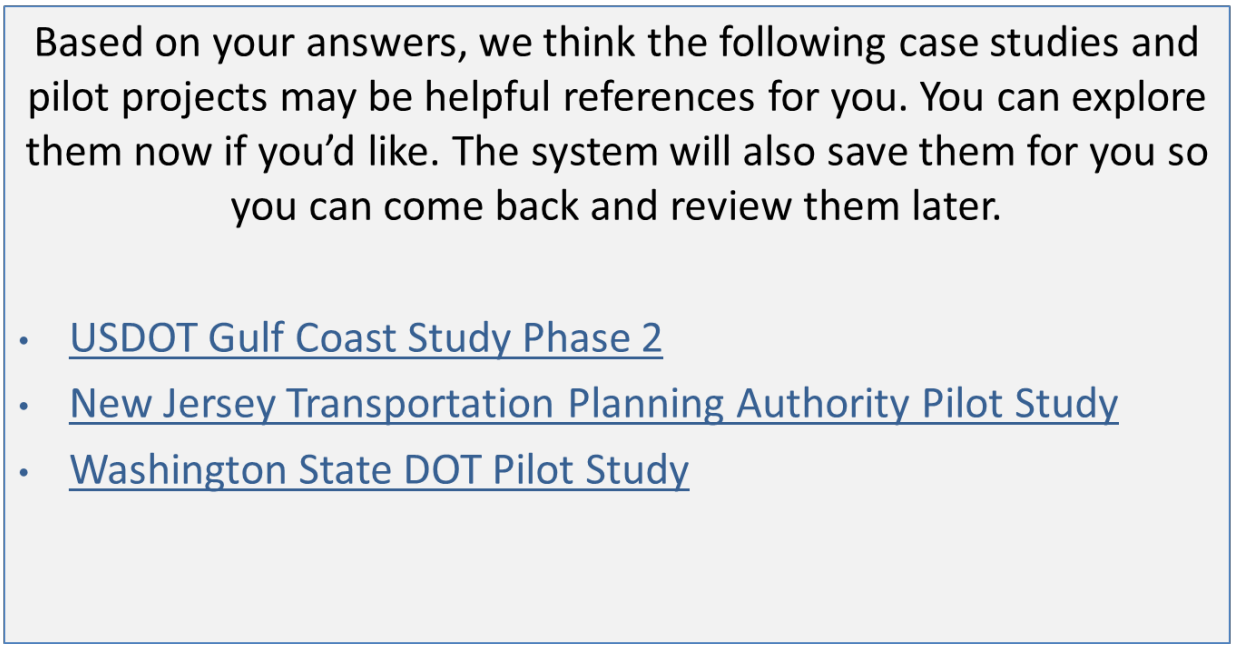


Figure 9: Illustration of Expert System feedback based on user objective selection

In this example, the Expert System would continue to guide users through a series of additional project scoping questions recommended in the FHWA Climate Change Vulnerability Assessment Framework, including:

- Who is your target audience?
- Which transportation facilities should be included?
- What types of products should the assessment generate?
- Who will use the products and in what ways?
- Which climate impacts are you concerned about?

For each question, the system would document users' answers and provide the opportunity to explore related resources, which could help in the project scoping process (e.g., pointing to relevant case studies or research reports).

By guiding users through the scoping process, the Expert System could help identify potential data gaps and provide suggested references on how to fill them. Or, the system may guide users to less data-intensive techniques and tools, which could provide alternatives to full-scale, data-intensive techniques.

For example:

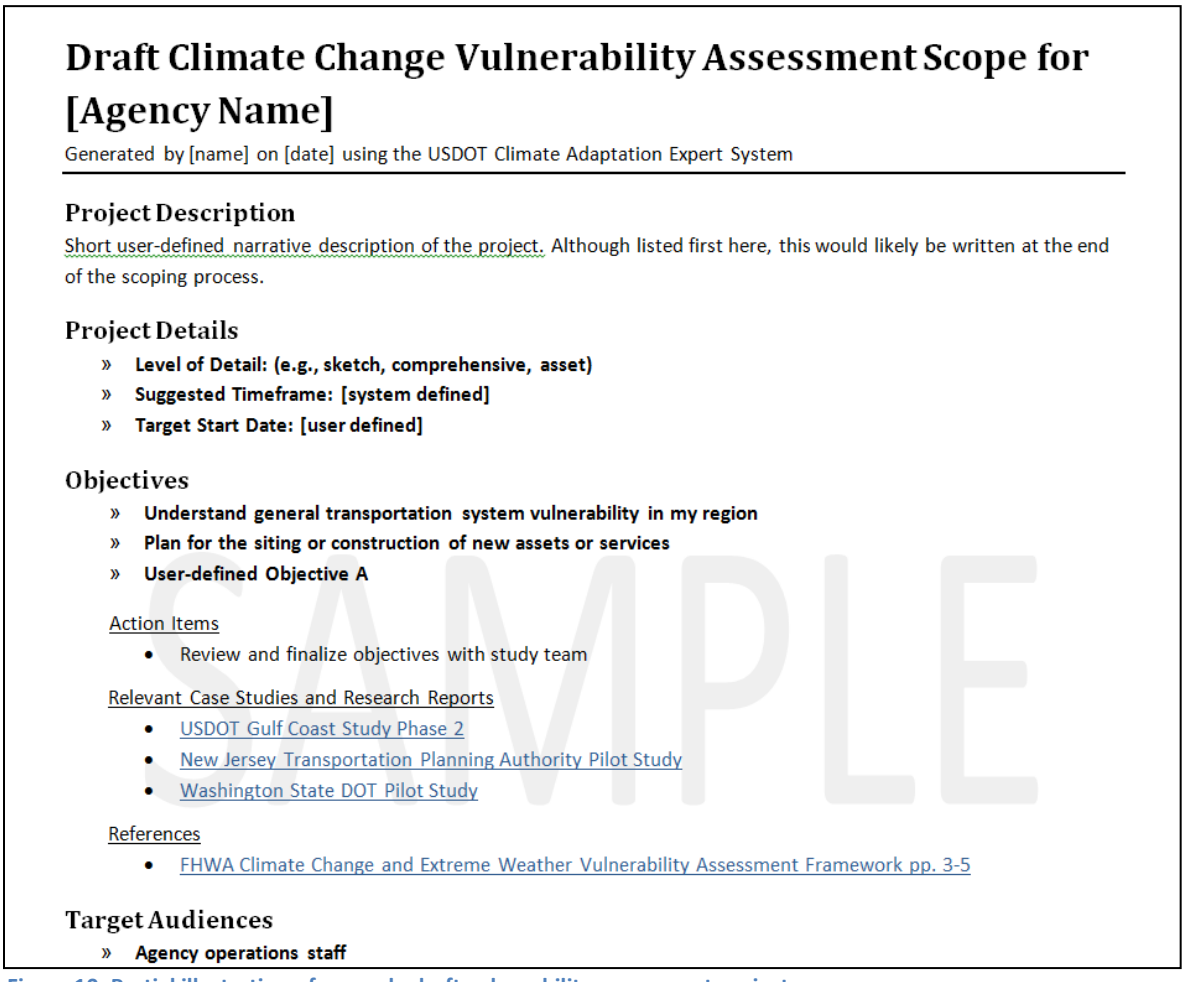
- If the user's agency has limited geographic location information for its transportation assets, the system could suggest using high-level tools to visualize changes like sea-level rise, which can be overlaid onto aerial imagery as a first step before undertaking a full-scale assessment. The system could also point the user to resources on how pilot agencies have developed asset inventories for vulnerability analyses.
- If the user's agency is not sure which climate variables to consider in its vulnerability assessment, the system could suggest variables based on agency location and answers to other scoping questions. The system could then provide examples of variables and impact thresholds

used by pilot communities.

4.3.4 Potential project scoping outputs

A key aspect of the Expert System concept is the ability for users to document project scoping decisions made using the system, and to highlight unanswered questions. Again referencing the TurboTax® analogy, the system would take step-by-step guided inputs from the users and generate comprehensive summary documents. In the FHWA Vulnerability Assessment Framework example, a potential output could be a draft vulnerability assessment project plan, showing all decisions made through the guided approach, suggested next steps and action items, and relevant resources. The latter items would be informed by and filtered based on answers to earlier questions about the agency and its priorities.

As envisioned, the system would allow users to view, edit, and revise outputs through the Expert System website or to create downloadable, printable, static copies, as in the example shown in Figure 10.



Draft Climate Change Vulnerability Assessment Scope for [Agency Name]

Generated by [name] on [date] using the USDOT Climate Adaptation Expert System

Project Description

Short user-defined narrative description of the project. Although listed first here, this would likely be written at the end of the scoping process.

Project Details

- **Level of Detail: (e.g., sketch, comprehensive, asset)**
- **Suggested Timeframe: [system defined]**
- **Target Start Date: [user defined]**

Objectives

- **Understand general transportation system vulnerability in my region**
- **Plan for the siting or construction of new assets or services**
- **User-defined Objective A**

Action Items

- Review and finalize objectives with study team

Relevant Case Studies and Research Reports

- USDOT Gulf Coast Study Phase 2
- New Jersey Transportation Planning Authority Pilot Study
- Washington State DOT Pilot Study

References

- FHWA Climate Change and Extreme Weather Vulnerability Assessment Framework pp. 3-5

Target Audiences

- **Agency operations staff**

Figure 10: Partial illustration of example draft vulnerability assessment project scope

4.3.5 Maximizing usefulness and approachability

The Expert System concept presented above is designed primarily to help those new to or overwhelmed by the wealth of information and guidance about climate change. However, the Volpe Center team recognizes that users of the Expert System will come from a variety of backgrounds, not just the transportation sector, and that many users may be seeking a more direct, unguided experience.

Therefore, the Volpe Center team recommends that an implementation of the Expert System concept also include features to allow for keyword searching (e.g., Google search) of the resource database. To enable this function, resources would need to be thoroughly catalogued with relevant key words. Furthermore, the team recommends that the Expert System be structured to appeal both to transportation professionals as well as local government or non-governmental organization employees who may not be trained in transportation.

4.4 Reflective Case Study: Central New Mexico Climate Change Scenario Planning Project

In support of FHWA, the National Park Service, the Fish and Wildlife Service, the Bureau of Land Management, and others, the Volpe Center led an interagency climate change, land use, and transportation scenario planning pilot project in the four-county region including and around Albuquerque, New Mexico, from 2013 to 2015. Working closely with the metropolitan planning organization in the region, the Mid-Region Council of Governments (MRCOG), the Volpe Center helped the region consider the implications of five potential future climate change futures on the region as inputs into its long-range transportation plan. What follows is a reflective account of how the project team might have used the Expert System described in Chapters 3 and 4 of this report had it been implemented by sponsor agencies and was available at the time the project took place.

4.4.1 Introduction

The purpose of this case study is to apply a hypothetically implemented version of the Expert System concept to a region that wants to adapt its transportation system to possible climate change impacts. For the purposes of this hypothetical case study, the project team selected the Central New Mexico Climate Change Scenario Planning (CCSP) project since several stakeholders are familiar with this project and it was recently completed. More information on this project can be found at www.volpe.dot.gov/nmscenplan. While the CCSP project ended in June of 2015, for the purposes of this hypothetical case study, the project would start whenever the Expert System is completed.

4.4.2 Step 1: Choose starting path

During the scoping phase of the project, a member of the CCSP project team would go to a website where the Expert System exists. The first screen of the Expert System (Figure 2) would ask the user to select one of a short list of high-level questions about the type of information for which they are looking. Each of these topics, particularly the first, third, fourth, and fifth, would be of interest to the CCSP project team since the region had not substantively discussed climate change in the context of transportation in the region prior to the initiation of the CCSP. For this example, the user would select the first topic: “Understand how climate change can impact transportation infrastructure and facilities, generally.”

4.4.3 Step II: Filtering resources through step-by-step guidance

Next, the Expert System would show the user how many resources by type exist based on the response the user selected (left side of Figure 3) and would ask the user the first of a series of filtering questions (right side of Figure 3) to narrow down the search results. The CCSP user would select "MPO or RPO" since they would likely be working for MRCOG, which led the CCSP in the region. The resource matrix would be queried each time a filtering question is answered (left side of Figure 3).

The Expert System would then ask a second filtering question (Figure 4) to narrow down and tailor the list of available resources even further. The CCSP user would select "Planning and Programming" since the CCSP project focused on integrating climate change considerations into its long-range transportation plan. The Expert System would refine the number of relevant resources further. All resources in the Expert System are currently categorized according to the questions being asked by the user.

The Expert System would then ask the CCSP user in which types of climate change or extreme weather impacts is the CCSP user interested (Figure 5). Being an inland area, the CCSP user would select the two items in which they are most interested: heavy precipitation and flooding and extreme heat and heat waves.

The Expert System's final questions under the topic of generally understanding the impact of climate change on transportation infrastructure and facilities would be about the mode(s) and timeframe(s) of interest (Figure 6). Since MRCOG's Long-Range Transportation Plan (LRTP) is multimodal, the CCSP user would select the three main modes of interest in the plan as well as a 20-40 year timeframe.

4.4.4 Results

As shown in this hypothetical example, by asking only five or so questions, the Expert System could greatly reduce the initial list of available resources. The CCSP user could then comb through this much more manageable list of results.

Of particular interest to the CCSP user would be the FHWA climate change adaptation pilot final reports, which were released in 2015. These reports describe in detail how MPOs and State DOTs across the country have addressed climate change in their transportation planning processes in several different ways. The CCSP user could skim through these reports, find the best one that aligns with what they would like to accomplish, and then use that report as a model for their nascent climate change planning process.

If MRCOG had questions about the process used by an MPO or State DOT in a report, they could contact an Expert System manager to gather more information. The manager could then contact FHWA or, with permission from FHWA, the MPO or State DOT directly.

Once aware of an entity using the Expert System, the Expert System manager could contact the user periodically to check-in on their progress. Once the user's work is complete, any deliverables can be added to the Expert System for the benefit of future users.

5. Conclusions and Recommendations

This report presents the results of the 2013 Volpe Innovation Challenge winning project on Climate Change Adaptation and Resilience Support for Practitioners. The project team identified 272 climate change-related resources from across the Federal Government, including 72 (and increasing) resources within the various USDOT agencies. The largest producer of climate change-related tools, data, and resources within USDOT is the FHWA (sometimes on behalf of the USDOT Climate Center), which has developed a framework for assessing asset vulnerability and a number of analytical tools to aid transportation practitioners in executing projects. FHWA is continuing to expand their resources as well as working to find new ways to present material and facilitate practitioner usage, which will undoubtedly assist practitioners in taking further action on climate change adaptation and resilience.

In addition to existing tools and resources, the gap analysis the project team performed as part of this project identified a strong desire on the part of transportation practitioners to see climate change analyses, tools, data, and resources be integrated into existing planning and analysis tools rather than being treated separately as a stand-alone issue. The other key theme was a desire for cost-benefit analysis tools that can take into account not only the costs associated directly with transportation asset disruption but also the related indirect effects on the local and regional economy and other systems. Other highly sought resources included expanded tools for predicting extreme events regionally, expanded impacts assessment (e.g., environmental justice issues),and potential strategies to address synergies between adaptation and mitigation.

The project team developed an “Expert System” concept that is intended to help novices to experienced practitioners more easily navigate among available resources and identify those most relevant to his/her project. The Expert System is envisioned to guide practitioners through the scoping and tool selection process and to document decisions and highlight remaining unanswered questions or action items. Such a system could be implemented within existing USDOT resource compilations (e.g., as part of the FHWA Vulnerability Assessment Framework website/system) or could be implemented more broadly to address more types of Federal resources (e.g., as part of the White House Council on Environmental Quality’s Climate Change Toolkit). The Expert System is a concept that would need to be implemented and maintained by sponsor agencies. The next step would be to develop an implementation plan for the system, as well as for expanding and maintaining the underlying database of resources.

At a minimum, the database of resources would need to be periodically updated and refreshed with new resources added and outdated ones removed. However, the system might be improved by expanding the scope of the system beyond Federal Government resources. Foreign governments are also working to improve the resilience of their transportation systems and may have research, data, and tools of relevance to the U.S. transportation context. Furthermore, non-governmental non-profits and academic researchers have also produced climate change adaptation tools and resources which would be valuable additions to a more comprehensive Expert System. There could also be opportunities to integrate crowd-sourcing into the system, by allowing users to suggest that resources be added or removed, and potentially providing a simple voting or “like” mechanism, which would allow users to indicate to each other which resources they find most valuable for certain activities. In this manner, the database of resources might be made largely self-sustaining.

As this report’s reflective case study showed hypothetically, the Expert System, if implemented, could greatly reduce the number of potentially relevant Federal resources of interest for a specific user,

enabling them to focus on a smaller, more customized list of resources. The system could also help users overcome “climate information overload” by guiding them through key project scoping decisions and suggesting relevant resources based on user input.

The team has coordinated extensively with the USDOT modal agencies, the USDOT Climate Center, and other stakeholders to discuss the findings of this effort (see Appendix A: Coordination and Collaboration for a detailed list). This report serves as a summary and a stepping-off point for possible implementation of the Expert System concept or further resource development within USDOT. The team looks forward to continuing to support USDOT modal agencies in researching and developing resources for State, regional, and local practitioners working to address climate change in their areas.

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Appendix A: Coordination and Collaboration

Interagency coordination within the USDOT and external coordination and collaboration were key goals of both the Innovation Challenge program and the OST-R office that provided additional funding. The team undertook extensive outreach, coordination, and collaboration to gather information and feedback during the project, and also presented the work in progress to various stakeholders. These outreach and coordination efforts are described in Table 2.

Table 2: Presentations, outreach, and coordination undertaken to gather information and share outcomes of the Climate Change Support for Practitioners project.

Coordination Type	Organizations	Date(s)	Outcome
Data request	USDOT modal agencies	December 2014 – February 2015	Review, update, and confirmation of matrix resource list
Data request	State and regional transportation practitioners	December 2014 – February 2015	Input on perceived resource needs for gap analysis
Presentation / Feedback request	USDOT Climate Center Adaptation Workshop	February 25, 2015	Raised awareness among USDOT agencies and stakeholder groups on project efforts and gap analysis; received feedback on stakeholder opinion on priority gaps to be addressed
Presentation	US Global Change Research Group	March 26, 2015	Raised awareness of project
Presentation	White House Council on Environmental Quality	April 3, 2015	Raised awareness of project
Presentation / Feedback request	National Adaptation Forum session (with Kristin Baja, Baltimore)	May 11, 2015	Raised awareness of project and gathered feedback on perceived gaps/opportunities as well as Expert System concept
Teleconference	Federal Emergency Management Agency	May 15, 2015	Raised awareness of project, shared matrix
Presentation	USDOT Lunch and Learn	June 16, 2015	Raised awareness of project
Presentation / Feedback Session	FHWA Sustainable Transport and Climate Change (STACC) Team	June 16,2015	Raised awareness of project, discussed potential uses of Expert System idea in context of FHWA framework
Presentation	USDOT Climate Center	To be determined	Presented final report and discussed potential next steps
Ongoing discussions	FHWA STACC Team	2014-2015	Regular discussion, review, and input on project development and Expert System idea

Appendix B: Federal Climate Change Resources (as of April 2015)

The matrix of climate change adaptation resources described in Section 2 is attached. The matrix was compiled via a web search for all U.S. Government climate change adaptation resources relevant to transportation conducted in summer 2014 and updated in April 2015. While the intent of this exercise was to produce a close-to-comprehensive list of resources, because climate change is an active, fast-paced area of research, it is likely that additional resources have been made available since the initial scan was conducted.

USDOT resources were reviewed by the agencies in February 2015, revised, and categorized. However, the non-USDOT resources were not reviewed by the respective agencies, nor categorized.
Link to Excel spreadsheet of resources:

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