FHWA-HEP-15-019

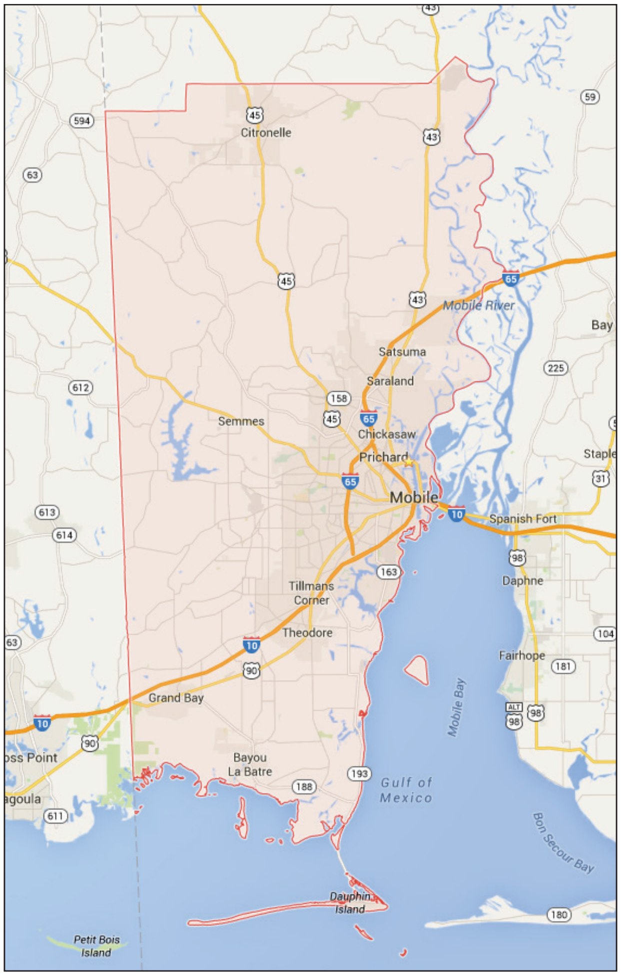
U.S. Department of Transportation
Federal Highway Administration

U.S. DOT Gulf Coast Study, Phase 2

Task 3.1: Task 3.1: Screen for Vulnerability

Support for Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study Phase 2 developed methodologies for evaluating vulnerability and adaptation measures for local transportation systems. These transferrable methodologies were pilot tested in Mobile, Alabama. The project team evaluated the impacts on six transportation modes (highways, ports, airports, rail, transit, and pipelines) from projected changes in temperature and precipitation, sea level rise, and the surges and winds associated with more intense storms.

The third task of the project involved combining all of the information gathered about asset criticality, projected changes in climate, and asset sensitivity to climate changes, to identify which critical assets might be most vulnerable to climate change. The study examined 67 assets, selected to be representative of the most critical assets across all modes of the Mobile transportation system.



Map of Study Area

Objectives

- Develop and pilot test methodologies for screening large numbers of diverse transportation assets for vulnerability
- Identify the critical assets most vulnerable to climate change in Mobile
- Identify system-level vulnerabilities of Mobile's transportation network, such as modes or geographic regions that are particularly vulnerable, or climate stressors or timeframes that may be of particular concern

Approach

The Gulf Coast Study used an indicators approach to identify how assets in Mobile may be vulnerable to the projected changes in temperature, precipitation, sea level rise, and storms. The study identified indicators that align with each of the three components of vulnerability, which are:

- **Exposure**— Extent to which an asset experiences climate variability and change
- **Sensitivity**—Degree to which an asset is affected by exposure (i.e., if all assets were equally exposed, which would experience the greatest damage?)
- **Adaptive capacity**—Ability of a system to adjust, repair, and respond to damage to an asset

An indicator is a representative data element that can be used as a proxy measurement for the overall exposure, sensitivity, and adaptive capacity of each asset to the

Component	Indicator	Rationale
Exposure	Number of days per year above 95°F	Stakeholders indicated that temperatures exceeding 95°F affect service, operations, and workforce conditions in Mobile.
Sensitivity	Past experience with temperature	Highway segments that already experience rutting or other issues from high temperatures may experience worsening problems as the temperature increases.
	Truck traffic	Pavement experiences greater stress from heavy vehicle traffic, so segments with high volumes of truck traffic may be more sensitive to rutting as temperatures increase.
	Pavement binder used	Asphalt may experience rutting if pavement temperatures exceed the high temperature thresholds in the pavement design.
Adaptive Capacity	Replacement cost	Replacement costs for each asset are used as a rough proxy for the ease in which assets could be repaired or replaced. Resources are assumed to be more easily mobilized for lower cost repairs, and replacement costs may indicate overall complexity, size, and expense of the asset itself.
	Detour length	Detour length is used as an indicator of redundancy in the system. Segments with longer detour lengths assumed to have less adaptive capacity than segments with shorter detours.
	Disruption duration	Disruption duration is used to indicate the timeframes necessary to restore service to assets. Length of time for the disruption to clear is an indicator of how well the system can deal with the climate impact.

Table 1: Indicators Used to Assess Highway Vulnerability to High Temperatures

various climate stressors. For example, paving materials vary in their sensitivity to temperature, so the type of paving materials used for an asset can provide an indication of how sensitive that asset may be to high temperatures.

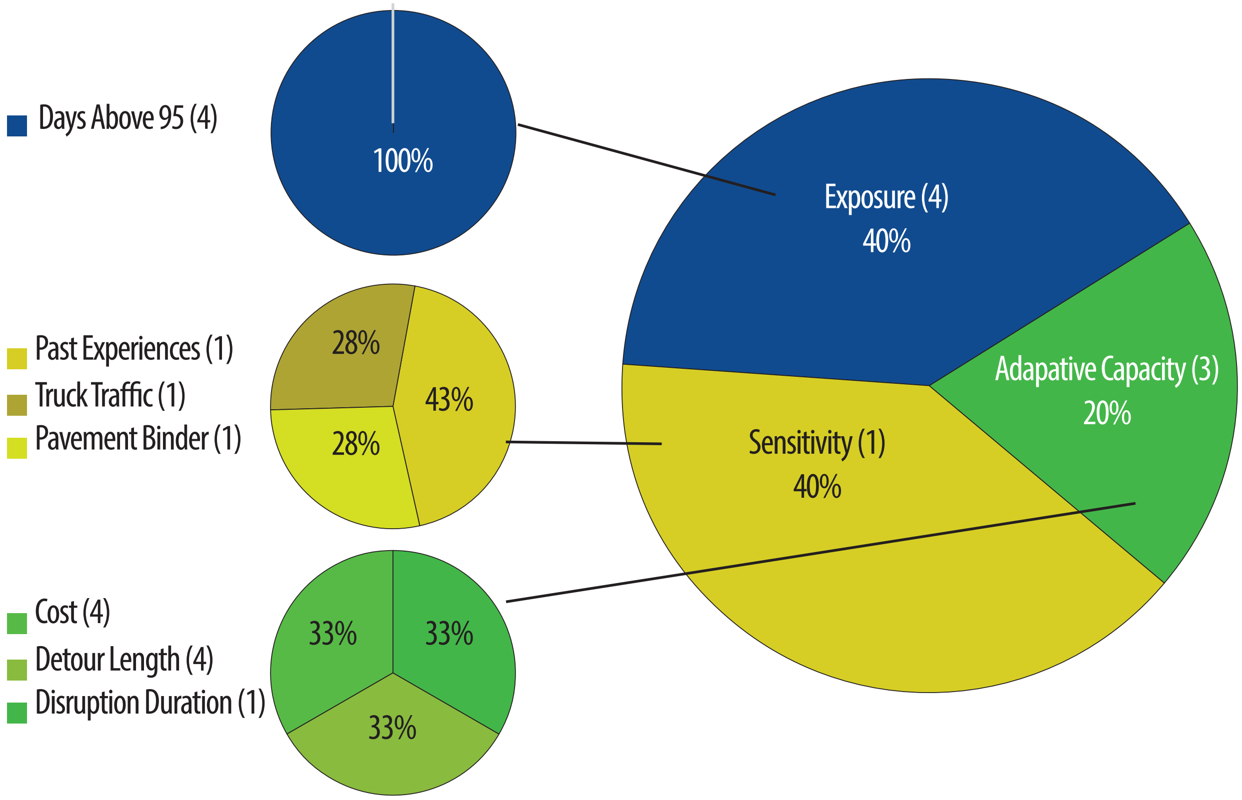
The approach involved the following four steps.

1. **Identify Indicators.** The project team identified exposure indicators for each climate stressor, sensitivity indicators for each climate stressor and transportation mode, and adaptive capacity indicators for each transportation mode. These indicators were selected based on stakeholder input, expert judgment, and data availability. For example, the indicators used to assess highway vulnerability to high temperatures are shown in Table 1.

2. **Collect Data on Indicators.** The project team then collected and compiled data about each asset for the indicators. The climate projections developed earlier in the study served as exposure indicators (e.g., modeled storm surge depth at a particular asset). Data on sensitivity and adaptive capacity indicators came from a combination of nationally available datasets (e.g., the National Bridge Inventory) and local sources. In many cases, there were no existing datasets about the indicators, so the project team conducted interviews and surveys with local experts and asset managers to collect the information.

3. **Establish a Scoring Approach.** The project team then developed an approach to convert data on indicators into a single vulnerability score for each asset and climate stressor. First, each indicator was rated on a scale of 1-4 based on its value (where 4 is most vulnerable), then indicator scores were weighted and averaged to develop a vulnerability score (Figure 1). Stakeholder involvement was key to this process.

4. **Refine and Finalize Indicators and Scoring Approach.** An indicators approach will never perfectly capture local circumstances or asset-specific characteristics. Rather, it provides a starting point for understanding relative vulnerability of assets. Therefore, the final step of the vulnerability assessment was to vet the results with stakeholders and local experts. The team subsequently adjusted some indicator weights or scoring approaches based on this input. Therefore, the final step of the vulnerability assessment was to vet the results with stakeholders and local experts. The team subsequently adjusted some indicator weights or scoring approaches based on this input.



Component	Indicator	Indicator Value	Indicator Score	Indicator Weight	Component Score	Component Weight	Overall Vulnerability Score
Exposure	Days above 95	105	4	100%	4	40%	2.6
Sensitivity	Past Experience	No	1	43%	1	40%	
	Truck Traffic	2723	1	28%			
	Pavement Binder	PG 67-22	1	28%			
Adaptive Capacity	Cost	$210,276,000	4	33%	3	20%	
	Detour Length	Hours	4	33%			
	Disruption Duration	65 Miles	1	33%			

Figure 1: Example of Vulnerability Score Calculations: Vulnerability of the Cochrane Bridge to High Temperatures (numbers in parentheses represent indicator or component scores, percentages represent the indicator or component weights)

Figure 2: A Port in Mobile and the Wallace Tunnel, both found to be vulnerable to climate changes.

Key Results and Findings

The vulnerability screen found that sea level rise and storm surge are the most significant climate stressors for the Mobile transportation system, meaning that these stressors may affect the most assets, most severely. Many of Mobile's critical transportation assets are located on the coast and in low-lying areas exposed to sea level rise and storm surge. These exposed assets also tended to be sensitive, and thus vulnerable, to these stressors.

In addition, the screen identified several specific assets in Mobile as being highly vulnerable to multiple climate stressors, including the Alabama State Docks and several other Mobile River ports, the Wallace Tunnel, SR-193 near the Theodore Industrial Canal, and the I-10 bridge across Mobile Bay.

Lessons Learned

The indicator-based vulnerability screening approach offers a systematic, transparent approach to screen for vulnerability across a large number of assets. However, this type of approach will never perfectly capture local circumstances or asset-specific details, so **preliminary results should be vetted with knowledgeable, local stakeholders.**

Data collection can be difficult and time-consuming, but it can have value for an agency beyond the vulnerability assessment. For example, many vulnerability indicators could become fields in an asset management system.

Perfect information is not necessary, even for an indicator-based vulnerability assessment. Using what data are available for an initial screen can develop a starting point for understanding vulnerability and engaging stakeholders. The results could then be refined through a stakeholder vetting process.

Vulnerability assessment outputs need to be tailored to decision-making. Understanding how the vulnerability assessment results will be used is an important early step in designing an appropriate approach for an agency.

Tools and Resources for Conducting Vulnerability Assessments

The Gulf Coast Study developed the Vulnerability Assessment Scoring Tool (VAST) to help walk users through the step-by-step process to conduct an indicator-based vulnerability screen like the one conducted for Mobile. VAST, an Excel-based tool, takes a user through the key steps and questions necessary to conduct a vulnerability assessment, such as: choosing climate stressors and assets to evaluate; selecting indicators of exposure, sensitivity, and adaptive capacity; and converting indicator data into vulnerability scores.

The FHWA Climate Change and Extreme Weather Vulnerability Assessment Framework provides additional tools and resources for conducting vulnerability assessments.

In addition, existing databases can provide a valuable resource for collecting information for a vulnerability assessment. For example, the National Bridge Inventory or transportation agency asset management systems can provide useful data. Further, geospatial analyses can be a helpful tool for evaluating vulnerability.

For More Information

Resources:

Gulf Coast Study:
http://www.fhwa.dot.gov/environment/climate_change/adaptation/ongoing_and_current_research/gulf_coast_study/

Contacts:

Robert Hyman
Sustainable Transport and Climate Change Team
Federal Highway Administration
robert.hyman@dot.gov, 202-366-5843

Robert Kafalenos
Sustainable Transport and Climate Change Team
Federal Highway Administration
robert.kafalenos@dot.gov, 202-366-2079

Brian Beucler
Hydraulics and Geotechnical Engineering Team
Federal Highway Administration
brian.beucler@dot.gov, 202-366-4598

U.S. Department of Transportation
Federal Highway Administration