FHWA-HEP-14-053

U.S. Department of Transportation
Federal Highway Administration

U.S. DOT Gulf Coast Study, Phase 2

The U.S. Department of Transportation (U.S. DOT) conducted a comprehensive, multi-phase study of the Central Gulf Coast region to better understand climate change impacts on transportation infrastructure and identify potential adaptation strategies. For Phase 2 of the study, U.S. DOT sought to develop methods for evaluating vulnerability and adaptation measures that could be used by other transportation agencies and pilot tested them on the transportation system 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 storm surges and winds associated with more intense storms. The project resulted in a detailed assessment of the Mobile transportation system's vulnerability as well as approaches for using climate data in transportation vulnerability assessments; methods for evaluating vulnerability and adaptation options; and tools and resources that will assist other transportation agencies in conducting similar work.

Objectives

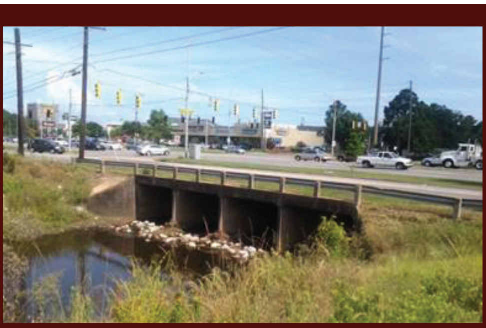
- Develop and pilot test a methodology for evaluating the vulnerability of a metropolitan transportation system to climate change
- Use lessons learned through the work in Mobile to develop tools and approaches that could be employed by other regions to identify which transportation systems need to be protected, and how to protect/adapt those systems

Approach

Determine criticality. A single transportation system is comprised of many assets, which can number in the hundreds or thousands. Because conducting a vulnerability assessment on such a large number of assets was not feasible, the project team first identified the assets considered to be critical to Mobile.

The project team developed a scoring system that ranked each asset's criticality as High, Medium, or Low. Criticality was evaluated using mode-specific criteria related to *socioeconomic* importance, *use and operational* characteristics, and the *health and safety* role in the community. These criteria were scored using methods encompassing statistics on use (e.g., port cargo volumes); traffic modeling (to determine impact on the system if a particular segment were to become inaccessible); and expert judgment. The scores were then averaged to determine an overall criticality score, which was used to select the most critical assets across different modes to evaluate for vulnerability.

Gather and process climate information. The project team developed climate information relevant to transportation planning to characterize plausible future climate scenarios in Mobile. Figure 1 summarizes the climate stressors, scenarios, and timeframes used for projecting future climate conditions in Mobile.



Airport Boulevard Culvert over Montlimar Creek in Mobile, Alabama. Photo credit: Jake Keller (Parsons Brinckerhoff).

Dauphin Island Bridge in the Central Gulf Coast region. Photo credit: Beth Rodehorst (ICF International).

Natural gas pipeline terminal in Mobile, Alabama. Photo credit: Beth Rodehorst (ICF International).

Climate Stressor	Scenarios	Timeframes	Approach
Temperature	B1, A2, and A1Fi emissions scenarios	2010-2039 (near-term) 2040-2069 (mid-term) 2070-2099 (end-of-century)	Projections were statistically downscaled from a variety of global climate model outputs, and compared to the current baseline to estimate change. Projections were developed for numerous variables. Results focused on shorter-duration extremes (e.g., number of days above 95 degrees) instead of average seasonal temperature.
Precipitation & Runoff	B1, A2, and A1Fi emissions scenarios	2010-2039 (near-term) 2040-2069 (mid-term) 2070-2099 (end-of-century)	Precipitation projections were calculated using a similar approach for temperature.
Sea Level Rise	30 cm (1 ft) of global sea level rise by 2050; and 75 cm (2.5 ft) and 200 cm (6.6 ft) of global sea level rise by 2100		Global sea level rise values were adjusted based on local data on subsidence and uplift of land.
Storm Surge and Wind	11 storm scenarios based on historical storms modeled with different trajectories, intensities, and sea level rise	Not applicable	11 storm scenarios were developed using Hurricane Georges and Hurricane Katrina as base storms, and then adjusting certain characteristics of the storms to simulate what could happen under alternate conditions. Storm surge was modeled for each of these storm scenarios using the ADvanced CIRculation model (ADCIRC). ADCIRC also provided estimates of wind speeds. Wave characteristics were simulated using the Steady State spectral WAVE (STWAVE) model.

Figure 1: Summary of Projected Climate Information Developed Under Phase 2 of the Gulf Coast Study.

The study developed projections for dozens of variables, representing a range of longer-term averages to short-term extremes, but ultimately relied primarily on changes in extremes to understand vulnerability. The team tailored temperature and precipitation data to capture changes in the short-term extreme events. For example, the amount of rain falling within a 24-hour period during a 10-year event is more likely to indicate potential impacts to transportation infrastructure, designed to withstand such events, than seasonal or monthly precipitation averages.

Screen critical assets for vulnerability. Several hundred assets were considered to be highly critical. Since detailed vulnerability assessments could not be conducted on each asset, this study identified appropriate "indicators" of the three components of vulnerability (exposure, sensitivity, and adaptive capacity). These indicators are characteristics of an asset that may suggest how exposed, sensitive, or the adaptive capacity of each asset is to the projected changes in climate. The project team scored indicators on a scale of 1 through 4 and then calculated a composite vulnerability score for each asset (see Figure 2). Assets received a vulnerability score for each of the five climate stressors studied.

Conduct engineering assessments of selected vulnerable assets. The project team then conducted more detailed assessments for 11 of the transportation assets likely to be vulnerable. Zeroing in on a specific feature of the asset (such as the embankment of a roadway) and a particular climate stressor (such as storm surge), these detailed analyses considered the engineering design specifications and evaluated how the asset might be vulnerable to the climate stressor. The project team also evaluated specific potential adaptation options. This work represents some of the most detailed assessments to date of transportation vulnerability and adaptation for a wide range of transportation assets. Each of these analyses comprises an individual case study based on unique methodologies and results.

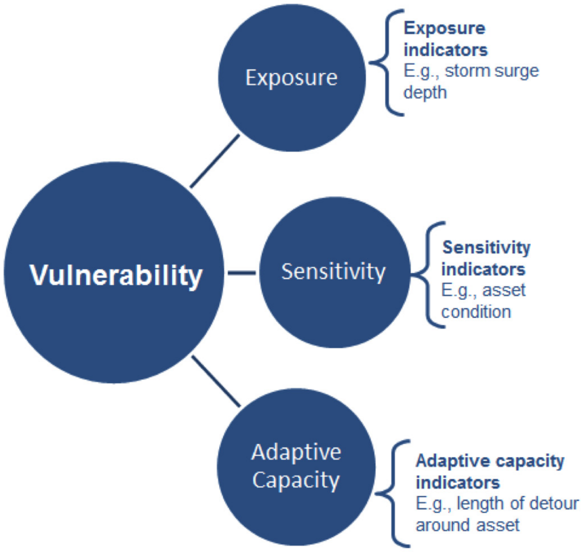


Figure 2: Using Indicators to Assess the Three Components of Vulnerability

Key Results & Findings

Storm surge and sea level rise appear to pose the greatest threat to Mobile's transportation system (see Figure 3 as an example). Overall, vulnerabilities tended to be greatest near the coast, due in part to the fact that a lot of transportation infrastructure is concentrated near the Bay and Mobile River, and the coastal areas tend to be low-lying and thus more vulnerable to not only sea level rise and storm surge but also precipitation.

Specific findings for each of the transportation modes include:

- **Highways appear to be particularly vulnerable to storm surge and sea level rise** due to both exposure and sensitivity to those stressors.
- **The port and marine waterway system in Mobile is highly vulnerable to storm surge** and moderately vulnerable to sea level rise and increases in precipitation.
- **Airports are most vulnerable to temperature**, due to sensitivity of runways and taxiways to damage from heat. The airports are considered to have low vulnerability to sea level rise and storm surge due to higher elevations or inland locations.
- **Rail lines in Mobile appear to be most vulnerable to sea level rise and storm surge** due to location.
- **Only one of the critical transit facilities (the GM&O facility) is exposed to sea level rise and storm surge, and it is highly vulnerable to those climate stressors.** Meanwhile, the Beltline facility, which is situated inland, is moderately vulnerable to flooding and wind damage during major storms.
- **On-shore pipelines in Mobile have relatively low vulnerability to climate change** due to the fact that they are often buried underground or are located in areas not expected to be exposed to extreme events. (Pipelines were qualitatively assessed due to data limitations.)

Example Opportunities for Adaptation. The engineering assessments evaluated adaptation options for the specific assets evaluated. Example findings include:

- Culvert example (vulnerable to heavy precipitation): Adding one cell on each side of the existing crossing would be the most cost-effective way to bring the culvert into compliance with the state's freeboard requirement under potential future precipitation levels.

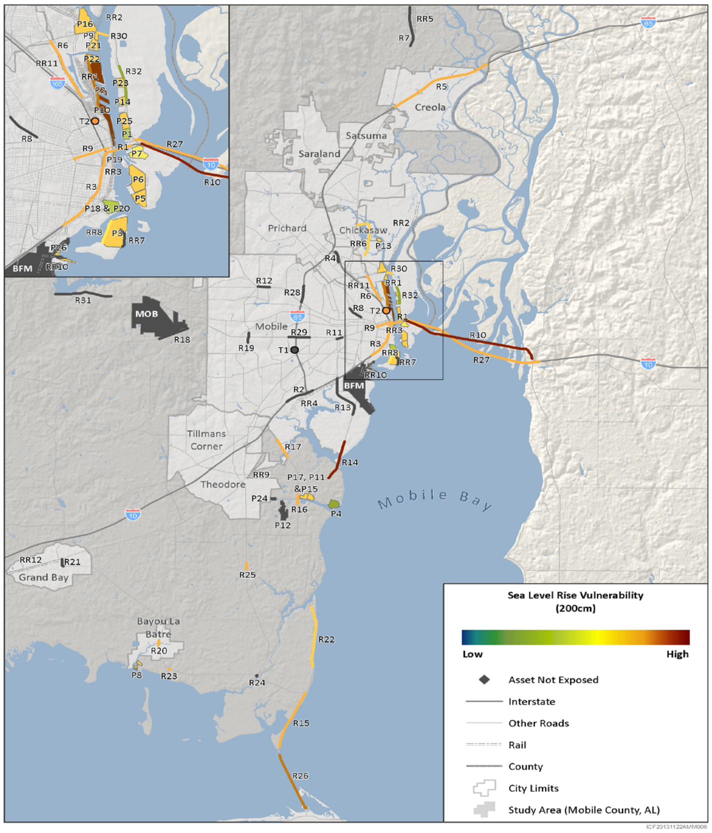


Figure 3: Geographic Distribution of Vulnerabilities of Representative Assets to Sea Level Rise of 2.0 meters (6.6 feet), All Modes

- Bridge example (vulnerable to sea level rise): Sea level rise could reduce the vertical clearance over the river enough that larger ships may not be able to pass under the bridge studied. Structural solutions to deal with this challenge include raising the bridge deck or retrofitting it to have moveable spans. A non-structural approach would be to undertake community planning actions to prepare for a future where large ships could not navigate the Mobile River past the bridge.
- Bridge example (vulnerable to storm surge): The bridge abutments studied were not designed to withstand modeled storm surge and waves, but their riprap, bulkhead, and willow mattresses should offer sufficient protection to withstand modeled surges. Thus, maintenance of these protective structures is as important as maintenance of the structures themselves.

Lessons Learned

Overall, the project benefited from strong engagement from local transportation officials, environmental groups, academics, and business leaders. The broader public could have been better engaged; their support of climate change adaptation activities is important.

The study also revealed several important lessons about methods for understanding vulnerability and beginning adaptation, including the following:

Assessing Criticality. Stakeholder input is essential for identifying assets that are critical to the community. A quantitative criticality assessment that focuses on use, role in the economy, access to medical or job facilities, and other highly specific factors may undervalue assets that are important to the community for less tangible and quantifiable reasons. Similarly, it is important to ground-truth any desk study with the transportation officials who manage the assets.

Using Climate Data. It is important to be able to concisely convey projected changes in climate in terms that are understandable to transportation practitioners and supported by robust science. Attempting to articulate climate projections from multiple emissions, sea level rise, or storm scenarios, for multiple timeframes and using multiple models, can result in an extremely large dataset. A streamlined approach may be just as helpful to portray a set of possible futures.

In the engineering assessments, the project team grappled with the challenge of putting climate projections into terms that resonate with engineers. Further research on how to bridge the gaps between climate science and engineering needs would greatly enhance the ability of transportation practitioners to prepare for climate change.

Assessing Vulnerability. The use of indicators, which draw on existing data that is well-known to planners, can provide a good starting point for screening assets. Local knowledge was invaluable in assessing vulnerability and can supplement gaps in quantitative data sets to assist with the evaluation of more qualitative indicators. When using indicators, care should be taken to ensure that quantitative scoring systems are not skewing results.

Risk Management Tools and Resources

The project team developed several tools and resources to help other agencies capitalize on the methods developed and tested under this project. These resources include:

- Guidance on **Assessing Criticality in Transportation Adaptation Planning**
- **Sensitivity Matrix Tool** to identify potential climate stressors to transportation assets
- **Coupled Model Intercomparison Project (CMIP) Climate Data Processing Tool** to "translate" projected changes in local temperature and precipitation into terms that are relevant to transportation stakeholders
- **Vulnerability Assessment Scoring Tool** (VAST) to help structure an indicator-based vulnerability assessment
- **Engineering Case Studies** that demonstrate an 11-step adaptation approach

The resources are housed within a **web-based vulnerability assessment framework**, with videos, reports, and other resources to assist transportation practitioners at each stage of their assessments, available at www.fhwa.dot.gov/environment/adaptationframework.

For More Information

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

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