



U.S. Department  
of Transportation  
**Federal Highway  
Administration**

FHWA Climate Resilience Pilot Program:

# Tennessee Department of Transportation

The Federal Highway Administration's (FHWA)'s Climate Resilience Pilot Program seeks to assist state Departments of Transportation (DOTs), Metropolitan Planning Organizations (MPOs), and Federal Land Management Agencies (FLMAs) in enhancing resilience of transportation systems to extreme weather events and climate change. In 2013-2015, nineteen pilot teams from across the country partnered with FHWA to assess transportation vulnerability to extreme weather events and climate change and evaluated options for improving resilience. For more information about the pilot programs, visit: [http://www.fhwa.dot.gov/environment/climate\\_change/adaptation/](http://www.fhwa.dot.gov/environment/climate_change/adaptation/).

Tennessee's transportation infrastructure plays a critical role in the interconnectivity of the U.S. transportation system, as it comprises key segments of major east-west and north-south corridors across the nation. In just the past few years, extreme weather events (e.g., flooding, heat waves, and extended periods of severe cold) have caused some of the worst damage in Tennessee's history. The Tennessee Department of Transportation (TDOT) partnered with Vanderbilt University faculty and students to conduct an extreme weather vulnerability assessment of transportation infrastructure across the state. The project team first compiled a statewide inventory of the most critical transportation infrastructure. Using a combination of historical and projected climate information and stakeholder feedback, the project team then developed rankings of vulnerability to temperature extremes, precipitation, wind, and tornadoes in each county. The assessment confirmed that different areas of the state are vulnerable to different extreme weather events, but that high winds and heavy precipitation are the events of greatest concern for transportation assets across the state.



## Scope

The study team undertook a statewide assessment of the vulnerability of all major transportation modes to impacts from temperature extremes (both high and low), precipitation (including drought, flooding, snow, and ice), wind, and tornados through the year 2040 (the planning horizon of TDOT's Long Range Transportation Plan).

## Objectives

- Assemble a statewide GIS-based inventory of Tennessee's critical transportation assets across multiple modes.
- Use future climate and historical weather scenarios, quantify asset damage potential and resilience to these weather and climate events, and determine asset vulnerability and "hot spots" where critical transportation assets are most vulnerable to extreme weather events.



Rockslide along a road in Polk County, TN, following heavy precipitation.  
Photo credit: TDOT.



A sinkhole on Interstate 24 in Clarksville, TN, following heavy precipitation.  
Photo credit: TDOT.



Flooding on Briley Parkway in Nashville, TN.  
Photo credit: TDOT.

## Approach

**Develop an inventory of transportation assets.** The study team undertook a comprehensive data collection effort to identify the geographic location and corresponding characteristics of individual assets within 12 different asset types. The team sought information from state and federal agencies, third party data providers, and local stakeholders to assemble a GIS database that covered all of Tennessee as well as a 10-mile buffer zone into bordering states.

**Identify assets critical to transportation system operations.** The study team developed criteria for what constitutes a critical asset and applied them to the transportation assets in the GIS database. The team defined a critical transportation asset as any portion of the transportation system without which there would be an immediate, direct, and substantial disruption to the transportation system at the local, regional, or national level. To “ground truth” the asset inventory, its characteristics, and degree of criticality (“critical,” “important,” or “other”), the team held a series of regional stakeholder meetings.

**Determine historical and future extreme weather scenarios to which critical transportation assets may be exposed.** The study team used the National Weather Service’s storm events database to identify 23 event types that occur in Tennessee, which the team then aggregated into nine extreme weather event categories. For each of the nine categories, the study team compiled the annual average number of recorded events for each of the ninety-five counties in the state. This assessment of historical weather provided a baseline for determining the extent to which Tennessee is exposed to these events.

To develop an understanding of future climate conditions, the study team reviewed several climate models and tools with a focus on their applicability to the project scope. Researchers at the University of Georgia used CMIP3 data to generate downscaled monthly averages of both precipitation and temperature for every county in Tennessee. The study team then used the U.S. DOT CMIP Climate Data Processing Tool to provide a more detailed analysis of future precipitation and temperature extremes in the state’s four major cities: Nashville, Knoxville, Chattanooga, and Memphis. The team analyzed historic extreme weather data and performed a trend analysis to predict future patterns (by location and intensity) for extreme weather scenarios that are not traditionally covered by future precipitation and temperature conditions. Finally, the team generated annual expected extreme weather frequencies by county by applying a factor to the baseline conditions using the results of these analyses.

### Transportation Asset Types Included in Inventory

- Roads (interstate, state, and U.S. highways)
- Railroads
- Rail yards
- Navigable waterways
- Ports
- Locks
- Bridges
- Airport runways
- Maintenance and salt facilities
- Transportation support systems (TDOT buildings)
- Transit (transfer hubs, terminals, fleet storage)
- Pipelines (oil and natural gas)

### Assess impacts to assets from extreme weather.

The study team developed a survey sent out to over 400 geographically dispersed transportation stakeholders across the state (220 responded). The survey presented a series of extreme weather scenarios for each asset type, corresponding to events with the potential to cause damage and/or disruption in the state. It asked respondents to evaluate the anticipated degree of damage/disruption according to a four-point qualitative scale (nominal, moderate, significant, and catastrophic). The study team then converted the qualitative rankings received into numerical scores by assigning values as follows: nominal=1, moderate=2, significant=3, and catastrophic=4. The team generated an average qualitative score (impact score) for each weather event and asset type combination.

**Combine information into an overall measure of vulnerability.** The study team multiplied the annual expected frequency of each type of extreme weather event and the impact score for the asset type when exposed to each event. The team derived this vulnerability score for each unique weather/asset combination and mapped it for every county in Tennessee. The team overlaid the inventory of critical assets on the vulnerability maps to discern the locations where certain asset types appear to have the greatest potential vulnerability (see Figure 1). Finally, the team developed a list of the most vulnerable critical asset types across the state (by identifying those with a threshold score) and categorized them by county and the extreme weather event(s) to which they are vulnerable.

## Future Vulnerability for Roads and Interstates by County Increases in High Precipitation (Hydrologic)

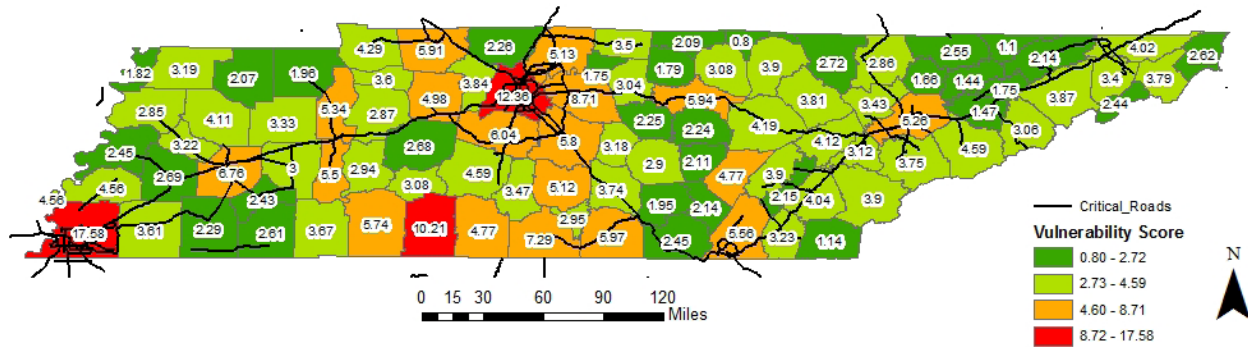


Figure 1. Vulnerability scores for critical roads (shown with black lines) exposed to an extreme hydrologic event. Red indicates higher vulnerability. Source: TDOT

## Key Results & Findings

**Sources of vulnerability.** Only a few of the nine extreme weather categories emerged as likely to cause high vulnerability to transportation assets. This was due to either a relatively low expected frequency of occurrence or because the transportation assets were considered capable of withstanding the effect of these events without considerable damage or disruption. High winds and heavy precipitation (flooding) are events of greatest concern across the state and to multiple transportation asset classes.

**Areas of vulnerability.** Various regions of the state are more prone to certain types of extreme weather events. Shelby County (Memphis) and Davidson County (Nashville) are expected to be the most vulnerable to extreme weather across all categories. The greatest single concern is the potential for flooding in the Memphis area.

Coupled with higher precipitation levels projected for this area, a future flooding event could have serious implications for passenger and freight transport, both locally and more widespread (given the importance of Memphis to the regional and national transportation system). Middle and East Tennessee have a propensity for rockslides where steep slopes and limestone formations are prevalent. Areas with relatively high hydrologic vulnerability scores in locations with significant rockslide potential pose potential vulnerability for further consideration (see Figure 2). Winter weather events are a potential issue for certain counties in East Tennessee, but climate projections suggest that it may become a declining concern.

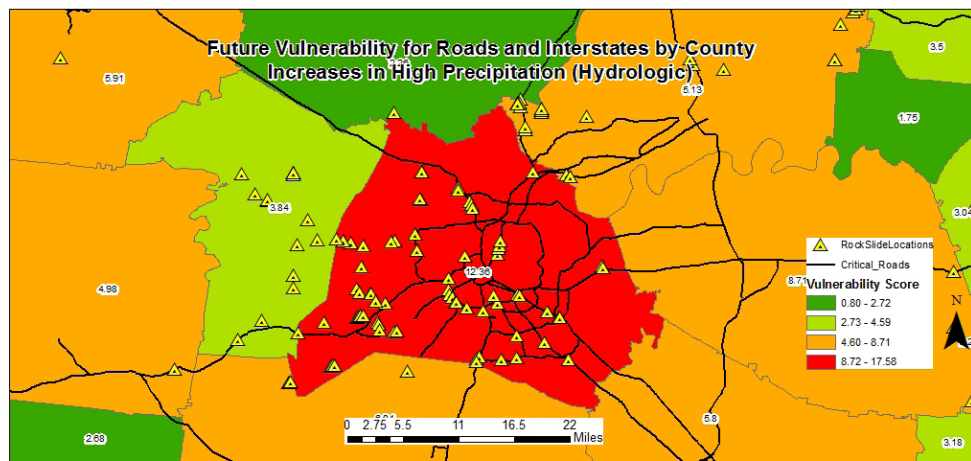


Figure 2. Rockslide locations (indicated with a triangle) in Davidson County, relative to critical roads (indicated in black). Red areas indicate high vulnerability. Source: TDOT

## Lessons Learned

**Screen assets for vulnerability to identify which deserve further analysis.** Conducting a statewide assessment of a wide variety of transportation assets was an ambitious task, ultimately requiring the study team to group the assets into generic asset categories that could not be further differentiated. However, the process served as a valuable screening effort to identify assets that warrant a more detailed study.

**Ensure ample time for conducting a comprehensive assessment.** The process of carrying out a comprehensive study can take a considerable amount of time and delay project completion. The project timeline needed to accommodate the completion of a thorough analysis that incorporated stakeholder feedback and appropriate data in a manageable timeframe.

“This project represents TDOT’s first attempt to understand the impacts of extreme weather on transportation assets across the state... a starting point for integrating extreme weather risk into the agency’s management, planning, and operational practices.”

– TDOT Pilot Team

## Next Steps

**Conduct more detailed vulnerability assessments.** Conducting a follow-up study of 15–20 specific critical assets identified as highly vulnerable would improve TDOT’s understanding of its extreme weather vulnerability in important locations.

**Inform the development of TDOT’s risk-based transportation asset management plan (TAMP).** The study’s transportation asset inventory and identification of critical transportation assets could serve as valuable input to TDOT’s risk-based TAMP. Additionally, the study’s process to determine extreme weather vulnerability could be applied to other risks under consideration in the risk-based TAMP.

**Communicate site-specific results to local stakeholders.** Develop a series of briefing books, tailored to each of the four TDOT regions, to communicate the study results.

### For More Information

**Final report available at:**

[www.fhwa.dot.gov/environment/climate/adaptation/2015pilots/](http://www.fhwa.dot.gov/environment/climate/adaptation/2015pilots/)

**Contacts:**

**Alan Jones**

Manager, Policy Office  
Long Range Planning Division, Tennessee  
Department of Transportation  
[Alan.Jones@tn.gov](mailto:Alan.Jones@tn.gov), 615-741-6832

**Becky Lupes**

Sustainable Transport & Climate Change Team  
Federal Highway Administration  
[Rebecca.Lupes@dot.gov](mailto:Rebecca.Lupes@dot.gov), 202-366-780

