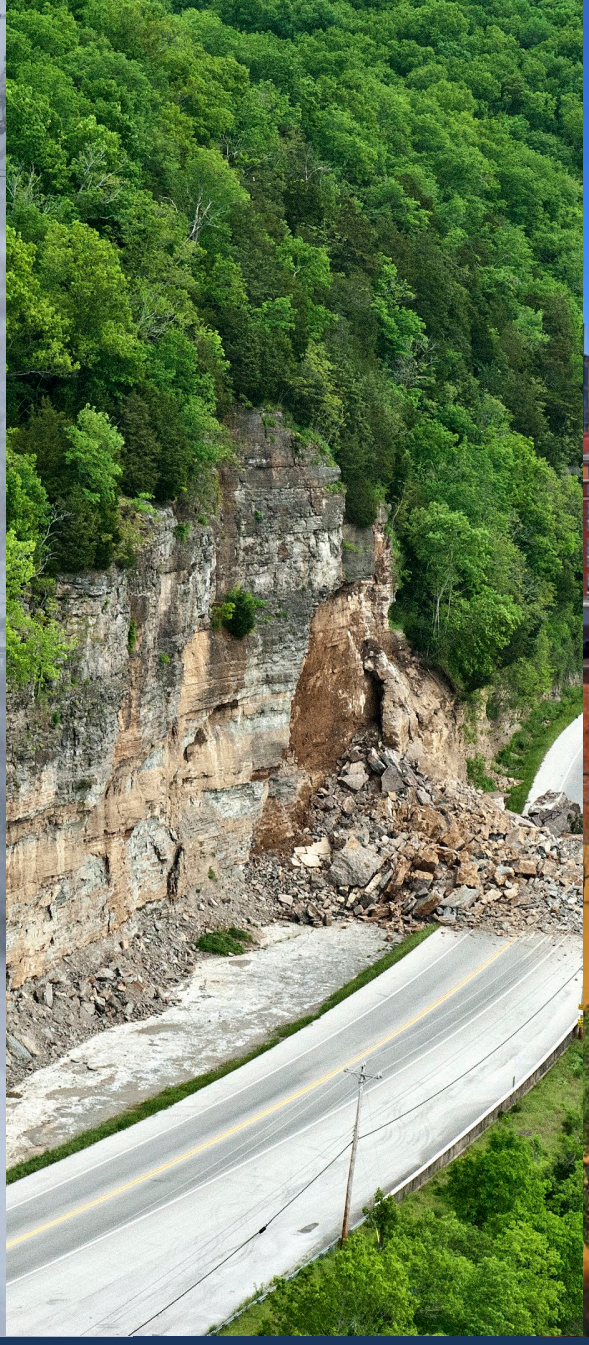

Transportation Resilience Improvement Plan (TRIP)

June 2024

TN TDOT Department of Transportation

U.S. Department of Transportation
Federal Highway Administration

Tennessee Division

404 BNA Drive, Suite 508
Nashville, Tennessee 37217
Phone (615) 781-5770

August 6, 2024

In Reply Refer To:
HDA-TN

Mr. Matt Meservy
Director, Planning Division
Tennessee Department of Transportation
505 Deaderick Street,
Nashville, TN 37243

Subject: Transportation Resilience Improvement Plan for Tennessee

Dear Mr. Meservy:

The Federal Highway Administration (FHWA) Tennessee Division has completed its review of the Tennessee Department of Transportation (TDOT) Transportation Resilience Improvement Plan (TRIP) submitted electronically on June 24, 2024. Based on the review of the TRIP, the FHWA finds that the plan complies with the requirements of Title 23 United States Code (U.S.C.) 176(e).

With this determination, TDOT may request up to an 87% Federal share for projects funded under 23 U.S.C. 104(b)(8) that have been prioritized on the TRIP, per 23 U.S.C. 176(e)(1)(B)(i). In doing so, please ensure that all applicable project authorization requests in the Fiscal Management Information System (FMIS) include a Recipient Remark identifying the project proposed for reduction and the percentage of reduction.

If you have any questions about this approval, please contact Zachary Coleman, Transportation Planning Specialist, at Zachary.Coleman@dot.gov.

Sincerely,

SEAN MICHAEL SANTALLA
Digitally signed by SEAN MICHAEL SANTALLA
Date: 2024.08.06 11:24:51 -05'00'

Sean Santalla, AICP
Program Development Team Leader

cc: Mr. Gilberto DeLeon, Deputy Division Administrator, FHWA TN Division
Ms. Jacinda Russell, Field Operations and Finance Team Leader, FHWA TN Division
Ms. Dysha Weems, Finance Manager, FHWA TN Division
Mr. Zachary Coleman, Transportation Planning Specialist, FHWA TN Division
Mr. Steve Allen, Director, Local Programs & Community Investments Division, TDOT
Ms. Andrea Noel, Programs Supervisor, Local Programs & Community Investments Division, TDOT

STATE OF TENNESSEE
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BUTCH ELEY
DEPUTY GOVERNOR &
COMMISSIONER OF TRANSPORTATION

BILL LEE
GOVERNOR

June 24, 2024

Mr. Dan Hinton, Division Administrator
Federal Highway Administration
Tennessee Division Office
404 BNA Drive
Building 200, Suite 508
Nashville, TN 37217

RE: Tennessee Transportation Resilience Improvement Plan (TRIP) Submittal

Mr. Dan Hinton,

On behalf of the Tennessee Department of Transportation (TDOT), I am providing you with a copy of the State's Transportation Resilience Improvement Plan (TRIP) for review and certification.

TDOT has developed the TRIP in accordance with the PROTECT program requirements, 23 U.S.C. 176(e), that demonstrates a systemic approach to transportation system resilience and is consistent with and complementary of the State and local mitigation plans required under section 322 of the Stafford Act (42 U.S.C. 5165); and includes a risk-based assessment of vulnerabilities of transportation assets and systems to current and future weather events.

We look forward to your review and certification of the TRIP, please do not hesitate to contact me matt.meservy@tn.gov if you have any question or need anything further.

Sincerely,

Matt Meservy, PE, TDM-CP
Director TDOT Planning Division

ABSTRACT

Extreme weather and related natural disaster events have required the Tennessee Department of Transportation (TDOT) to strategically manage its transportation network in the face of changing conditions, often with limited resources. Through the federal PROTECT (Promoting Resilient Operations for Transformative, Efficient, and Cost-saving Transportation) program, TDOT will receive $158 million in formula funds over a five-year period to improve the resilience of existing transportation systems and assets, with an opportunity to apply for additional funds through the PROTECT discretionary grant program. Accordingly, TDOT has developed this Transportation Resilience Improvement Plan (TRIP) to document its strategic resilience planning process in adherence with PROTECT requirements, with the goal of extending resilience initiatives by integrating resilience into the Department's current practices and implement strategic projects that will lead to a more sustainable transportation system. The plan was prepared in concert with TDOT's TRIP Advisory Committee and is focused on pavements, structures, geotechnical, and multimodal assets. The plan is organized into five chapters which introduce the federal policies and strategic objectives guiding the development of the plan; summarize existing and future natural hazard risks; describe TDOT's existing resilience practice; introduce a framework for resilience investment prioritization; actions to improve the resilience practices; and discuss a roadmap for implementation. The plan document is supplemented with appendices that provide important background information.

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Acknowledgments

TDOT's Planning Division is grateful to the many contributors, reviewers, and advisors to the Transportation Resilience Improvement Plan (TRIP). This includes our TRIP Advisory Committee for assisting with prioritization, timing, and assignments. TDOT would like to acknowledge the external contribution of Vanderbilt University for providing the research, analysis, outline, and draft plan. A special thanks to the TDOT contributors who shared data and assisted with interpretation.

This plan was funded through the Promoting Resilient Operations for Transformative, Efficient, and Cost-saving Transportation (PROTECT) formula funding program by the Tennessee Department of Transportation (TDOT) and the Federal Highway Administration (FHWA).

Executive Summary

Extreme weather and related natural disaster events, hereafter referred to as “extreme weather events”, have required the Tennessee Department of Transportation (TDOT) to strategically manage its transportation network in the face of changing conditions, often with limited resources. Through the federal PROTECT (Promoting Resilient Operations for Transformative, Efficient, and Cost-saving Transportation) program, TDOT will receive $158 million in formula funds over a five-year period (Fiscal Years 2022-2026) to improve the resilience of existing transportation systems and assets, with an opportunity to apply for additional funds through the federal PROTECT discretionary grant program. Accordingly, TDOT has developed this Transportation Resilience Improvement Plan (TRIP) to document its strategic resilience planning process in adherence with PROTECT requirements, with the goal of extending these processes to other resilience initiatives by integrating resilience into the Departments current practices and implement strategic projects that will lead to a more sustainable transportation system. The plan was prepared in concert with the TRIP Advisory Committee and is focused on pavements, structures, geotechnical, and multimodal assets. The plan addresses immediate and long-range planning activities and investments of the State and is organized into five chapters which introduce the federal policies and strategic objectives; summarize existing and future natural hazard risks; describe TDOT's existing resilience practice; introduce a framework for resilience investment prioritization; recommend actions to improve the resilience practices; and discuss a roadmap for implementation. The plan document is supplemented with appendices that provide important background information and includes the priority project list of immediate investment needs.

Need for Resilience Planning in Tennessee

In recent decades, Tennessee has experienced a variety of extreme weather events across the State. Understanding and preparing for these types of events, through resilience planning and investment, is therefore crucial for managing and mitigating future risks. Examination of these risks within Tennessee, as informed by both historical events and future projections, results in the following observations:

- Tennessee is subject to a variety of extreme weather risks, including floods, landslides/rockfalls, tornadoes, strong winds, excessive heat, drought, wildfires, ice storms, and flash/freeze events. For western Tennessee, the threat of an earthquake is also a key risk. These risks are important considerations for adaptation planning.
- Over the past two decades, there has been a steady increase in the number of billion-dollar storm events within the State. As these financial estimates only take into consideration physical damage and other direct losses, the number of billion-dollar events when considering indirect losses (e.g., business continuity, traffic delays, etc.) and intangible losses (e.g., community identity, social cohesion, etc.) is likely underestimated. Additionally, there are a considerable number of disaster events that occur in Tennessee that are extremely costly, albeit not categorized as a billion-dollar event.

- This trend directly impacts how TDOT does business today and is expected to put additional strain on the Department in the future as greater resources must be diverted in response to these occurrences.
- A future concern is the expected change in temperature and precipitation over time. The rate and amount of heavy precipitation can trigger costly disaster events such as flooding and landslides/mudslides, while soaring temperatures can have a debilitating effect on transportation workers, system users, and asset condition and performance.

Transportation Resilience: Current Practice

To better understand how TDOT engages in resilience practices, a literature review and a series of internal interviews were conducted. Information gained from these efforts established a baseline understanding of existing resilience perspectives, knowledge, and practices. The findings from these activities were organized into three categories: 1) structures and processes, 2) tools and technology, and 3) technical capacity and collaboration. Key findings within each area are summarized below.

Structures and Processes

- TDOT does not currently have a formal governance structure, policies, or definition for resilience at the Department level.
- TDOT and its stakeholders have developed a variety of planning documents addressing risk management, project prioritization, and emergency management. However, the creation of a plan focused exclusively on resilience and that draws clear linkages between these existing plans is needed.
- TDOT recognizes that resilience is a consideration throughout the life cycle of its assets. Efforts to incorporate resilience at the asset level have focused on material selection, design, construction, and maintenance. These efforts are well documented in TDOT"s Transportation Asset Management Plan (TAMP). However, further coordination between the TAMP and other risk and resilience documents is still needed.
- Although TDOT already works closely with its emergency management partners to respond to hazard events, the Department would like to increase coordination on resilience efforts moving forward.

Tools and Technology

- Currently, TDOT has limited resilience-specific data, tools, and technology to directly inform decision-making.
- There is an interest in investing in additional resilience data, tools, and technology - especially those that are hazard-specific and time-sensitive.
- TDOT has a robust data management system which can be leveraged for resilience decision-making moving forward.

Technical Capacity and Collaboration

- TDOT staff expressed interest in a centralized resource hub to better share and access existing resilience resources.

- Additional training for TDOT staff on resilience concepts and practices is needed. Training focused on key definitions and how staff can implement resilience concepts into daily business operations was recommended.
- Overall, communication on resilience activities remains limited or siloed. The development of a communication strategy would be beneficial for obtaining buy-in and improving awareness, both internally and externally.
- Continued external engagement and collaboration is necessary, especially for emergency management planning and the development of Resilience Improvement Plan (RIPs) by Metropolitan Planning Organization (MPOs) and Rural Planning Organization (RPOs).
- TDOT has developed a PROTECT website that can be leveraged to share information on resilience activities both internally and with external stakeholders.

Resilience Investment Prioritization Strategy

TDOT has developed and plans to implement an investment prioritization strategy to help select PROTECT-eligible projects. The framework, depicted below, provides a stepwise methodology to assess the importance of an activity or location for resilience investment based on two key criteria: 1) critical transportation assets and 2) extreme weather risks. A "criticality score" is determined using a variety of traditional and innovative metrics that capture the importance of an asset to TDOT's strategic goals. Risk criteria include historical and current event exposure, social vulnerability, and community resilience, leading to a "risk score".

The framework, shown below, can be applied to any prospective project or maintenance activity to improve the resiliency of an asset, regardless of the type of transportation asset, its geographical location, or the types of extreme weather risk an area is experiencing.

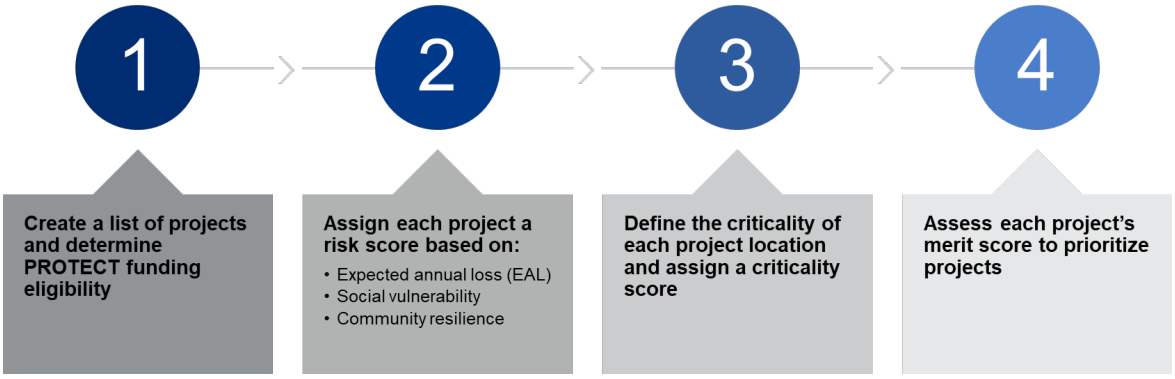

Figure 1. Resilience investment prioritization strategy framework

This resilience investment strategy will be used to identify, evaluate, prioritize, and fund resilience projects. Implementation of the strategy includes project identification, project evaluation, and funding allocation. All projects assessed through this process will be evaluated and used to update the State's resilience priority project list.

Resilience Improvements

While a variety of practices already exist within the Department to incorporate resilience in daily operations, opportunities exist to strengthen the focus on resilience. Specific actions are identified in the TRIP that provide a path forward in keeping with this vision. These actions are organized according to whether they align with enhancements to structure and processes, tools and technology, or technical capacity and collaboration. Actions may be undertaken by using a phased approach, focusing first on those actions deemed to be more time-critical and achievable within available resources.

Structure and Processes

Arguably the most important element to mainstreaming resilience within TDOT is to establish and maintain a formal structure and processes that achieve the following objectives:

- Implement a strong governance structure and culture to ensure resilience activities are adopted by TDOT and remain sustainable in the long-term.
- Operationalize resilience in all agency activities, enabling TDOT staff to fully embrace resilience as a strategic objective and core business practice.
- Implement a knowledge management approach to resilience practices to ensure business continuity and enable these practices to be adopted by new employees and by different groups within TDOT.

The following actions would strengthen TDOT's resilience structure and processes:

1. *Establish formal agency definition for resilience and associated resilience goals and objectives.*
2. *Designate a Resilience Coordinator.*
3. *Establish resilience as a key strategic objective for TDOT's Long Range Transportation Plan (LRTP).*
4. *Adopt a multi-modal transportation resilience perspective.*
5. *Introduce use of resilience metrics in the project scoping and planning process, and integrate into existing transportation investment scenarios (i.e., TAMP life cycle planning).*
6. *Update design standards to address system resilience over the lifetime of the asset.*
7. *Pursue nature-based solutions to improve system resilience.*

Tools and Technology

Maximizing the utilization of tools and technology to strengthen TDOT resilience will achieve the following objectives:

- Implement a resilience investment prioritization framework for evaluating candidate resilience projects.
- Monitor and report on the resilience of assets over time, utilizing data and performance metrics, to enhance decision-making on how to best prepare for and respond to extreme weather events.
- Leverage the availability of existing tools and data in support of resilience decision-making.
- Utilize real-time monitoring systems and early warning for swift responses.

The following actions would achieve these tools and technology objectives:

1. *Implement the resilience investment prioritization framework to assist in assessing the merits of prospective projects.*
2. *Continue to track funding required to respond to extreme weather events at the Department level.*
3. *Continue to conduct research on innovative practices with potential to improve system resiliency.*
4. *Utilize asset maintenance data to identify chronic system issues related to extreme weather events.*

Technical Capacity and Collaboration

Maintaining and enhancing technical capacity and collaboration enables staff to gain proficiency in strengthening resilience through training, knowledge management, and effective communication strategies. Accomplishing this transcends improving internal capabilities to also reinforce collaboration and communication with external stakeholders on resilience activities, who serve as partners in building transportation system resilience throughout the State. The following actions would address these considerations:

1. *Develop and implement a knowledge management and workforce development strategy to establish staff proficiency in performing resilient practices.*
2. *Broaden communication and feedback mechanisms focused on sharing resilience activities with key external stakeholders.*
3. *Maintain and expand TDOT's PROTECT website to include the most recent resilience resources.*
4. *Assist MPOs, RPOs and local agencies in developing their own resilience improvement plans.*
5. *Enhance communication and coordination with emergency management agencies regarding planning, response, and recovery strategies.*

Roadmap for Implementation

This plan represents a means for TDOT to formalize and grow its resilience program utilizing a holistic, systematic, and incremental approach. It has been designed to leverage TDOT's existing resilience practices as a foundation upon which to grow the departments adoption of resilience as a core business practice. The plan's success will rely on continual internal coordination and collaboration, as well as between TDOT and its key external stakeholders. Consequently, TDOT expects to make updates to the TRIP to ensure that it reflects the immediate and long-range planning activities and investments of the State.

Glossary of Key Terms and Acronyms

ASCE	American Society of Civil Engineers
BIA	Business Impact Analysis
BIL	Bipartisan Infrastructure Law
CDC	Center for Disease Control
CMIP5	Coupled Model Intercomparison Project Phase 5
DOT	Department of Transportation
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
HMGP	Hazard Mitigation Grant Program
IIJA	Infrastructure Investment and Jobs Act
LRTP	Long Range Transportation Plan
MPO	Metropolitan Planning Organization
NHS	National Highway System
NOAA	National Oceanographic and Atmospheric Administration
NRI	National Risk Index
NWS	National Weather Service
PA	Public Assistance
PROTECT	Promoting Resilient Operations for Transformative, Efficient, and Cost-saving Transportation
RCP	Representative Concentration Pathway
RIP	Resilience Improvement Plan
RPO	Rural Planning Organization

STIP	Statewide Transportation Improvement Program
SVI	Social Vulnerability Index
SSI	Sinkhole Susceptibility Index
TAMP	Transportation Asset Management Plan
TDEC	Tennessee Department of Environment and Conservation
TDOT	Tennessee Department of Transportation
TEMA	Tennessee Emergency Management Agency
TEPP	Transportation Emergency Preparedness Plan (TEPP)
TRIP	Transportation Resilience Improvement Plan
WCRP	World Climate Research Programme

Chapter 1 Introduction

Within the past decade, resilience, defined herein as "the ability to anticipate, prepare for, or adapt to conditions or withstand, respond to, or recover rapidly from disruptions,"[1] has become an increasingly important consideration in maintaining a robust transportation system. Extreme weather and related natural disaster events have required a State Department of Transportation (DOT), like the Tennessee Department of Transportation (TDOT), to strategically manage its transportation network in the face of changing conditions, often with limited resources.[2] Recently, policy and funding at the federal level has provided an opportunity for TDOT to more fully consider the resilience of its extensive network of assets and the communities it serves from a planning perspective.

The following discussion provides background on resilience initiatives and policies at the federal level, and how they have motivated the TRIP's development.

1.1 Federal Resilience Programs

Historically, federal transportation resilience policies and programs have focused on post-event response to emergencies or disasters. These laws, such as the Robert T. Stafford Disaster Relief and Emergency Assistance Act,[3] enable financial and/or physical assistance for States following a federally declared emergency event. However, as the intensity, frequency, and financial losses of extreme weather events continue to increase,[4] there has been a collective shift from responding to these events to planning for and mitigating the associated risks of these events. This shift has been reflected in federal initiatives, where a risk-based approach to transportation planning and management has been adopted. For example, States are required to develop a Hazard Mitigation Plan to be eligible for certain types of federal, non-emergency disaster assistance.[5] Until recently, there has not been a designated federal funding source for State DOTs to improve the resilience of existing assets that is not tied to other federal performance goals or programs.

Goals of Infrastructure Investment and Jobs Act

In late 2021, the White House signed the Infrastructure Investment and Jobs Act (IIJA), also referred to as the Bipartisan Infrastructure Law (BIL), into law, which provides a substantial

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[1] FHWA. (2023, October 13). *Resilience Definitions*. https://highways.dot.gov/research/infrastructure/resilient-pavements/definitions

[2] For the remainder of this report, "extreme weather and related natural disaster events" will be referred to as "extreme weather events."

[3] Robert T. Stafford Disaster Relief and Emergency Assistance Act, Pub. L. No. H.R.2617, 117th Congress, U.S. Government Publishing Office (2022).

[4] NOAA National Centers for Environmental Information (NCEI). (2023). *U.S. Billion-Dollar Weather and Climate Disasters*. https://doi.org/10.25921/stkw-7w73

[5] FEMA. (2023, April 25). *Mitigation Planning and Grants*. https://www.fema.gov/emergency-managers/risk-management/hazard-mitigation-planning/requirements

investment in U.S. infrastructure and communities. As per the IIJA, a total of $550 billion has been earmarked to cover the current and future funding requirements for the nation's infrastructure, including roads, bridges, transit, water, and broadband infrastructure, during the fiscal years 2022 through 2026.[6] Specific investment goals are summarized in Figure 2.

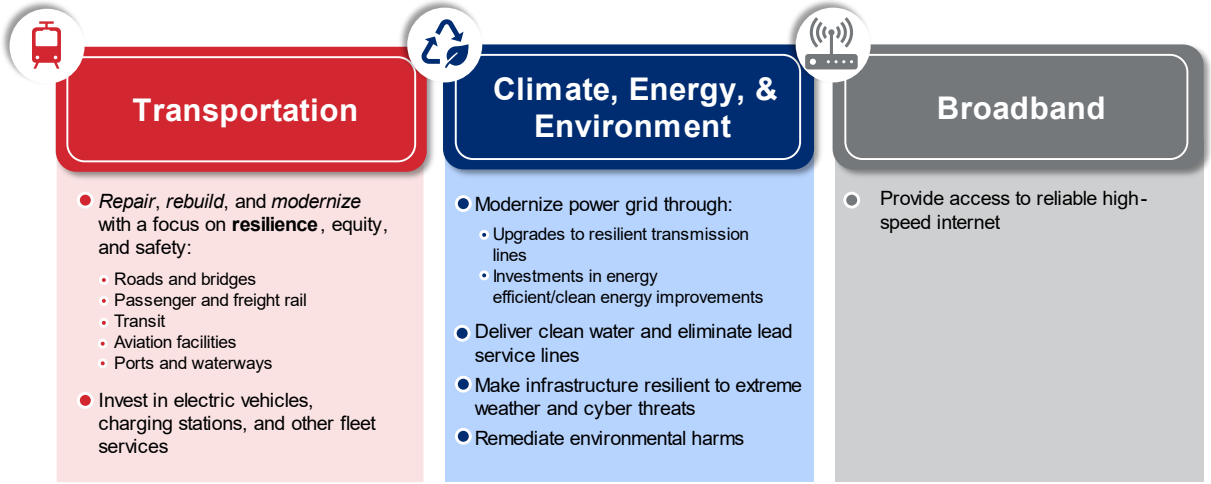


Figure 2. IIJA program goals[7]

The law emphasizes the importance of planning for and mitigating the impact of extreme weather events on the nation's transportation assets, as codified in 23 U.S.C. § 176 - the Promoting Resilient Operations for Transformative, Efficient, and Cost-saving Transportation (PROTECT) program.

PROTECT Program Goals

PROTECT provides funds, through both formula funding and competitive discretionary grants, to help transportation agencies improve the resilience of existing transportation systems and assets.

Under the PROTECT formula funding program, $7.6 billion total[8] will be apportioned to State DOTs between fiscal years 2022 and 2026. TDOT's portions of this formula funding will amount to $158 million over the five-year period.[6] The PROTECT formula funding program provides a federal share of 80% of the total project cost for eligible projects. However, States can increase the total federal share by:

- **Developing a Resilience Improvement Plan (RIP) with a prioritized project list (7%).**

[6] FHWA. (2023, December 5). *Bipartisan Infrastructure Law*. https://www.fhwa.dot.gov/bipartisan-infrastructure-law/

[7] The White House. *A Guidebook to the Bipartisan Infrastructure Law for State, Local, Tribal, and Territorial Governments, and Other Partners.* (2022).

[8] FHWA. *Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) Formula Program Implementation Guidance*. (2022).

- **Incorporating or referencing the developed RIP in metropolitan transportation plans or statewide long-range transportation plans (3%).**

The federal share is only available for projects deemed eligible under PROTECT. This includes resilience-focused activities for highway infrastructure, public transportation, or ports. Specific eligible initiatives include:

- **Planning Activities**: Developing a RIP; resilience planning, predesign, design or data tools to simulate transportation scenarios or vulnerability assessments; technical capacity building to facilitate vulnerability assessment and community response strategies; and evacuation planning and preparation.
- **Resilience Improvements**: Improving the ability of surface transportation to withstand extreme weather events or increase robustness to future changing conditions.
- **Community Resilience and Evacuation Routes**: Strengthening and protecting evacuation routes for emergency events.
- **At-Risk Coastal Infrastructure**: Strengthening, stabilizing, hardening, elevating, relocation or enhancing the resilience of highway and non-rail infrastructure.[9]

PROTECT also provides competitive discretionary grants with similar goals to the formula funding program. Discretionary grants are divided into two key categories: 1) planning grants and 2) resilience improvement grants. These grants help agencies assess and plan for system vulnerabilities in the face of current and future climate conditions, and directly invest in resilience improvement activities focused on surface transportation, communities, coastal infrastructure, and natural infrastructure.

1.2 Scope of Tennessee's Transportation Resilience Improvement Plan

The TRIP has been developed to document TDOT's strategic resilience planning process in adherence to the PROTECT formula funding program requirements. The plan looks at a long-term horizon, consistent with the Long Range Transportation Plan, of twenty-five years and short term, to be consistent with the STIP, of three-years. By directly addressing extreme weather and resilience through a systemic approach, the plan furthers TDOT's mission of providing "a safe and reliable transportation system that supports economic growth and quality of life."

Resilience Improvement Plan Goals

In accordance with PROTECT's program goals and TDOT's long-range guiding principles[10], the goals of the TRIP are to:

[9] Note that since Tennessee does not have any coastal infrastructure, this activity type is not directly relevant to TDOT.

[10] TDOT's long-range planning guiding principles are to: 1) preserve and manage the existing system, 2) support the State's economy, 3) maximize safety and security, 4) provide for the efficient movement of people and freight, 5) build partnerships for sustainable and livable

- Serve as a time-phased planning document for the consideration and investment in transportation resilience improvements throughout the State of Tennessee.
- Develop a data-focused, risk-based, and systematic approach for assessing existing and future vulnerabilities of the State's transportation network to extreme weather events, and to analyze and prioritize potential resilience improvements.
- Promote and standardize coordination and planning between TDOT and other transportation stakeholders on resilience improvement projects throughout the State.
- Synthesize and enhance TDOT's structure and process, tools and technologies, and technical capacity and collaboration within the area of resilience.
- Provide a framework for the consideration of equity and community resilience in TDOT's resilience planning process.

Appendix I. RIP Requirements Reference Table provides a summary of specific sections in the TRIP and how they relate to each of the PROTECT program requirements.

Transportation Assets

Within the TRIP, resilience and investment planning is considered across four key asset groups. These groups, summarized in Figure 3, represent assets eligible for PROTECT funding. Moving forward, additional multimodal assets may be considered, such as airports and rail, in the resilience planning process.

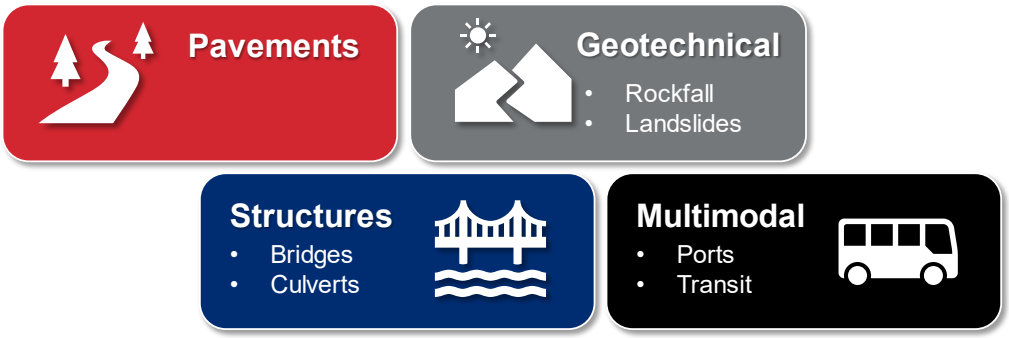


Figure 3. Assets considered in the TRIP

Reporting and Implementation

The TRIP was developed in concert with an Advisory Committee. The TRIP Advisory Committee included individuals with roles and responsibilities throughout TDOT's divisions, as well as external stakeholders, representative of diverse resilience interests. Appendix II. Transportation Resilience Improvement Plan Advisory Committee provides a list of Committee members who contributed to plan development. Such broad stakeholder engagement was considered vital to formulating and implementing a resilience improvement plan that is holistic, systematic, and inclusive, as both coordination within TDOT and among interagency partners is important to a successful outcome. It is expected that the TRIP will serve as TDOT's primary resilience planning

communities, 6) protect natural, cultural and environmental resources, and 7) emphasize financial responsibility.

and implementation document, which will be updated on a regular basis to ensure it reflects the current state of resilience planning within the Department.

1.3 Plan Organization

The remaining chapters in the TRIP provide an overview of the need, existing practices, and proposed framework for resilience planning within TDOT. A summary of each chapter and its corresponding contents is provided in Table 1. Supplemental information is contained in appendices located in the back of the plan document.

Table 1. Summary of Plan Chapters

	Chapter	Content Summary
2	Need for Resilience Planning in TN	Describes existing and future threats TDOT faces in terms of extreme weather
3	Transportation Resilience for TDOT	Synthesizes existing structure and processes, tools and technology, and technical capacity and collaboration surrounding resilience planning within TDOT
4	Resilience Investment Prioritization Strategy	Presents TDOT's strategy for selecting, analyzing, and prioritizing projects for resilience improvement investments
5	Recommendations and Pathways for Implementation	Provides a summary of existing opportunities and actions TDOT can leverage with regard to enhancing transportation resilience in Tennessee

Key Takeaways—Chapter 1

- Through the PROTECT program under IIJA, TDOT will receive $158 million over a five-year period to improve the resilience of existing transportation systems and assets. Additionally, TDOT may apply for PROTECT discretionary grants with similar goals to the formula funding program.
- The PROTECT formula funding program provides a federal share for eligible projects, with additional shares available if an agency develops a Resilience Improvement Plan (RIP) with a prioritized project list and incorporates or references the developed RIP in metropolitan transportation plans or statewide long-range transportation plans.
- The TRIP has been developed to document TDOT's strategic resilience planning process in adherence to the PROTECT formula funding program requirements.
- The key goals of the TRIP are to serve as a time-phased planning document, be data-driven, promote standardization and documentation of practices, and provide an objective, resilience investment framework that considers equity and community resilience.
- Within the TRIP, TDOT is considering resilience and investment planning across four key asset groups—pavements, structures, geotechnical, and multimodal.
- The TRIP was developed in concert with the Transportation Resilience Improvement Plan Advisory Committee and external stakeholders, representing diverse interests.

Chapter 2 Need for Resilience Planning in TN

The 2023 Tennessee State Hazard Mitigation plan identified and prioritized the following natural hazards: drought, earthquake, extreme temperatures, flood, geologic hazards, severe storms, tornado, and wildfire. In recent decades, Tennessee's infrastructure has been impacted by a variety of extreme weather events across the State. Damaging winds, floods, landslides and rockfalls, tornadoes, wildfires, heat waves, and winter storms, among other occurrences, have resulted in significant economic, environmental, and social consequences. For TDOT, this has meant emergency repairs, additional preservation and maintenance, and other activities to minimize transportation system disruptions and impacts to system safety and performance. Understanding and preparing for these types of events, by integrating resilience planning and investment, is therefore crucial for managing and mitigating existing and future risks. The TRIP complements the Tennessee State Hazard Mitigation Plan which is consistent with the requirement under section 322 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (42 U.S.C. 5165).

2.1 Extreme Weather within TN

Given Tennessee's geography and size, its transportation infrastructure and communities are exposed to a myriad of extreme weather events ranging in frequency and severity. In 2015, TDOT conducted a comprehensive analysis of extreme weather events and their potential impacts on the State's transportation infrastructure.[11] Through this study, TDOT assessed National Weather Service (NWS) storm data to better understand which event types were most notable within Tennessee. These storm events, which represent gradations in the severity of specific weather conditions, were aggregated into nine broader extreme weather event categories—cold, hot, wind, twister, hydrologic, lightning, hail, drought, and winter-related events—to help facilitate a more comprehensive analysis.

The study revealed that Tennessee is subject to various extreme weather events, with specific regions more susceptible to different hazard types (Figure 4). Among these, high winds and heavy precipitation, particularly flooding, emerged as significant concerns affecting multiple transportation asset classes statewide. While winter weather has historically posed challenges in certain counties of East Tennessee, climate projections indicated a diminishing concern in the future. Additionally, Shelby County (Memphis) and Davidson County (Nashville) were identified

[11] Abkowitz, M., Camp, J., & Dundon, L. (2015). *Assessing the Vulnerability of Tennessee Transportation Assets to Extreme Weather*. Tennessee Department of Transportation.

as areas with high vulnerability to extreme weather events, due in part to the sizeable population living in those locations. The report's greatest concern centered around the potential for flooding in the Memphis area, where a future event could have far-reaching implications for both passenger and freight transport. Additionally, the study highlighted the propensity for rockslides, primarily in Middle and East Tennessee, due to steep slopes and limestone formations. Areas with elevated hydrologic vulnerability scores in regions with significant rockslide potential were deemed to require special consideration.

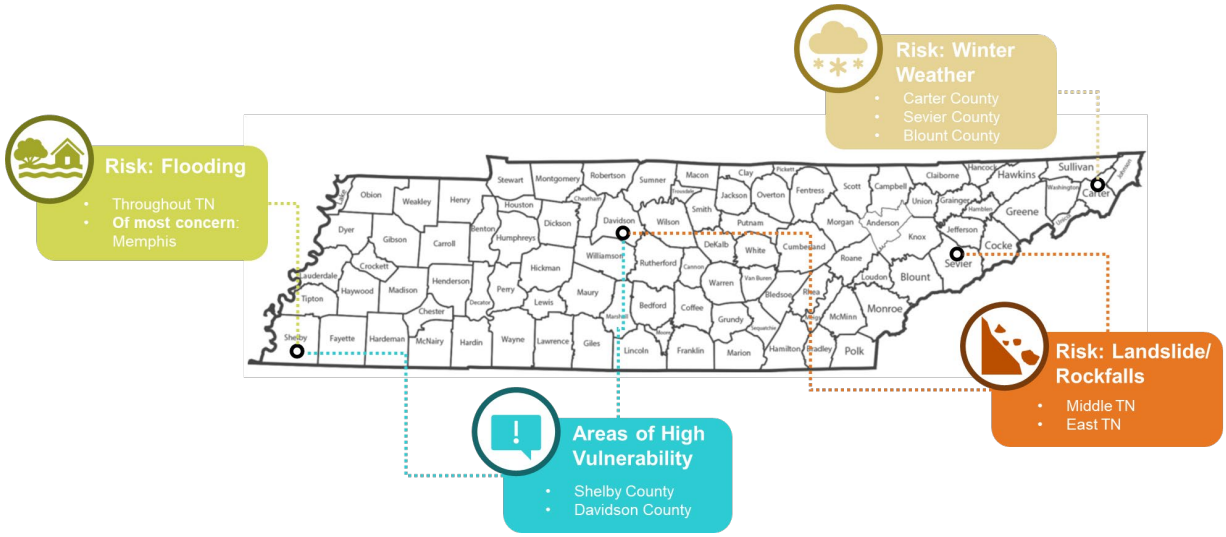


Figure 4. Key extreme weather events in TN

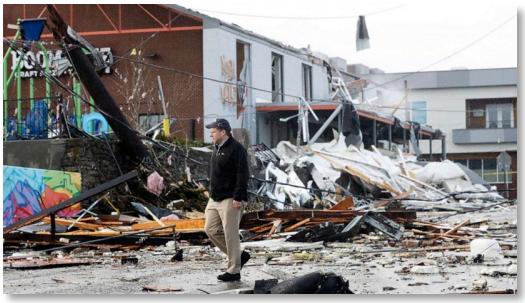
Since this study was performed, additional data has emerged to further identify extreme weather risks that threaten the State. This information has been assimilated into the Federal Emergency Management Agency's (FEMA) National Risk Index (NRI).[12] This index was developed to help communities assess their risk to eighteen distinct natural hazards. The risk index utilizes eight risk categorizations: "very high," "relatively high," "relatively moderate," "relatively low," "very low," "no rating," "not applicable," and "insufficient data."

The NRI results applicable to Tennessee, and not captured in detail in the report summary above, are summarized below and in Figure 5 through Figure 9:

Earthquakes: Within Tennessee, the risk of earthquakes is relatively low, though some counties in the west part of the state are identified as having a "relatively moderate" risk. One outlier is Shelby County, as its earthquake risk is "relatively high"—the highest rating in the state.

[12] Zuzak, C., E. Goodenough, C. Stanton, M. Mowrer, A. Sheehan, B. Roberts, P. McGuire, and J. Rozelle. (2023). National Risk Index Technical Documentation. Federal Emergency Management Agency, Washington, DC.

Landslides: Counties in the east and the middle part of the State are considered as having "relatively moderate" risk. Hamilton and Sevier counties were identified as having the highest landslide risk, classified as "relatively high".



Strong Winds: While most of the State is subject to "relatively moderate" or "relatively low" risk ratings for strong winds, Davidson, Williamson, Rutherford, Maury, Knox, and Hamilton counties are characterized as having "relatively high" risk for strong winds.

Tornadoes: Risk ratings for tornadoes are "relatively moderate" or "relatively low" for most parts of the State. However, seven counties were identified as having a "relatively high" rating: Madison, Montgomery, Sumner, Davidson, Rutherford, Hamilton, and Knox counties. Notably, Shelby County bears a "very high" risk rating for tornadoes; this may be due in part to its high social vulnerability and low community resilience.

Ice Storms: Thirteen counties were identified as having a "relatively moderate" risk to ice storms, four counties were identified as having a "relatively high" risk, and two counties, Sumner and Knox, were identified as having "very high" risk.

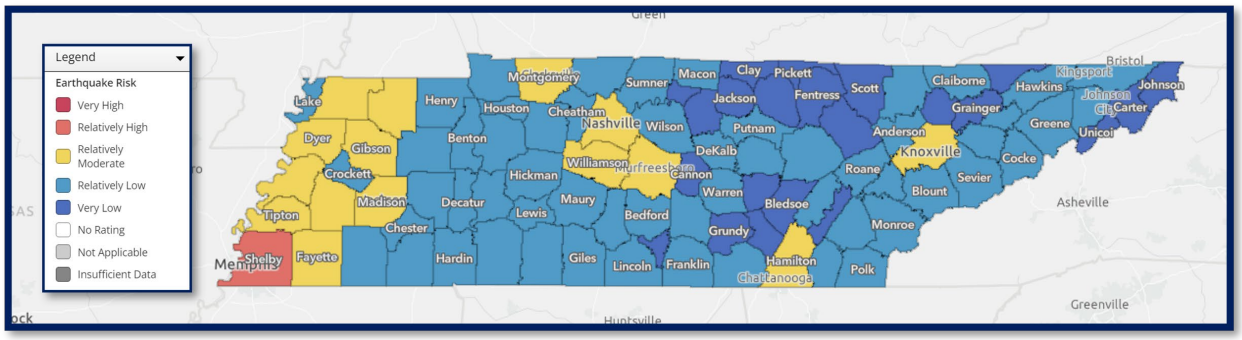


Figure 5. FEMA NRI for Tennessee—earthquakes

Figure 6. FEMA NRI for Tennessee—landslides

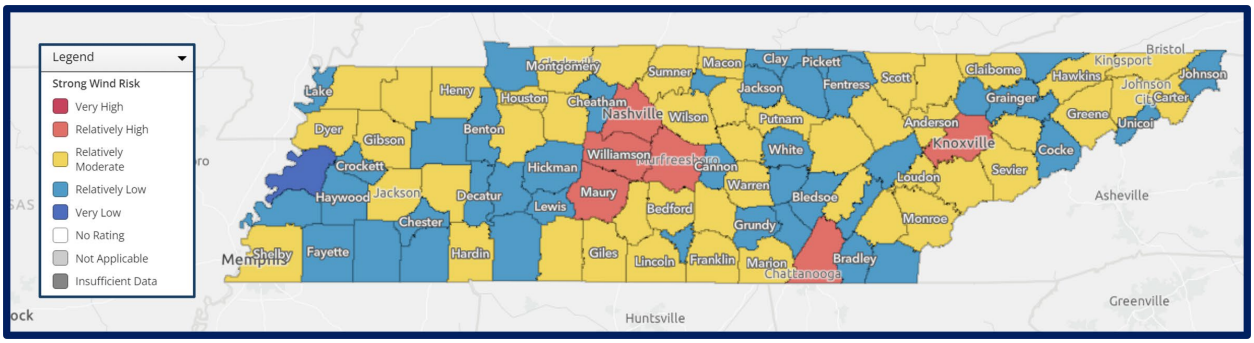


Figure 7. FEMA NRI for Tennessee—strong winds

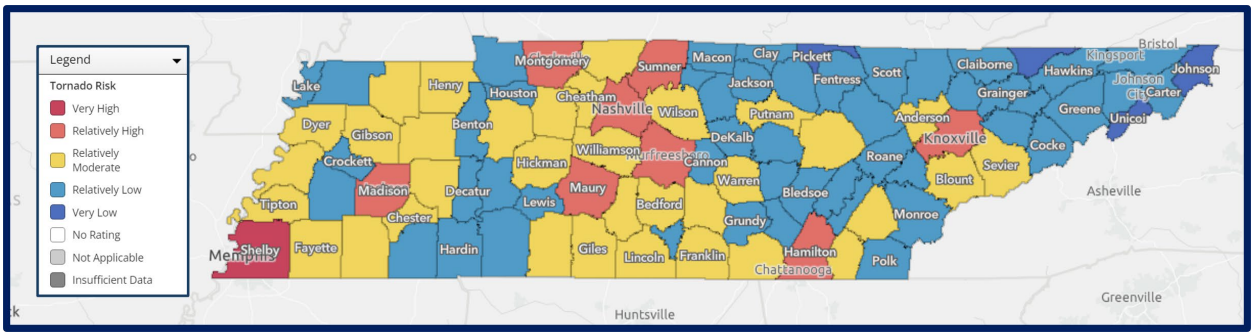


Figure 8. FEMA NRI for Tennessee—tornadoes

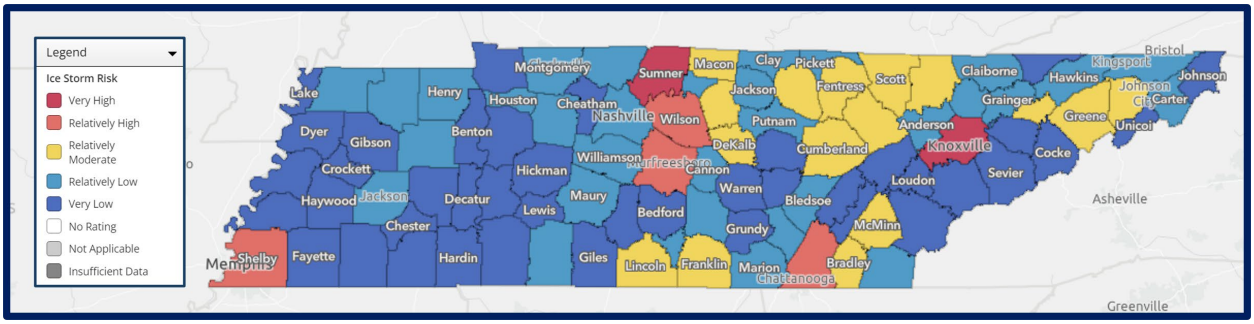


Figure 9. FEMA NRI for Tennessee—ice storms

2.2 Summary of Historic Loss and Damage

Extreme weather events have caused significant loss and damage in Tennessee throughout history. However, within the past two decades, the frequency and intensity of these events has increased, resulting in higher average loss and damage for TDOT and the State overall. Figure 10 shows the increase in financial losses Tennessee has experienced since 1980 for the most impactful extreme weather events, referred to as billion-dollar storms, as reported by the National Oceanic and Atmospheric Administration (NOAA). Between 2003 and 2023, there has been a steady increase in the number of billion-dollar storm events within the State[13]. As these financial estimates only take into consideration physical damage and other direct losses, the number of billion-dollar events when considering indirect losses (e.g., business continuity, traffic delays, etc.) and intangible losses (e.g., community identity, social cohesion, etc.) is likely underestimated. This trend directly impacts how TDOT does business today, and it is expected to put additional strain on the Department in the future as greater resources must be diverted in response to these occurrences.

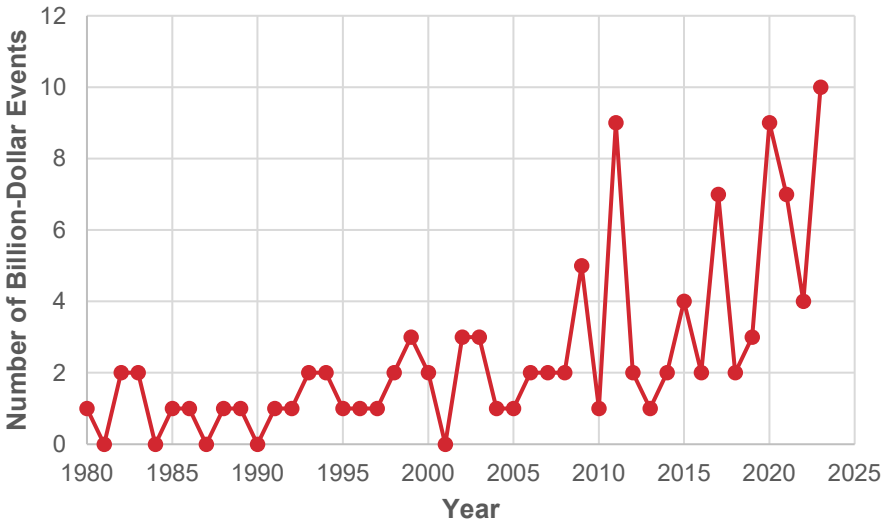


Figure 10. Billion-dollar storm events in TN over time

[13] NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2023). https://www.ncei.noaa.gov/access/billions/, DOI: 10.25921/stkw-7w73

Declared Disaster Events

Another useful source to quantify and explain the history of extreme weather events that have occurred within Tennessee is FEMA's Declared Disaster database. The database provides an overview of federally declared disaster events for which the State may be eligible for resources or funds to respond. From 2019-2023, FEMA provided federal funding for sixteen extreme weather-related declared disasters within Tennessee, mostly via the Public Assistance (PA) Program and, to a lesser extent, the Hazard Mitigation Grant Program (HMGP). Of these sixteen events, thirteen were characterized as severe storms (see Figure 11). The impact of each event can be quantified via the grant dollars awarded to the State (see *Appendix III. FEMA Declared Disasters in TN (2019-2023)).*

TDOT's Transportation Asset Management Plan (TAMP)[14] highlights the impact these emergency events have had on transportation infrastructure. As part of the plan's *23 CFR Part 667 Periodic Evaluation of Facilities Repeatedly Requiring Repair and Reconstruction Due to Emergency Events* analysis, TDOT examined emergency response data, including declared disaster data previously described, to identify pavements or bridges that have required repeated repair or reconstruction. Between January 1, 1997, and June 30, 2022, twenty-three emergency events were identified as having directly impacted TDOT's primary assets. These events were further categorized into the following eight types: bridge strikes, flooding, ice storms, landslides, rockfall, rockslides, slope failures, and tornado damage. The most impactful events, affecting more than one location, included an ice storm on January 28, 2009; flooding, landslides/rockslides from April 30 to May 2, 2010; flooding on April 19, 2011; statewide flooding from February 26 to March 2, 2019; slope failures, flooding, and tornado damage from February 6 to March 10, 2020; and flooding on August 21, 2021.

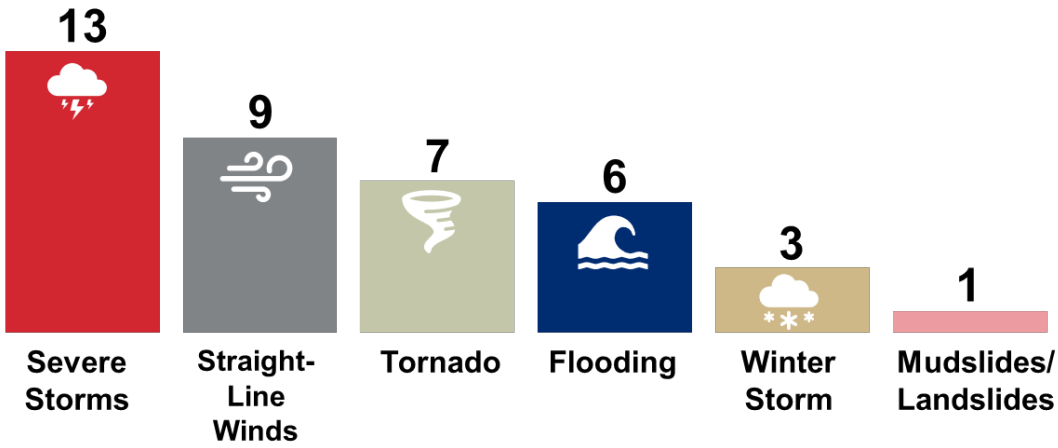


Figure 11. Category of events for declared TN disasters occurring between 2019-2023[15]

[14] Tennessee Department of Transportation. (2023). *Transportation Asset Management Plan 2022*.

[15] Many of these declared disaster events involved multiple event categories. The data can be viewed in Appendix III.

2.3 Future Extreme Weather Risks

Given the impact of historic extreme weather activity in Tennessee and the recent trend towards more frequent and intense events, it becomes critically important to consider future threats to TDOT's transportation network. This section discusses the projected extreme weather risks that the State transportation network can expect to face in the future. This A summary of projected extreme weather trends is also addressed in the Tennessee State Hazard Mitigation Plan.[16]

Temperature and Precipitation Projections

Of particular concern is the expected change in temperature and precipitation over time. The rate and amount of heavy precipitation can trigger disaster events such as flooding and landslides/mudslides, among others. Meanwhile, soaring temperatures can have a debilitating effect on transportation workers and system users. Additionally, temperature and precipitation fluctuations can also have a lasting impact on asset condition and performance. For instance, extreme heat can cause increased pavement deformation such as rutting, while high-intensity precipitation events can lead to bridge scour.

Due to these potential impacts, an assessment of the expected change in extreme temperature and precipitation was conducted as part of TRIP development. The assessment focused on defining baseline and projected conditions for the six climate regions within the State, as defined by the Tennessee Advisory Commission on Intergovernmental Relations (TACIR): 1) Cumberland Plateau, 2) Highland Rim, 3) Inner Coastal and Alluvial Plain, 4) Nashville Basin, 5) Ridge and Valley, and 6) Unaka-Smoky Mountains (see Figure 12).

Figure 12. Tennessee climate regions[17]

[16] Tennessee Emergency Management Agency. (2023). *State of Tennessee Standard State Hazard Mitigation Plan*.

[17] Tennessee Advisory Commission on Intergovernmental Relations. (2020). *Collaborating to Improve Community Resiliency to Natural Disasters*.

Data from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project, Phase 5 (CMIP5)[18] was used to establish baseline and projected temperature and precipitation estimates for each of the six climate regions. CMIP5 projections for mid-century (i.e., 2030-2060) conditions were evaluated under Representative Concentration Pathway 8.5 (RCP 8.5) conditions, which assumes carbon emissions continue at the same rate as present day. The data was used to assess changes in "extremes" between the baseline and projected values for each of the following:

- **"Very Hot" Day Temperature:** "Very Hot" is defined as the 95th percentile temperature.
- **"Extremely Hot" Temperature:** "Extremely Hot" is defined as the 99th percentile temperature.
- **"Very Cold" Day Temperature**: "Very Cold" is defined as the 5th percentile temperature.
- **"Extremely Cold" Day Temperature**: "Extremely Cold" is defined as the 1st percentile temperature.
- **"Very Heavy" 24-hr Precipitation Amount**: "Very Heavy" is defined as the 95th percentile precipitation.
- **"Extremely Heavy" 24-hr Precipitation Amount**: "Extremely Heavy" is defined as 99th percentile precipitation.
- **Average Number of Days per Year Above Baseline "Very Hot" Temperature**
- **Average Number of Days per Year Above Baseline "Extremely Hot" Temperature**
- **Average Number of Baseline "Very Heavy" Precipitation Events per Year**
- **Average Number of Baseline "Extremely Heavy" Precipitation Events per Year**

As shown in Table 2 and Figure 13, the most notable change between baseline and projected temperature values is the average number of days per year above the baseline for "Very Hot" (95th percentile) and "Extremely Hot" (99th percentile) temperatures. The Cumberland Plateau and Unaka-Smoky Mountains are predicted to experience the greatest relative change for these metrics, with the projected number of days experiencing "Very Hot" and "Extremely Hot" temperatures being 3 to 10 times greater than present day. The 95th and 99th percentile of high temperatures in the remaining regions are also expected to increase over time as shown in Table 2.

Additionally, while historical "Very Hot" and "Extremely Hot" temperatures ranged from 88 to 94 and 92 to 98 degrees Fahrenheit for the various climate regions, respectively, the projected "Very Hot" and "Extremely Hot" temperatures were estimated to be 6 degrees warmer on average. This suggests that Tennessee will likely be facing a dramatic increase in the frequency and magnitude of extreme hot temperatures and their corresponding impacts. In other words, the State of Tennessee will see an increase in both the temperature of extreme heat events and the number of days in which extreme heat events, based on today's definitions of extreme heat, occur, leading to additional stress on system workers, users, and the infrastructure itself.

[18] Pierce, D. W., Cayan, D. R., Maurer, E. P., Abatzoglou, J. T., & Hegewisch, K. C. (2015). Improved Bias Correction Techniques for Hydrological Simulations of Climate Change. *Journal of Hydrometeorology*, *16*(6), 2421–2442. https://doi.org/10.1175/JHM-D-14-0236.1

Table 2. Historic and Projected Extreme Heat Values within TN

Climate Region	"Very Hot" Day Temperature (deg F)		"Extremely Hot" Day Temperature (deg F)	
	Baseline	Projected	Baseline	Projected
Cumberland Plateau	88.07	94.19	91.94	98.35
Highland Rim	92.37	98.40	97.24	103.52
Inner Coastal Plain and Alluvial Plain	93.99	100.32	97.92	104.52
Nashville Basin	92.61	98.50	96.93	103.12
Ridge and Valley	90.36	95.93	94.32	100.25
Unaka-Smoky Mountains	90.00	96.13	93.74	100.41

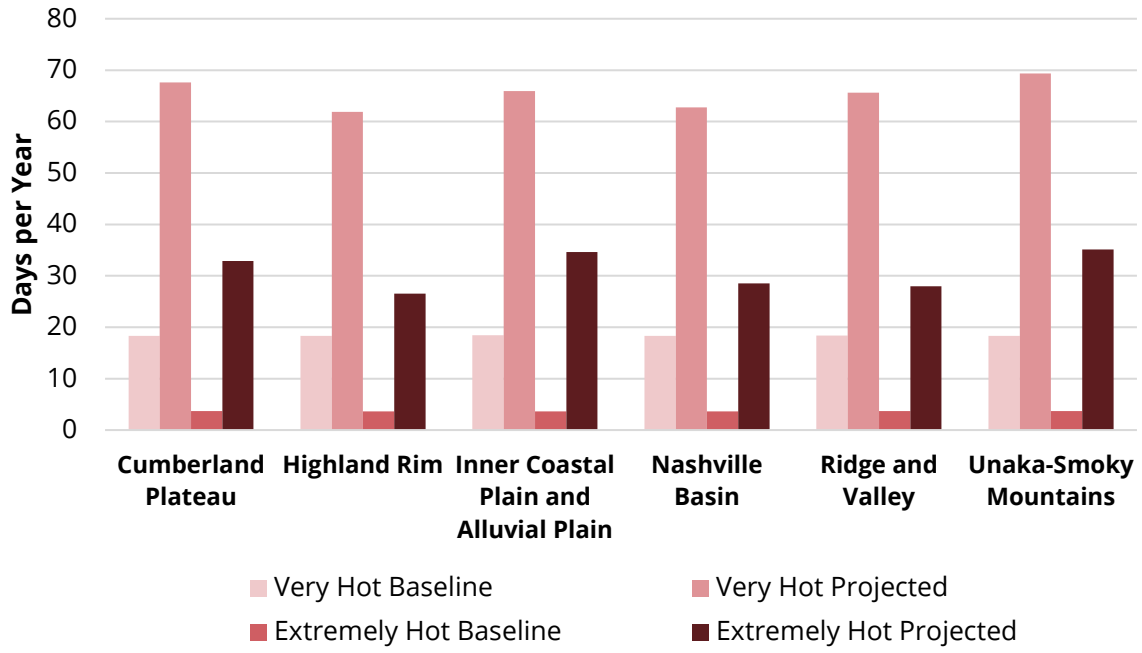


Figure 13. Historical and projected extreme heat days within TN by climatic region

For cold weather, it is projected that the 1st percentile temperatures ("Extremely Cold" temperatures) will experience the greatest relative change, as shown in Table 3. This indicates that the average "cold" temperatures for the State will generally increase (i.e., become warmer). An assessment of the average number of days below freezing showed similar trends; for all

climate regions, the average number of days below freezing is expected to decrease over time, indicating that more moderate winter temperatures can be expected.

Table 3. Historic and Projected Extreme Cold Values within TN

Climate Region	"Very Cold" Day Temperature (deg F)		"Extremely Cold" Day Temperature (deg F)	
	Baseline	Projected	Baseline	Projected
Cumberland Plateau	18.06	21.57	7.46	12.18
Highland Rim	17.09	20.96	5.88	11.42
Inner Coastal Plain and Alluvial Plain	22.16	25.82	11.84	16.74
Nashville Basin	17.55	22.00	6.80	12.41
Ridge and Valley	18.41	22.00	9.01	13.74
Unaka-Smoky Mountains	16.20	20.16	6.02	11.20

Table 4 and Figure 14 summarize the projected change in extreme precipitation events for each region based on CMIP5 projections. For all regions, modest increases can be expected in the amount and number of days where “Very Heavy” and “Extremely Heavy” precipitation are expected to occur. Should this be the case, an increase in flooding and landslide/rockslide events may result.

Table 4. Historic and Projected Extreme Precipitation Values within TN

Climate Region	“Very Heavy” 24-hr Precipitation Amount (in)		“Extremely Heavy” 24-hr Precipitation Amount (in)	
	Baseline	Projected	Baseline	Projected
Cumberland Plateau	0.94	0.98	1.68	1.81
Highland Rim	0.90	0.97	1.64	1.82
Inner Coastal Plain and Alluvial Plain	0.95	1.00	1.66	1.80
Nashville Basin	0.89	0.95	1.56	1.67
Ridge and Valley	0.69	0.73	1.22	1.32
Unaka-Smoky Mountains	0.70	0.74	1.20	1.27

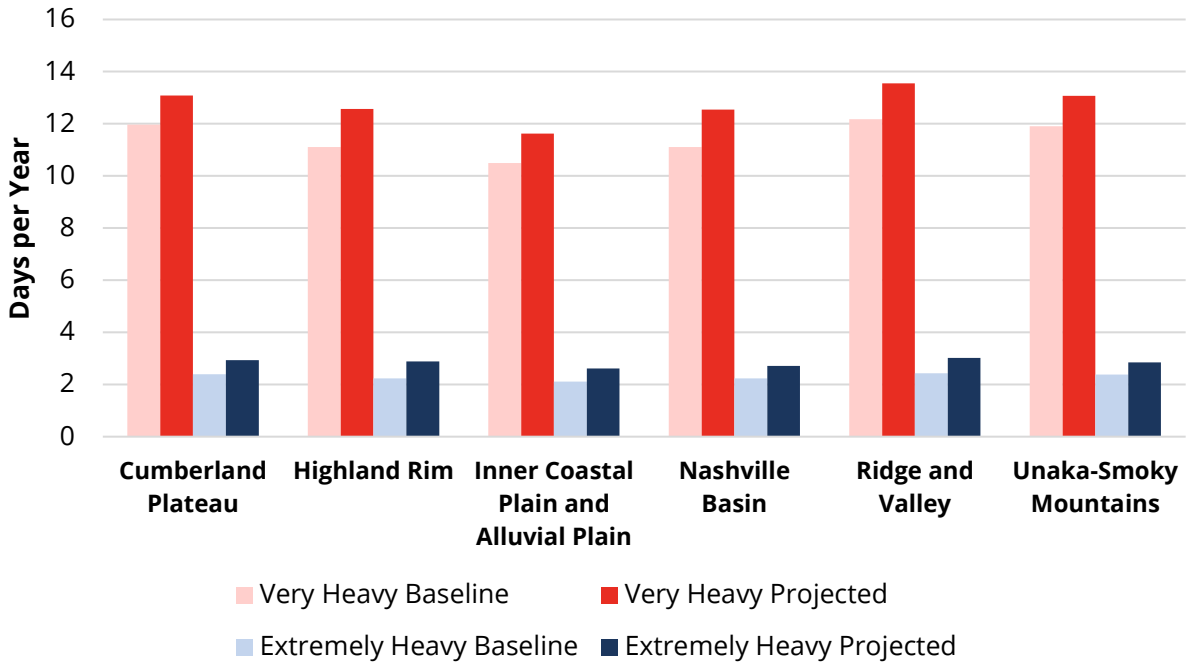


Figure 14. Historical and projected precipitation values within TN by climatic region

An understanding of these risks, both historical and future, provides valuable insight as to how TDOT can make more informed decisions regarding extreme weather resilience investments in different regions throughout the State. While it is difficult for the Department to fully prepare for and respond to each extreme weather type, this information can help inform the types of policies and practices that should be implemented in response to known and evolving threats.

Key Takeaways—Chapter 2

- Tennessee is subject to a variety of extreme weather risks, including floods, landslides/rockfalls, tornadoes, strong winds, excessive heat, drought, wildfires, ice storms, and flash/freeze events. For western Tennessee, the threat of an earthquake is also a key risk. These risks are important considerations for adaptation planning.
- Over the past two decades, there has been a steady increase in the number of billion-dollar storm events within the State. As these financial estimates only take into consideration physical damage and other direct losses, the number of billion-dollar events when considering indirect losses (e.g., business continuity, traffic delays, etc.) and intangible losses (e.g., community identity, social cohesion, etc.) is likely underestimated. Additionally, there are a considerable number of disaster events that occur in Tennessee that are extremely costly, albeit not categorized as a billion-dollar event.
- This trend directly impacts how TDOT does business today and is expected to put additional strain on the agency in the future as greater resources must be diverted in response to these occurrences.
- A future concern for TDOT is the expected change in temperature and precipitation over time. The rate and amount of heavy precipitation can trigger costly disaster events such as flooding and landslides/mudslides, while soaring temperatures can have a debilitating effect on transportation workers, system users, and asset condition and performance.

Chapter 3 Transportation Resilience: Current Practice

As described in Chapter 2, Tennessee's transportation network has and will continue to be exposed to a multitude of extreme weather threats, impacting both safety and performance. It is therefore important for TDOT to have institutions and practices in place to effectively prepare for and mitigate the impact of these events. This chapter helps assess the current state of resilience activity within the Department, including familiarity with resilience concepts and specific practices that have already been adopted by TDOT. It serves to establish a resilience baseline and a basis for identifying opportunities to enhance the Department's resilience program moving forward.

3.1 Background

To better understand how TDOT engages with resilience concepts and activities, a comprehensive literature review was performed. The review consisted of a scan of TDOT planning documents, external research reports, and resilience planning documents developed by other State DOTs.

Concurrently, internal staff interviews were conducted for the purpose of understanding existing resilience perspectives, knowledge, and practices. A diverse set of leaders throughout the Department were selected for these interviews, representing different asset types and divisions. Key survey questions included:

- How is resilience understood within TDOT?
- To what extent is resilience planning a part of existing agency operations?
- What resilience tools, resources, and knowledge are utilized within different parts of the Department?
- Do various divisions within TDOT have the capacity and willingness to adopt new resilience practices?
- What challenges and opportunities exist to enhance resilience policies and practices within TDOT?

The findings from these activities are organized into three distinct categories: 1) structure and processes, 2) tools and technology, and 3) technical capacity and collaboration. These categories were adapted from *Integrating Resilience Concepts and Strategies into Transportation Planning: A Guide*[19], which identified key building blocks for the effective incorporation of resilience into transportation planning. A summary of the types of practices associated with each category appears in Figure 15.

[19] National Academies of Sciences, Engineering, and Medicine. (2023). Integrating Resilience Concepts and Strategies into Transportation Planning: A Guide. Washington, DC: The National Academies Press. https://doi.org/10.17226/27192

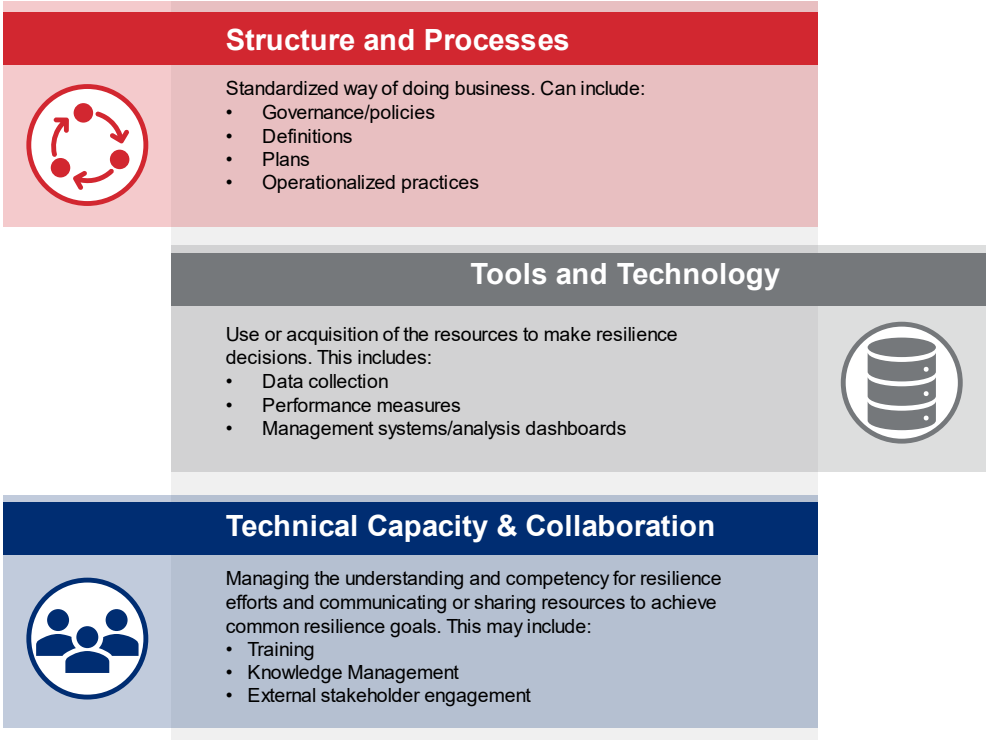


Figure 15. Organizational building blocks for resilience integration

3.2 Structure and Processes

Structure and processes are standards and policies used to integrate best practices into existing operations. TDOT relies on organizational structures and institutionalized processes to achieve its agency objectives, including those involving resilience. Discussion in this section is divided into agency governance and resilience practices, respectively.

Governance

Governance refers to the overarching institutions, policies, and definitions adopted by an agency. With regard to resilience, Tennessee does not currently have any formal policies or state statutes mandating the inclusion of resilience in planning, design, or construction processes, however resilience is referenced in various plans, studies, and program areas within TDOT.

Another important part in developing a robust governance structure is creating standardized agency definitions. While TDOT has defined resilience in different ways in previous planning and research documents, the Department has not formally adopted a definition for resilience. Evidence of this finding was supported in staff interviews, where participants were asked to define resilience as they understand it. There were distinct categorizations of resilience that emerged from these conversations, often appearing correlated with primary responsibilities of the division or group. For example, divisions that deal directly with physical components of the transportation system (e.g., roadways, structures, environment) tended to view resilience as the ability to maintain system functions and "bounce back" after a disruption. Other definitions focused on organizational and individual resilience. Definitions also appeared to be contingent

on prior exposure to resilience planning. Those who indicated a familiarity with terms like "vulnerability" and "resilience" cited previous planning experience and exposure to documents like the TAMP. Overall, responses could be grouped into three themes, as depicted in Figure 16.

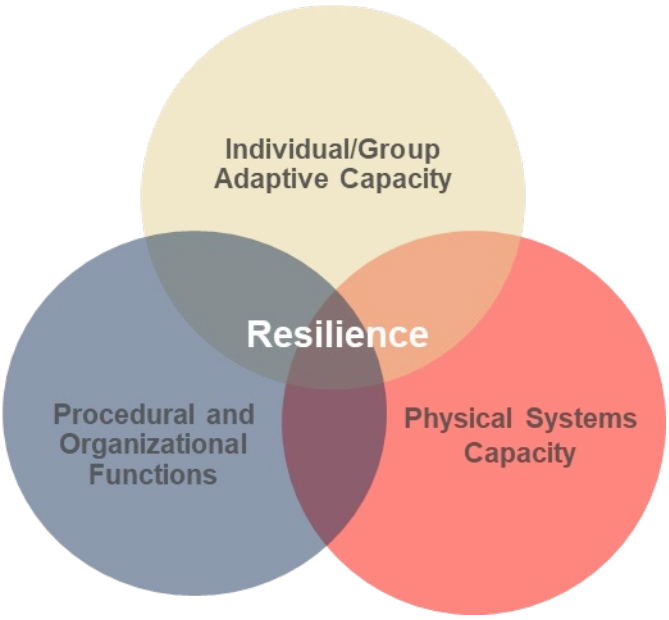


Figure 16. Categories of resilience as articulated by TDOT interviewees.

The definitions of resilience gleaned from the interviews are generally aligned with definitions developed by key national organizations (e.g., Transportation Research Board, FEMA, American Society of Civil Engineers (ASCE)). These definitions focus on addressing different stages of an extreme weather event, including preparation, adaptation, and recovery, and the importance in incorporating social and environmental factors as key resilience considerations.

Resilience Practices

Existing resilience practices within TDOT are summarized separately below according to whether they pertain to planning, operations, or emergency management, respectively.

Resilience Planning

Table 5 lists key planning documents developed by TDOT and its external stakeholders that reference resilience. Collectively, while these planning documents include reference to planning activities that can be associated with resilience (e.g., emergency management, risk management, project prioritization), none explicitly focus on resilience planning per se. Therefore, the TRIP represents the first planning document solely dedicated to transportation resilience within TDOT.

Table 5. Summary of Resilience Planning Documents Relevant to TDOT

Source	Author	Relationship to Resilience
Business Impact Analysis (BIA) Report	TDOT	Summarizes critical business processes and supporting resources within TDOT and assesses the impacts of outages or disruptions. While the analysis was conducted at the organizational level, it provides a summary of the agency's key business processes and a framework for evaluating the impacts of disruptions, which are important in defining organizational resilience.
Transportation Emergency Preparedness Plan (TEPP)	TDOT	Refers to a series of plans focused on addressing issues the State's transportation system are likely to face during an emergency event and guiding TDOT's response. The document consists of detailed plans on various emergency management topics, including hazard analysis, basic emergency operations, continuity of operations, disaster operation guidelines, catastrophic action planning, and emergency communications.
State Priority Rating Model	TDOT	Summarizes the prioritization methodology used by TDOT to assess airport system needs. While this document does not directly address resilience, the prioritization methodology includes some resilience-focused metrics (e.g., environmental considerations, criticality metrics).
Assessing the Vulnerability of Tennessee Transportation Assets to Extreme Weather	Vanderbilt University	Summarizes the findings of an extreme weather vulnerability assessment for the State's transportation network. The assessment included all major transportation infrastructure within Tennessee and explored key extreme weather scenarios and impacts the State would face moving forward.
Transportation Asset Management Plan	TDOT	Summarizes how the agency addresses resilience through its risk management and life cycle planning efforts. The plan also highlights the impact emergency events have had on the agency's transportation infrastructure. As part of the plan's *23 CFR Part 667 Periodic Evaluation of Facilities Repeatedly Requiring Repair and Reconstruction Due to Emergency Events* analysis, TDOT evaluated emergency response

Source	Author	Relationship to Resilience
		data to identify pavements or bridges that have required repeated repair or reconstruction.
Tennessee State Hazard Mitigation Plan 2023	Tennessee Emergency Management Agency (TEMA)	Provides a comprehensive overview of Tennessee's efforts in reducing vulnerability to all hazards. The plan identifies key stakeholders, findings from a risk, vulnerability, and capability assessment, and proposes mitigation strategies to help strengthen community resilience throughout the State.
Unstable Slope Management Program Plan	TDOT	Describes TDOT's unstable slope management program. The document serves as an important reference for understanding how TDOT mitigates risk related to slope movements due to landslides on TDOT right-of-way.
Statewide Transportation Improvement Program (STIP)	TDOT	TDOT's fiscally constrained planning document. The plan lists proposed improvements to TDOT's existing system, including regionally significant state and local roadway, bridge, bicycle, pedestrian, safety, and public transportation projects. While the document is not focused on resilience, it does reference PROTECT as a funding program and represents a clear opportunity for TDOT to integrate resilience into its existing long-range planning efforts.
Tennessee Statewide Multimodal Freight Plan 2023	TDOT	TDOT's statewide multimodal freight plan guides advancement of a multimodal freight transportation system, assesses all freight modes and intermodal connectivity, and supports strategic goals and investment strategies in Tennessee's freight system. The plan includes goals, prioritization criteria, and investment strategies to improve freight resiliency by supporting investing in protection for freight reliant roadways from flood, landslide and other hazards; supporting supply chain redundancy (via alternative routes or modes for long term or short term solutions); and supporting investment components to reduce the severity of impacts of extreme weather and natural disasters on freight mobility.

Resilience Operations

In addition to the aforementioned documents, TDOT engages in ad hoc resilience practices, for example undocumented design, construction, and maintenance activities, where resilience is inherently considered. For pavement and bridges specifically, TDOT utilizes the following strategies:

- **Materials**: Selection of appropriate materials for existing and future extreme weather conditions to which the asset will be exposed. For pavements, this includes choice of the appropriate binder, while for bridges the use of weather-resistant materials, such as epoxy steel, can help reduce increased asset deterioration due to extreme weather events.
- **Design**: Robust design standards exist for many key assets. These standards help the agency design for extreme weather through considerations such as drainage.
- **Construction**: Focuses on delivering projects which meet construction requirements. This allows for flexibility in construction scheduling to ensure proper finishing and curing of its assets.
- **Maintenance**: Emphasizes utilizing the right treatment at the proper time to maintain its existing assets in a state of good repair. Additionally, TDOT has increased its preventive maintenance efforts, an important activity for reducing transportation asset vulnerability to extreme weather.

The TAMP provides additional details on specific operations and research underway to improve pavement and bridge resilience throughout an asset's lifecycle.

Emergency Management

Within Tennessee, TEMA is the primary agency responsible for responding to emergency events. However, TDOT works closely with TEMA and other emergency planning organizations to respond to incidents occurring on or near the transportation network. Specifically, TDOT directly supports TEMA when traffic control, workforce, and other resources are needed leading up to and following emergency events. Outside of the Department's close coordination with TEMA, TDOT has also developed an Emergency Preparedness Plan which considers planning, training, and other activities necessary to support its emergency response activities.

Key Takeaways—Structure and Processes

- TDOT does not currently have a formal governance structure, policies, or definition for resilience at the agency level.
- TDOT and its stakeholders have developed a variety of planning documents addressing risk management, project prioritization, and emergency management. However, the creation of a plan focused exclusively on resilience and that draws clear linkages between these existing plans is needed.
- TDOT recognizes that resilience is a consideration throughout the life cycle of its assets. Efforts to incorporate resilience at the asset level have focused on material selection, design, construction, and maintenance. These efforts are well documented in TDOT's Transportation Asset Management Plan (TAMP). However, further coordination between the TAMP and other risk and resilience documents could strengthen resilience efforts by TDOT.
- Although TDOT already works closely with its emergency management partners to respond to hazard events, TDOT would like to increase coordination on resilience efforts moving forward.

3.3 Tools and Technology

Tools and technology help support the implementation of existing and enhanced resilience practices, leading to more effective risk-informed decision-making. Tools and technology are critical in making efficient and objective decisions for both capital and operational investments. To that end, data collection, performance metrics, management systems, and analysis methods represent important resources in developing and implementing a resilience program.

While TDOT has a robust internal data management system, the data collected and stored does not include network-level, resilience information; instead, information on an asset's ability to withstand extreme weather is mostly considered at the project level. Although the adaptive capacity of a particular asset can be inferred based on its maintenance history, design information and performance records, TDOT does not currently utilize a measure for assessing the resilience of a particular asset. When asked about existing data used during disruption events, interviewees mentioned external data sources such as National Weather Service (NWS) alerts rather than internal data sources. However, while TDOT does not have specific resilience data or metrics used to inform its resilience decision-making, TDOT is currently conducting research to identify the types of data necessary for planning and design. For pavements specifically, TDOT has funded research to quantify historic and projected weather parameters for pavement design.

Similarly, TDOT does not currently have resilience-focused decision support tools or dashboards. TDOT does, however, use existing management tools like BRIDGEWATCH to monitor extreme weather events, such as storms and flooding, and alert TDOT when specific threshold events have been met. This allows bridge owners to respond through inspection or similar activities, thereby increasing system safety.

Moving forward, many interviewees indicated an interest in investing in resilience tools and technology. When asked about useful types of data, tools, or technology, many described a need for real-time system reporting and development of hazard-specific metrics or procedures for each division that would trigger alerts. Additionally, given TDOT's robust data management system, the Department could leverage existing data and tools to inform resilience decisions. This includes using system performance and criticality metrics to identify key locations for resilience investment, as is described in Chapter 4, as well as using existing maintenance data to identify locations where additional investment may improve the overall resilience and life cycle of the asset.

Key Takeaways—Tools and Technology

- Currently, TDOT has limited resilience-specific data, tools, and technology to directly inform decision-making.
- There is an interest in investing in additional resilience data, tools, and technology –especially those that are hazard-specific and time-sensitive.
- TDOT has a robust data management system which can be leveraged for resilience decision-making moving forward.

3.4 Technical Capacity and Collaboration

Technical capacity and collaboration refer to TDOT's competencies, communication strategies, and coordination efforts with regards to resilience. Improving technical capacity and collaboration can help establish a uniform understanding of resilience as a concept and greater proficiency in operationalizing resilience practices within TDOT and with its external partners.

Training and Knowledge Management

Currently, TDOT does not have any resilience-focused training or knowledge management programs. Interviewees, however, indicated an interest in both. Specifically, they discussed the need for training on key definitions and the role resilience may play in the daily functioning of their departments. Several interviewees recommended the utilization of existing educational structures across and within TDOT divisions to facilitate this type of training.

In terms of knowledge management, many described an interest in developing a centralized hub for future resilience training, procedures, and documents. This is because most staff interviewed were uncertain if there was existing documentation and procedures related to resilience, and if so, where these resources were located. For the most part, existing communication on resilience-activities remains limited and siloed.

External Stakeholder Engagement

Throughout preparation of the TRIP, TDOT has actively engaged with the Federal Highway Administration (FHWA) to ensure the plan aligns with federal requirements. Additionally, regular communication has taken place with Tennessee's Metropolitan Planning Organizations (MPOs) and other local agencies to inform these parties of TRIP development.

Moving forward, TDOT expects to engage additional stakeholders via formal meetings and regular communication on existing resilience efforts being undertaken within Tennessee. These mechanisms offer the potential to identify redundancies and synergies in transportation resilience planning efforts being conducted by various parties. Table 6 lists some of the potential stakeholders who could engage as part of this activity.

Notably, TDOT already interacts with many of these partners regarding statewide transportation issues. However, establishing focused resilience communication and coordination is warranted given the increase in frequency and intensity of extreme weather events. This includes opportunities to work closely with MPOs and Rural Planning Organizations (RPOs) choosing to develop or adopt a resilience improvement plan, and collaboration with TEMA in determining evacuation routes for different extreme weather event scenarios, among others.

With this goal in mind, TDOT has recently developed a webpage dedicated exclusively to PROTECT. The webpage currently provides information on the PROTECT program, extreme weather hazards within Tennessee, the impacts of extreme weather on the TDOT network, and how resilience improvement planning can help TDOT be more prepared and strategic. Moving forward, TDOT will utilize the site to share its TRIP and other resilience-focused information, as well as to invite feedback.

Table 6. Potential Resilience Planning External Stakeholders

Group	Stakeholders
Emergency Planning	• State Climate Office • Tennessee Emergency Management Agency • Tennessee Department of Economic and Community Development
Transportation Service Provider	• Chattanooga Area Regional Transportation Authority • Clarksville Transit System • Knoxville Area Transit • Memphis Area Transit Authority • WeGo – Metro Nashville
Planning Organization	• Metropolitan Planning Organizations (MPOs) • Rural Planning Organizations (RPOs)
Navigation/Freight	• CSX • Ingram Barge • Olin Corporation • RJ Corman • Tennessee Valley Authority - Navigation • US Army Corps of Engineers
Other	• FHWA • Citizen Groups • Elected Officials

Key Takeaways—Technical Capacity and Collaboration

- TDOT staff are interested in a centralized resource hub to better share and access existing resilience resources.
- Additional training for TDOT staff on resilience concepts is desired. Training focused on key definitions and how staff can implement resilience concepts in daily business operations was recommended.
- Overall, communication on resilience activities remains limited or siloed. The development of a communication strategy would be beneficial for obtaining buy-in and improving awareness, both internally and externally.
- Continued external engagement and collaboration is important, especially for emergency management planning and the development of Resilience Improvement Plans (RIPs) by MPOs and RPOs.
- TDOT has developed a PROTECT webpage that can be leveraged to share information on resilience activities both internally and with external stakeholders.

Chapter 4 Resilience Investment Prioritization Strategy

As part of the TRIP, TDOT has developed a systematic approach to prioritize resilience investments. The purpose of this strategy is to identify PROTECT-eligible projects and to rank order them in terms of transportation asset criticality and extreme weather risk. In doing so, the Department can make more informed decisions as to where PROTECT funds can be most effectively utilized. The resilience investment prioritization strategy is robust in its approach, taking into consideration potential projects that target pavements, structures, geotechnical and multimodal asset categories.

4.1 Strategy Framework

The framework provides a comprehensive methodology to assess the importance of transportation infrastructure for resilience investment based on two key criteria: 1) asset criticality and 2) extreme weather risk. A "criticality score" is determined using a variety of traditional and innovative metrics that capture the importance of an asset to TDOT's strategic goals. Extreme weather risk criteria include historical and current extreme weather event exposure, social vulnerability, and community resilience, leading to a "risk score". These scores are normalized to arrive at an overall "merit score," from which decisions can be made as to how to allocate available PROTECT funds. The framework can be applied to any prospective project or maintenance activity to improve the resiliency of an asset, regardless of the type of transportation asset, its geographical location, or the types of extreme weather risk an area is experiencing.

Figure 17 provides an overview of the stepwise process used in the resilience investment prioritization framework. The following sections describe each of these steps in greater detail.

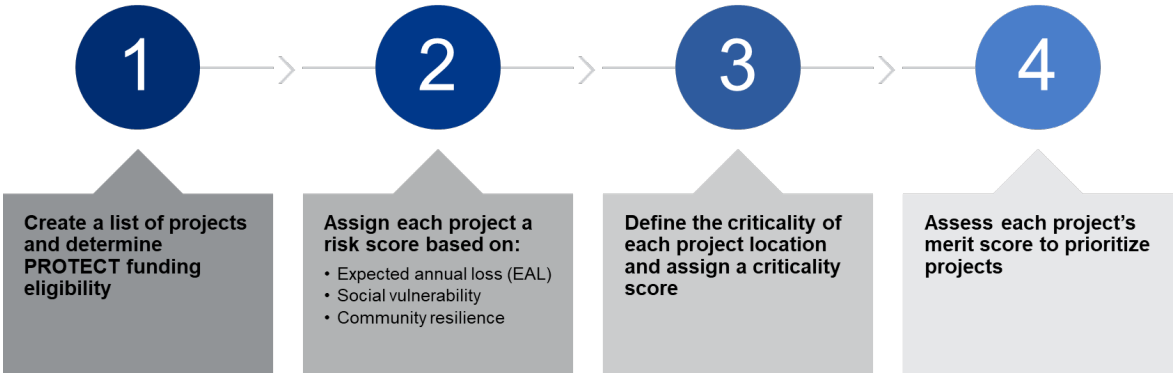


Figure 17. Resilience investment prioritization strategy framework

Step 1: Determine PROTECT Funding Eligibility

The process begins by defining a list of projects for funding consideration. Divisions within the Department may propose projects to be added to the list. All projects are subsequently assessed as to whether they meet PROTECT eligibility according to the eligible facilities,

activities, and costs described in the PROTECT Formula Program guidance.[8] Those projects determined to be PROTECT-eligible proceed to Step 2.

Step 2: Calculate the Extreme Weather Risk Score for each PROTECT-Eligible Project

Extreme weather risk, within the context of the investment prioritization framework, is defined using the FEMA National Risk Index (NRI).[12] The Index has been developed to help agencies and communities throughout the U.S. assess their vulnerability to 18 common natural hazards. Importantly, this information has been compiled and is available for every U.S. Census tract and county. Thus, a consistent and uniform metric can be applied to all candidate projects within the entire State.

To calculate extreme weather risk, the NRI utilizes three key components:

- **Expected Annual Loss (EAL)**: The expected annual loss is a measure of average annual economic loss in dollars, taking into consideration all natural hazards that threaten a specific area. This includes impacts to buildings, population, and agriculture, and is calculated as the product of the exposure to each natural hazard, annual frequency, and loss ratio.
- **Social Vulnerability**: Social vulnerability is a measure of the relative susceptibility to adverse impacts a community may have and is measured using the Center for Disease Control's (CDC) Social Vulnerability Index (SVI)[20]. Higher SVI values are associated with more vulnerable populations.
- **Community Resilience**: Community resilience represents a community's ability to prepare, respond, adapt, withstand, and recover from an event. The metric used to capture community resilience is based on the University of South Carolina's Hazards and Vulnerability Institute (HVRI)'s Baseline Resilience Indicators for Communities (HVRI-BRIC). A higher community resilience score indicates that a community is more resilient to the negative impacts of a natural hazard event[21].

These components interact to define the overall risk, normalized to a value between 0 and 100, considering all natural hazards that threaten a specific location. In FEMA's calculation of the National Risk Index, the following equation is used:

$$Risk\ Index = f(EAL) * f\left(\frac{Social\ Vulnerability}{Community\ Resilience}\right)$$

[20] Centers for Disease Control and Prevention/ Agency for Toxic Substances and Disease Registry/ Geospatial Research, Analysis, and Services Program. CDC/ATSDR Social Vulnerability Index 2020 Database US. https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html. Accessed on December 2023.

[21] Cutter, S.L., K.D. Ash, and C.T. Emrich, 2014. "The Geographies of Community Disaster Resilience," Global Environmental Change 29:65-77.

Therefore, a high EAL or social vulnerability score elevates the extreme weather risk while a high community resilience score diminishes the risk. The National Risk Index was chosen to assess transportation asset extreme weather risk as the index captures both system and community perspectives and was developed using well-referenced and reviewed datasets which are publicly available.

Step 3: Calculate the Asset Criticality Score for Each Project Location

The next step in the process is to define the criticality of the specified transportation asset under consideration. Four distinct asset categories were identified: 1) pavements, 2) structures (bridges, culverts), 3) geotechnical (rockfall, landslides), and 4) multimodal (ports, transit).[22] Criticality, in the context of this framework, is defined as the importance of the asset to the Department's ability to meet the following strategic goals: 1) preserve and manage the existing condition, 2) support the State's economy, and 3) provide efficient movement of people and freight.[23] For each of these goals, individual metrics have been defined to assess asset criticality (see Table 7 and *Appendix IV. Criticality Metrics*). Each of these metrics was selected based on data accessibility and ease of use. Thresholds, depicted in Table 7, are used to assign a relative value for each respective metric, with higher threshold values indicating that the asset is more critical to the transportation network. Each respective metric is normalized between 0-100 and weighted according to its relative importance; these weights were established in consultation with the TRIP Advisory Committee. The criticality score is then calculated as the sum of the weighted individual metrics.

Table 7. Example Criticality Metrics for Pavements, Structures, and Geotechnical Assets [24]

Strategic Goal	Subgoal	Metric	Thresholds	Weight
Preserve and manage the existing condition	Condition	Condition[25]	Based on asset type, according to TDOT condition ratings	17.5%
Support the State's economy	Serves areas of economic need	Per capita market income	1: High per capita income (top third of all TN counties) 2: Moderate per capita income	15%

[22] Future iterations of the methodology may consider additional asset sub-categories, for example rail and airports.

[23] Tennessee Department of Transportation. (2023). *State Transportation Improvement Program*.

[24] These criticality metrics are used for pavements, structures, and geotechnical asset types. Multimodal assets rely on a modified grouping of these metrics as detailed in *Appendix IV. Criticality Metrics*.

[25] Condition metrics vary by asset type. *Appendix IV. Criticality Metrics* summarizes condition metrics by type.

Strategic Goal	Subgoal	Metric	Thresholds	Weight
			3: Low per capita income (bottom third of all TN counties)	
	Value to interstate commerce	National Highway System route	0: Not on the NHS 1: On the NHS	7.5%
Provide efficient movement of people and freight	Access to essential facilities/routes	Access to multimodal routes	0: Not on a transit route or bike route 1: On a transit route or bike route	7.5%
	Traveler throughput	AADT	0-100 value based on TDOT-supplied data	17.5%
	Freight throughput	% trucks	0-100 value based on TDOT-supplied data	17.5%
	Detour length	Length of detour if route is impassable	0-5 value based on natural breaks of all detour lengths within the State	17.5%

Step 4: Calculate the Project Merit Score

The final step of the framework is to assign each project a merit score based on its corresponding extreme weather risk and asset criticality. As both the risk and criticality scores have been normalized to a 0-100 scale, the following equation is used to determine the merit score:

$$Merit\ Score = w_1 * \text{Risk Score} + w_2 * \text{Criticality Score}$$

In this equation, w_1 and w_2 represent the respective importance placed by TDOT on risk and criticality. Initially, these weights have both been set to 0.5, but may be adjusted as programming goals shift. An example of how this approach is implemented is provided in *Appendix V. Resilience Investment Prioritization Methodology in Practice: An Example*.

Merit scores can be used to assess the relative priority of projects within different asset classes (i.e., pavements, structures, etc.), geographical areas (e.g., TDOT regions, rural areas, disadvantaged transportation communities), and overall. This is an opportunity to make resilience investment decisions based on apportioning funds so that no asset class or geographical area is excluded from some level of funding consideration.

In addition to utilizing merit scores to establish PROTECT funding priorities, extreme weather risk and asset criticality can be plotted on a "heat map" as a reference point (see Figure 18). This additional perspective can be helpful in highlighting situations where projects may be characterized as high risk but low criticality, or low risk but high criticality. For such cases,

further consideration may be needed to evaluate whether the project should receive funding, even if the merit score does not suggest priority funding.

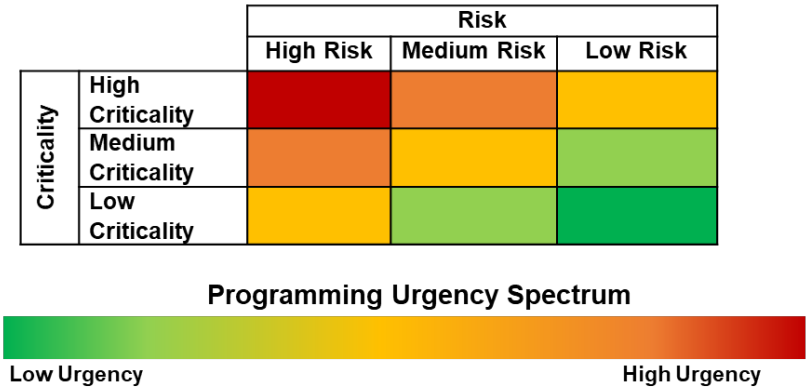


Figure 18. Risk-criticality heat map

4.2 Strategy Implementation

The resilience investment prioritization strategy will be used to identify, evaluate, prioritize, and fund projects focused on resilience. Note that it will be periodically reviewed and updated based on experience in applying the methodology and to incorporate new data that becomes available over time.

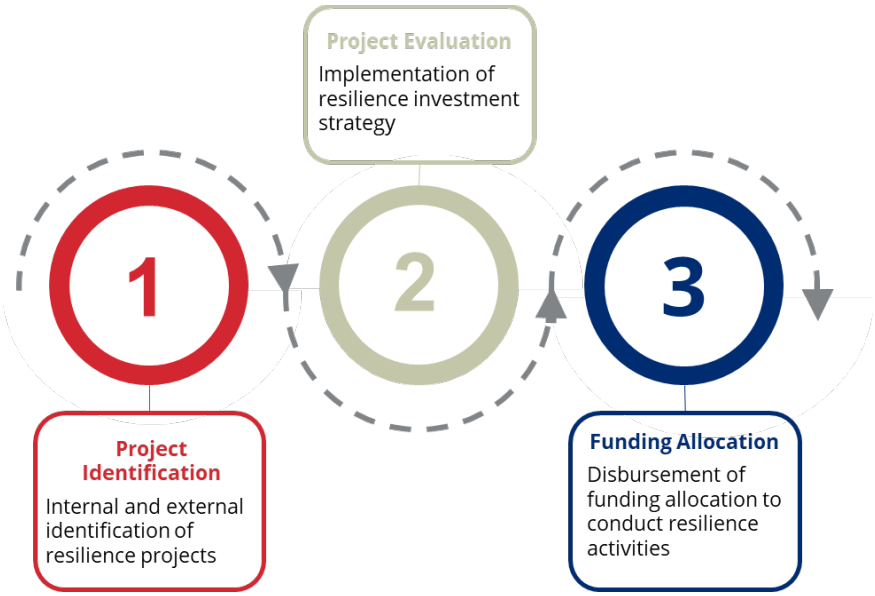


Figure 19. Resilience improvement project assessment process

Project Identification

The first step in the assessment process is project identification. TDOT will take a hands-on approach in identifying and prioritizing projects for PROTECT funding. In general, this process would entail input from TDOT divisions and regions, a review of the TAMP and/or recent events or factors as well as the identification of additional PROTECT-eligible projects within the STIP, Long Range Transportation Plan (LRTP), or other statewide planning documents.

Project Evaluation

Using projects identified in the previous step, TDOT will implement its resilience evaluation framework to assess each candidate project. Projects deemed eligible (Step 1 of the resilience investment strategy) will be assigned a total merit score such that each can be compared to other projects being evaluated. Each project merit score, ordered from highest to lowest value, will be listed, sub-divided by asset category, geographical location, and other project groupings, as desired.

Funding Allocation

The priority project list will be evaluated by TDOT's Resilience Coordinator and appropriate divisions in selecting projects to be programmed based on agency needs. For example, TDOT may elect to prioritize geotechnical projects in a given year due to an increased number of landslides or rockfalls at locations ineligible for emergency relief or similar funding mechanisms. In that instance, the geotechnical projects with the highest merit scores would be proposed for funding allocation, rather than non-geotechnical projects with high merit scores. The priority project list of immediate needs is included in *Appendix VI. Project Priority List* and will be updated annually based on needs.

Additionally, through this process, TDOT will identify potential projects for the PROTECT Discretionary Grant program. TDOT's Resilience Coordinator and appropriate divisions will work to develop proposals for projects considered strong candidates for funding consideration; this includes projects with high merit scores unable to be funded under the PROTECT formula funding program.

Key Takeaways—Chapter 4

- To address the growing extreme weather risk, TDOT developed a resilience investment prioritization strategy to help identify PROTECT-eligible projects.
- The strategy framework provides a stepwise methodology for TDOT to assess the importance of an activity or location for resilience investment based on two key criteria: 1) transportation asset criticality and 2) extreme weather risk.
- A "criticality score" is determined using a variety of traditional and innovative metrics that capture the importance of an asset to TDOT's strategic goals.
- Extreme weather risk criteria include historical and current extreme weather event exposure, social vulnerability, and community resilience, defined using the FEMA National Risk Index.
- The framework can be applied to any prospective PROTECT project or maintenance activity, regardless of the type of transportation asset, its geographical location, or the types of extreme weather risk an area is experiencing.
- TDOT intends to use the resilience investment strategy to identify, evaluate, prioritize, and fund resilience projects.
- All projects assessed through this process will be evaluated and used to update the State's resilience priority project list.

Chapter 5 Pathways for Implementation

As described throughout this plan, TDOT recognizes that while a variety of practices already exist within the Department to incorporate resilience into daily operations, there are opportunities to strengthen the focus on resilience. In the discussion to follow, topics collectively provide a path forward in keeping with this vision.

These items are organized according to whether they align with enhancements to structure and processes, tools and technology, or technical capacity and collaboration. They will be implemented using a phased approach, focusing first on items deemed to be more time-critical and achievable within available resources.

5.1 Structure and Processes

Arguably the most important element to mainstreaming resilience within TDOT is to establish and maintain a formal structure and processes that institutionalize the adoption of resilience throughout the Department. This is driven by a desire to achieve the following objectives:

- Implement a strong governance structure and culture to ensure resilience activities are adopted by the Department and remain sustainable in the long-term.
- Operationalize resilience in all Department activities, enabling staff to fully embrace resilience as a strategic objective and core business practice.
- Implement a knowledge management approach to resilience practices to ensure business continuity and to enable these practices to be adopted by new employees and by different groups within TDOT.

Internalize agency definition for resilience and associated resilience goals and objectives.

Having a formal agency definition for resilience and associated goals and objectives creates a clear vision in implementing "resilient practices". This ensures buy-in and momentum towards integrating resilience throughout the agency and helps create the case for additional resources to be devoted to resilience activities. Success in implementing this recommendation will require a strong commitment on the part of executive leadership to recognize resilience as an agency priority and act accordingly.

Designate a Resilience Coordinator

Successfully mainstreaming resilience into TDOT's mission will require a centralized approach. Using the PROTECT program as the foundational basis, establish a Resilience Coordinator role within TDOT with specific responsibilities for achieving desired actions. This role will establish formal processes for sharing and communicating resilience efforts and needs throughout the organization. A dedicated role would greatly further efforts in advancing resilience throughout the Department.

Establish resilience as a key strategic objective for TDOT's LRTP.

Extreme weather events are expected to increase in frequency and severity for several decades to come. TDOT's long-range transportation plan (LRTP) is a 25-year horizon vision document that reflects the application of programmatic transportation goals to project prioritization, it is

imperative to consider resilience over this time frame during the development of the LRTP. The PROTECT funding formula reflects this perspective by offering a reduction in State DOT match if the TRIP is referenced in the LRTP. The STIP represents a short-term, fiscally constrained view of statewide transportation projects that is consistent with the state's LRTP and the metropolitan transportation plans for resilience projects financed by the PROTECT program or by other funding sources need to be programmed to maintain alignment with how resilience is addressed within the LRTP.

Adopt a multi-modal transportation resilience perspective.

From a transportation resilience perspective, it has become clear that redundancy within the transportation network is necessary to better withstand various extreme weather threats. Creating this redundancy via multiple modes ensures that adequate mobility is maintained for all critical transportation needs, and in particular guarantees that socially vulnerable populations remain connected.

Introduce use of resilience metrics in the project scoping and planning process, and integrate into existing transportation investment scenarios (i.e., TAMP life cycle planning).

Establish specific resilience metrics and utilizing them in the project scoping and planning process explicitly during the project identification and implementation process. This strategy will prove useful in applications beyond the PROTECT program, as metrics can be used to help quantify resilience in project cost-benefit analysis and more accurately quantify return-on-investment for any proposed project that has a resilience component.

Update design standards to address system resilience over the lifetime of the asset.

Although infrastructure design should account for extreme weather events to minimize impacts, this is not adequately addressed in current design standards and guidance. Current design criteria for building and retrofitting transportation infrastructure are generally developed with an implicit assumption that extreme weather conditions will remain static over the design life. Given that the design life of most transportation infrastructure is in the range of many decades, and in some instances as long as 100 years, the upward trends in the frequency and severity of extreme weather events need to be included in these criteria. TDOT will utilize best practices for incorporating extreme weather projections to ensure structures are resilient throughout their design life and perhaps beyond, leveraging the availability of enhanced construction techniques and materials, and innovative stormwater management strategies.

Pursue nature-based solutions to improve system resilience.

Nature-based solutions aimed at improving transportation resilience (e.g., planting natural vegetation, employing green spaces, providing stormwater runoff, wetlands restoration, installing rocky shorelines, etc.) offer an opportunity to work with nature to achieve this goal. This is in contrast to trying to achieve the same outcome by investing in substantial infrastructure projects that can be costly to construct and maintain, and often succumb to natural forces over time. TDOT will undertake a concerted effort to identify locations and strategies where nature-based solutions are feasible and cost-effective.

5.2 Tools and Technology

Maximizing the utilization of tools and technology to strengthen resilience is based on achieving the following objectives:

- Implement a resilience investment prioritization framework for evaluating candidate projects.
- Monitor and report on the resilience of assets over time, utilizing data and performance metrics, to enhance decision-making on how to best prepare for and respond to extreme weather events.
- Leverage the availability of existing tools and data in support of resilience decision-making.
- Utilize real-time monitoring systems and early warning for swift responses.

Implement resilience investment prioritization framework to assist in assessing the merits of prospective projects.

The resilience investment prioritization framework, as defined in Chapter 4 of this document, is now available for use in evaluating the merits of potential resilience projects. As designed, the framework provides a holistic and systematic process for evaluating a candidate project for resilience funding, considering asset criticality, social vulnerability, and community resilience. This framework is applicable for selecting projects for PROTECT funding as well as for funding resilience projects using other available resources.

Although the framework has been developed using metrics that can be derived from readily available data, it can nonetheless present practical challenges in terms of its implementation when considering that the State of Tennessee is characterized by an emerging multimodal transportation network with varying physical and operational characteristics, covers seven different climate zones, is divided into 95 counties, and is defined by nearly 1,500 census tracts.

Continue to track funding required to respond to extreme weather events at the agency level.

As previously mentioned, TDOT has established a means for tracking funding required to respond to extreme weather events. Engaging in this activity helps determine why and where resilience investments are currently needed, while also enabling the Department to better anticipate future resilience funding needs. It also provides an opportunity to evaluate existing maintenance and preservation strategies to ensure they align with resilience goals and objectives. This can be effectively accomplished as part of routine updates made to the TAMP Part 667 analysis.

Continue to conduct research on innovative practices with potential for improving system resiliency.

Research is currently being conducted on the effects of different materials and design solutions have on system resiliency, with the intention of implementing improved methods and practices. This initiative serves as an example of proactive research activities that can be pursued to strengthen resilience. Further research should be encouraged that offers the potential to yield real-world benefits.

Utilize asset maintenance data to identify chronic system issues related to extreme weather events.

TDOT's Maintenance Division has been recording its activities for a considerable period of time, creating a trove of data from which to conduct a comprehensive analysis of the frequency and types of maintenance activities that have been performed at specific locations within the State in response to extreme weather events. Performing data analytics in this fashion will capture extreme weather risk more accurately in lifecycle planning, in addition to ensuring treatment selection considers asset history and future forecasts.

5.3 Technical Capacity and Collaboration

Maintaining and enhancing technical capacity and collaboration enables staff to gain proficiency in strengthening resilience through training, knowledge management, and effective communication strategies. Accomplishing this transcends improving internal capabilities to also reinforce collaboration and communication with external stakeholders on resilience activities, as they serve as partners in building transportation system resilience throughout the State.

Develop and implement a knowledge management and workforce development strategy to establish staff proficiency in performing resilient practices.

Staff interviewees expressed a need and desire to learn more about resilience as a concept and practice by gaining knowledge and experience with data, tools and processes to build technical capacity associated with their roles and responsibilities. Doing so provides awareness, education, engagement, and pathways to resilience action. It also provides greater appreciation for developing equitable resilience initiatives and fosters engagement in diverse professional networks. Staff will be encouraged to complete resilience training programs developed by the FHWA National Highway Institute.

Broaden communication and feedback mechanisms focused on sharing resilience activities with key external stakeholders.

TDOT currently engages with key external stakeholders in a variety of capacities, providing opportunities to share information on agency resilience activities. While helpful, this may not involve individuals in other organizations whose roles and responsibilities encompass resilience. Broadening communication and feedback mechanisms focused on sharing of resilience activities with key external stakeholders will ensure that the most knowledgeable people of ongoing resilience needs and opportunities are included in the conversation. This provides opportunities to confirm results, identify any impacted areas previously unknown, and ground truth critical community locations. The benefit derived from this approach is a growth in synergies and elimination of redundancies in a coordinated statewide effort to strengthen transportation resilience.

Maintain and expand TDOT's PROTECT website to include the most recent resilience resources.

The PROTECT website serves as a central information clearinghouse for resilience activities, initially focused on PROTECT-related initiatives. As the resilience improvement plan and related activities evolve, this clearinghouse becomes an important resource for staff and external stakeholders to access and share information more broadly. Hosting resilience information in

this manner provides transparency to the public on how resilience is being addressed and ensures resilience documentation remains accessible for all interested parties.

Assist MPOs, RPOs and local agencies in developing their own resilience improvement plans.

The TRIP establishes a first-of-its kind planning document in Tennessee that is exclusively focused on strengthening transportation resilience from a statewide perspective. This serves as a catalyst and resource for MPOs, RPOs and local transportation agencies to follow suit with their own resilience plans. This effort, will help build external buy-in and momentum in integrating resilience throughout the State, enable coordination on transportation resilience improvement planning throughout the State, and enhance opportunities for these agencies to compete for PROTECT discretionary grants and other resilience funding solicitations.

Enhance communication and coordination with emergency management agencies regarding extreme weather planning, response, and recovery strategies.

TDOT enjoys a strong working relationship with TEMA and other emergency management agencies. However, in many cases, documentation on the key practices and coordination efforts between these agencies remains disaggregated or undocumented. It will be important moving forward, to report on coordination efforts and update emergency management documentation (i.e. emergency operation plans, evacuation routes, etc.) to ensure business continuity over time. Existing emergency preparedness response and recovery practices should be reviewed to ensure socially vulnerable populations and transportation modes such as transit, bicycling and walkability have been considered.

5.4 Roadmap for Implementation

This plan and action items represent a means to formalize and grow the resilience program utilizing a holistic, systematic, and incremental approach. It has been designed to leverage existing resilience practices as a foundation upon which to increase adoption of resilience as a core business practice. The plan's success will rely on continual internal coordination and collaboration. Updates to the TRIP will be made to ensure that it reflects the most up-to-date practices and aspirations.

Appendix I. RIP Requirements Reference Table

Topic	Citation	Section Reference
The Plan Shall..		
Encompass immediate and long-range planning activities	...be for the immediate and long-range planning activities and investments of the State or metropolitan planning organization with respect to resilience of the surface transportation system within the boundaries of the State or metropolitan planning organization, as applicable	Chapter 1.2 - Scope of Tennessee's Transportation Resilience Improvement Plan
Demonstrate a system-wide approach	...demonstrate a systemic approach to surface transportation system resilience, and	Chapter 4 - Resilience Investment Prioritization Strategy
Consistency with State and local hazard mitigation plans	...be consistent with and complementary of the State and local mitigation plans required under section 322 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (42 U.S.C. 5165)	Chapter 1.1 - Federal Resilience Programs Chapter 2 – The Need for Resilience Planning and Chapter 3.2 - Structure and Processes
Risk-based assessment of assets and systems	...include a risk-based assessment of vulnerabilities of transportation assets and systems to current and future weather events and natural disasters, such as severe storms, flooding, drought, levee and dam failures, wildfire, rockslides, mudslides, sea level rise, extreme weather, including extreme temperatures, and earthquakes (23 U.S.C.176(e)(2)(A-C)).	Chapter 4 - Resilience Investment Prioritization Strategy
Shall, as appropriate..		
Natural disaster, extreme weather preparedness	...include a description of how the agency is prepared to respond to the impacts of weather events, natural disasters and is prepared for changing conditions;	Chapter 3.2 - Structure and Processes
Regulatory framework	...describe the codes, standards, and regulatory framework, adopted and enforced by the agencies, to ensure that resilience improvements within the	Chapter 1 - Introduction and 3.2 - Structure and Process

Topic	Citation	Section Reference
	impacted area of proposed projects that are included in the plan;	
Natural infrastructure	…consider the benefits of combining hard surface transportation assets, and natural infrastructure, through coordinated efforts by the Federal Government and the States;	Chapter 5 - Pathways for Implementation
Community infrastructure	…assess the resilience of other community assets, including buildings and housing, emergency management assets, and energy, water, and communication infrastructure;	Chapter 4 - Resilience Investment Prioritization Strategy
Other	…include such other information as the State or metropolitan planning organization considers appropriate	3.2 - Structure and Processes and 3.4 - Technical Capacity and Collaboration
May also..		
Evacuation routes	…designate evacuation routes and strategies, including multimodal facilities, designated with consideration for individuals without access to personal vehicles;	Chapter 5 - Pathways for Implementation
Emergency response	…plan for response to anticipated emergencies, including plans for the mobility of emergency response personnel and equipment and access to emergency services, including for vulnerable or disadvantaged populations;	3.2 - Structure and Process
Resilience-related policy	…describe the resilience improvement policies, including strategies, land-use and zoning changes, investments in natural infrastructure, or performance measures that will inform the transportation investment decisions of the State or metropolitan planning organization with the goal of increasing resilience;	Chapter 3 - Transportation Resilience for TDOT and Chapter 5 - Pathways for Implementation

Topic	Citation	Section Reference
Investment plan & priority projects	...include an investment plan that includes a list of priority projects and describes how funds apportioned to the State under section 104(b)(8), or provided by a grant under the PROTECT program would be invested and matched, which shall not be subject to fiscal constraint requirements;	Chapter 4 - Resilience Investment Prioritization Strategy and Appendix VI. Project Priority List
Supporting science and data	...use science and data and indicate the source of data and methodologies	Chapter 4 - Resilience Investment Prioritization Strategy

Appendix II. Transportation Resilience Improvement Plan Advisory Committee

Name	Organization/Division
Adam Price	TDOT - Structures
Amos Pulley	TDOT - Maintenance & Operations
Amy Rauch	TDOT - STID
Andrea Noel	TDOT - Planning
Austin Holliman	TDOT - Asset Management
Brandon Chance	TDOT - Environmental
Chris Harris	TDOT - Asset Management
Craig Philip	Vanderbilt University
Dan Pallme	TDOT - Freight & Logistics (rail)
David Lee	TDOT - Planning
Degee Roberts	TDOT - Planning
Heather Purdy Hall	TDOT - Materials & Tests
Janey Camp	Vanderbilt University
Joshua McDuffie	Vanderbilt University
Klint Rommel	TDOT - Environmental
Lauren Gardner	Vanderbilt University
Lia Prince	TDOT - Planning
Mark Abkowitz	Vanderbilt University
Matt Meservy	TDOT - Planning
Melanie Murphy	Federal Highway Administration
Michelle Nickerson	TDOT - Traffic Operations
Morgan Ballard	TDOT - Maintenance & Operations
Rennie Rath	Vanderbilt University
Robert Jowers	TDOT - Materials & Tests (R3)
Savannah Robertson	TDOT - Planning
Tom Quinn	TDOT - Structures
Xiaoyang Jia	TDOT - Pavement Management
Zachary Coleman	Federal Highway Administration

Appendix III. FEMA Declared Disasters in TN (2019-2023)

Event	Incident Start	Incident End	Declaration Date	Description	Total Public Assistance Dollars Obligated	Hazard Mitigation Grant Dollars Obligated
DR-4742-TN	8/7/2023	8/7/2023	9/27/2023	Severe Storms, Straight-line Winds, and Tornado	$940,312	
DR-4735-TN	7/18/2023	7/21/2023	9/4/2023	Severe Storms and Straight-line Winds	$856,253	
DR-4729-TN	6/25/2023	6/26/2023	8/17/2023	Severe Storms and Straight-line Winds	$934,461	
DR-4712-TN	3/1/2023	3/3/2023	3/17/2023	Severe Storms and Possible Strong Tornadoes	$5,473,228	
DR-4701-TN	3/31/2023	4/1/2023	4/7/2023	Severe Storms, Straight-line Winds, and Tornadoes	$4,161,170	
DR-4691-TN	12/22/2022	12/27/2022	3/8/2023	Severe Winter Storm	$4,516,854	
DR-4645-TN	2/3/2022	2/4/2022	3/11/2022	Severe Winter Storm	$35,372,031	
DR-4637-TN	12/10/2021	12/11/2021	1/14/2022	Severe Storms, Straight-line Winds, and Tornadoes	$13,783,248	

Event	Incident Start	Incident End	Declaration Date	Description	Total Public Assistance Dollars Obligated	Hazard Mitigation Grant Dollars Obligated
4609-DR-TN	8/21/2021	8/21/2021	8/23/2021	Severe Storm and Flooding	$38,387,978	$4,703,358
4601-DR-TN	3/25/2021	4/3/2021	5/8/2021	Severe Storms, Tornadoes, and Flooding	$19,812,148	
4594-DR-TN	2/11/2021	2/19/2021	4/21/2021	Severe Winter Storms	$16,498,761	
DR-4550-TN	5/3/2020	5/4/2020	7/9/2020	Severe Storms, Straight-line Winds, and Flooding	$11,135,470	$121,610
DR-4541-TN	4/12/2020	4/13/2020	4/24/2020	Severe Storms, Tornadoes, Straight-line Winds, and Flooding	$54,695,393	$3,208,184
DR-4476-TN	3/3/2020	3/3/2020	3/5/2020	Severe Storms, Tornadoes, Straight-line Winds, and Flooding	$63,915,999	$1,408,053
DR-4471-TN	10/26/2019	10/26/2019	12/6/2019	Severe Storm and Straight-line Winds	$13,796,690	$186,467
DR-4427-TN	2/19/2019	3/30/2019	4/17/2019	Severe Storms, Flooding, Landslides, and Mudslides	$22,109,481	$2,891,518

Appendix IV. Criticality Metrics

Table 8. Condition Metrics by Asset (Excluding Multimodal)

Asset	Thresholds
Pavement	• **1**: Good (based on federal metrics) • **2**: Fair (based on federal metrics) • **3**: Poor (based on federal metrics)
Bridges	• **1**: Good (based on federal metrics) • **2**: Fair (based on federal metrics) • **3**: Poor (based on federal metrics)
Culverts	• **1**: Excellent (based on TDOT culvert blockage and structural condition) • **2**: Good (based on TDOT culvert blockage and structural condition) • **3**: Fair (based on TDOT culvert blockage and structural condition) • **4**: Poor (based on TDOT culvert blockage and structural condition) • **5**: Critical (based on TDOT culvert blockage and structural condition)
Geotechnical	• **1**: Very Low Sinkhole Susceptibility Index (SSI) • **2**: Low SSI • **3**: Moderate SSI • **4**: High SSI • **5**: Very High SSI OR on the Top-46 List (TDOT High Risk Rock Slopes)

Table 9. Criticality Metrics for Ports (Multimodal)

Strategic Goal	Subgoal	Metric	Thresholds
Preserve and manage the existing condition	Condition	Condition	• **0-3** score based on age since last major reconstruction of port element
Support the State's economy	Serves Areas of Economic Need	Per capita market income	• **1**: High per capita income (top third of all counties) • **2**: Moderate per capita income • **3**: Low per capita income (bottom 6third of all counties)
	Value to Interstate Commerce	Identified in Multimodal Freight Plan Project List	• **0**: Not in the plan • **1**: In the plan
Provide efficient movement of people and freight	Access to Essential Facilities/Routes	Designated intermodal port (based on TN Statewide Multimodal Freight Plan)	• **0**: Not an intermodal port • **1**: Is an intermodal port
	Traveler Throughput	N/A	N/A
	Freight Throughput	Total average annual tonnage	• **0-3** based on natural breaks within the State from US Army Corps metrics
	Detour Length	N/A	N/A

Table 10. Criticality Metrics for Transit (Multimodal)

Strategic Goal	Subgoal	Metric	Thresholds
Preserve and manage the existing condition	Condition	Condition	Dependent on project type but dictated by Federal Transit Administration (FTA) condition metrics
Support the State's economy	Serves Areas of Economic Need	Per capita market income	• **1**: High per capita income (top third of all counties) • **2**: Moderate per capita income • **3**: Low per capita income (bottom third of all counties)
	Value to Interstate Commerce	Access to business districts	• **0**: Does not provides service to commercial/business district/job hubs • **1**: Provides service to commercial/business district/job hubs
Provide efficient movement of people and freight	Access to Essential Facilities/Routes	Access to multimodal routes	• **0**: Does not provide service to multimodal hubs (airport, port, or train station) • **1**: Provides service to multimodal hub (airport, port, or train station)
	Traveler Throughput	Ridership	• **0-5** based on natural breaks in unlinked ridership adjusted by population without vehicle access (reliant on FTA and census data)
	Freight Throughput	N/A	N/A
	Detour Length	N/A	N/A

Appendix V. Resilience Investment Prioritization Methodology in Practice: An Example

To better illustrate the resilience investment prioritization strategy framework, we provide an example herein on how the methodology can be employed. While the example is informed by real data, it is for illustrative purposes only and does not constitute an actual project currently under consideration by TDOT.

Suppose a project has been proposed to raise a bridge in Waverly, TN in an area that has routinely experienced flooding in the past decade. A determination has been made that the proposed improvement meets the PROTECT eligibility criteria; therefore, it becomes appropriate to assess the merit of the project. Note that the proposed project is associated with the Bridge asset category, and it is geographically located in TDOT Region 3.

Extreme Weather Risk Score

Using census tract data from FEMA's National Risk Index tool, as shown in Figure 20, Waverly is determined to have an extreme weather risk index characterized as Relatively High. Specifically, the area surrounding the project location is at High risk for a multitude of extreme weather, including lightning, strong wind, tornado, and riverine flooding. At the same time, the location has High social vulnerability and only Moderate community resilience to "bounce back." Based on this information, the overall risk score for the project location, as a percentile within Tennessee, is 93.50.

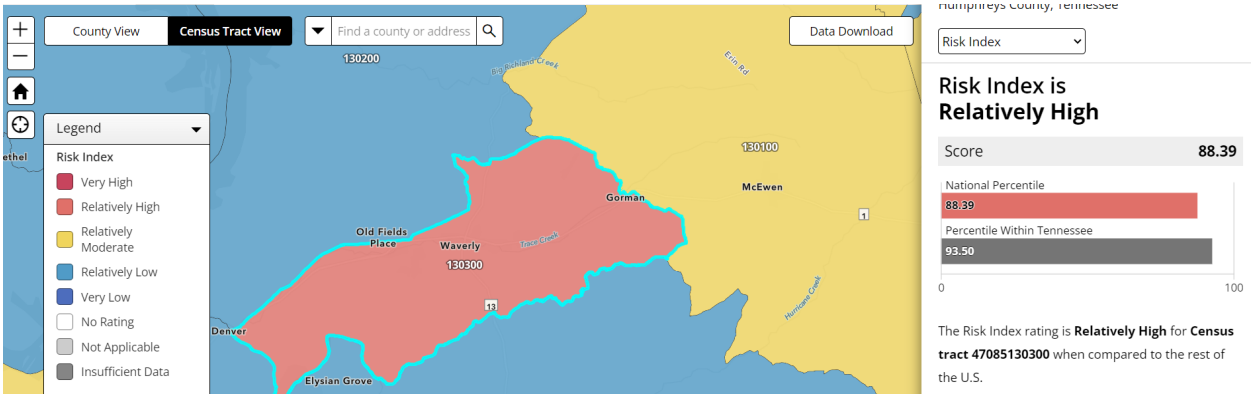


Figure 20. Risk score in Waverly, TN

Transportation Asset Criticality Score

The asset criticality score utilizes data collected by TDOT and other nationally available data sources. As shown in Table 11, the bridge location is in Fair condition with Low overall traffic, as well as Low truck traffic, and a Moderate detour length. Moreover, the project is located on a route that is not part of the NHS, does not serve as a primary transit or bike route, and is in a county with Moderate per capita income. Given these values and the thresholds described in

Table 7, a normalized score (0 to 100) was determined for each criticality metric. These normalized scores were then multiplied by the recommended criticality weight, and summed, to arrive at a total criticality score. The total criticality score for this project is 24.46.

Table 11. Criticality Metrics for the Example Project Location

Metric	Value	Score	Normalized Score	Weight	Weighted Score
Condition	Fair	2	50	0.175	8.75
Per capita market income	Moderate per capita income	2	50	0.15	7.5
National Highway System route	Not on the NHS	0	0	0.075	0
Access to multimodal routes	Not on a transit route or bike route	0	0	0.075	0
AADT	1,180	1.2	1.2	0.175	0.21
% trucks	1%	5.71	5.71	0.175	1
Length of detour if route is impassable	6 km	2	40	0.175	7

Merit Score

For the purposes of this example, to calculate the project's merit score, the weights are distributed equally between the risk score (93.50) and the criticality score (24.46). Therefore, w_1 and w_2 were both set to 0.5. Using the equation below, the merit score was calculated as follows:

$$Merit\ Score = 0.5 * 93.50 + 0.5 * 24.46 = 58.98$$sSuppose that TDOT made a budget allocation decision to fund two Bridge projects in Region 3 during the coming year. In addition to the Waverly project, suppose that three other proposed Bridge projects located in Region 3 were also assessed using the resilience investment prioritization strategy framework. Their respective merit scores were as follows: 1) 68.17, 2) 49.38, and 3) 42.56. As the proposed Waverly bridge project ranked second in priority, it was recommended for PROTECT funding.

Appendix VI. Project Priority List

Region	County	Route	Project Name	Project Scope
1	Blount	SR115	Jack and bore new pipe @ LM 18.18	Jack and bore 150-ft. of new 30-in. smooth wall steel casing adjacent to existing 30-in. corrugated metal pipe due to poor structure conditions. Install new end walls and riprap at outlet only for protection.
1	Blount	SR115	Rockfall @ LM's 11.1, 14.5, 14.7, 15.07 and 16.4	Project includes Scaling and trim blasting, debris removal within the catchment area, slope excavation and the installation of drape wire mesh, rock anchors/dowels and horizontal drains.
1	Campbell	I0075	Landslide @ MM 156.6	Removal of remaining slide material and repair retaining wall/rockfall fence. Construction of a soil nail wall at the top of slope and addressing the drainage along Rarity Mountain.
1	Campbell	SR090	Rockfall @ LM 2.2	Project includes realignment of the roadway by shifting it north to eliminate rockfall issues by providing adequate catchment area.
1	Campbell	SR297	Slip-line existing culvert @ LM 9.34	Slip-line existing 18-in. CMP with a 14-in. smooth wall HDPE.
1	Campbell	SR297	Slip-line existing culvert @ LM 9.67	Slip-line existing 24-in. RCP with a 22-in. smooth wall HDPE; construct straight headwall at inlet; place 15-ft x 12-ft riprap slope and channel armoring at outlet.
1	Carter	SR091	Open Cut and Replace Culvert or Pipe @ LM 14.18	Replace steel beams and deck of existing concrete slab structure (no changes proposed for the remaining portion of the structure; and no proposed direct impacts to stream).
1	Carter	SR091	Open Cut and Replace Culvert or Pipe @ LM 14.64	Replace steel beams and deck of existing concrete slab structure (no changes proposed for the remaining portion of the structure; and no proposed direct impacts to stream).
1	Carter	SR037	Rockfall @ LM 15.1	Project includes Scaling, debris removal within the catchment area, and the installation of rock dowels, drape wire mesh, concrete barrier and horizontal drains.
1	Cocke	I0040	Rockfall @ LM 18.2, 20.8	Project includes Scaling, debris removal within the catchment area and benches, and the installation of drape wire mesh.
1	Greene	SR172	Open Cut and Replace Culvert or Pipe @ LM 9.47	Remove and replace existing 54-in. metal pipe in poor condition with installation of new 60-in. reinforced concrete pipe, concrete end walls, and riprap apron only at outlet for protection.

Region	County	Route	Project Name	Project Scope
1	Hancock	SR033	Open Cut and Replace Culvert or Pipe @ LM 13.06	Remove and replace existing 60-in. corrugated metal pipe in poor condition with installation of new 14-ft X 7-ft. concrete box culvert and end walls. Install Class C riprap apron only at outlet for protection.
1	Hancock	SR033	Open Cut and Replace Culvert or Pipe @ LM 18.91	Remove and replace existing 72-in. galvanized metal arch pipe in poor condition with new corrugated steel arch pipe, including installation of end walls and embedded riprap apron only at outlet for protection.
1	Johnson	SR159	Rockfall @ 2.2, 2.3	Project includes Scaling and trim blasting, debris removal within the catchment area, and the installation of drape wire mesh, rock anchors/dowels, and horizontal drains.
1	Loudon	SR072	Slip-line existing culvert @ LM 0.11	Slip-line existing 36-in. CMP with a 32-in. smooth wall HDPE
1	Loudon	SR444	Slip-line existing culvert @ LM 0.60	Slip-line existing 18-in. CMP with a 14-in. smooth wall HDPE
1	Monroe	SR072	Jack and bore new pipe @ LM 9.07	Abandon existing 42-in. corrugated metal pipe in poor condition; Jack and bore new 42-in. steel casing pipe. Install new end walls and riprap aprons at both inlet and outlet for protection.
1	Monroe	SR360	Open Cut and Replace Culvert or Pipe @ LM 18.76	Remove and replace existing 66-in. corrugated metal pipe in poor condition with new reinforced concrete pipe including installation of end walls. Install permanent riprap outlet protection (between the outlet wing walls).
1	Monroe	SR360	Open Cut and Replace Culvert or Pipe @ LM 19.41	Remove and replace existing 60-in. corrugated metal pipe in poor condition with installation of new concrete structure, including installation of end walls and embedded riprap apron only at outlet for protection.
1	Scott	SR029	Slip-line existing culvert @ LM 7.69	Install 171-ft. of 34-in. HDPE slip-liner through the existing 42-in. CMP beneath SR-29. Also, remove existing 24-in. CMP (350-ft) that extends from 42-in. CMP outlet beneath SR-29, down to the toe of slope, and replace with riprap spillway/ditch (350-ft, w/ first 25-ft grouted)
1	Scott	SR052	Slip-line existing culvert @ LM 4.30	Slip-line existing 24-in. CMP with an 18-in. smooth wall HDPE
1	Sullivan	I026	Rockfall @ MM 1.7	Project includes excavation on slide material and installation of anchored wire mesh
1	Unicoi	SR036	Rockfall @ LM 6.3	Project includes Scaling, debris removal within the catchment area, slope excavation, and the installation of drape wire mesh, rock anchors/dowels, and horizontal drains.
2	Fentress	SR028	Slip-line existing culvert @ LM 31.774	Washout and slip-line existing 24-in. CMP with 22-in. HDPE culvert

Region	County	Route	Project Name	Project Scope
2	Grundy	SR002	Rockfall @ LM 25.2	Slide mitigation using rock buttress, tree clearing, paving, and striping
2	Grundy (Site1)	I24-EB	Rockfall @ LM 5.6	Rockfall mitigation using trim blasting and scaling overhangs; mesh and shotcrete stabilization, rockfall drapes, catchment area restoration.
2	Hamilton	SR002	Rockfall @ LM 4.6, 5.1	Rockfall mitigation, vegetation removal, trim blasting and scaling, rockfall drapes, drainage excavation
2	Hamilton	SR148	Rockfall @ LM 3.8	Rockfall mitigation, vegetation removal, trim blasting and scaling, rockfall drapes, drainage excavation
2	Marion	SR108	Landslide @ LM 2.8	Retaining wall construction, drainage improvements, haul roads, maintenance road, paving and striping
2	Overton	SR052	Open Cut and Replace Culvert or Pipe @ LM 5.74	Remove existing 48-in. corrugated metal pipe and replace with 60-in. reinforced concrete pipe (embedded 1.5-ft.), including a Class B riprap apron at the RCP outlet
2	Overton	SR164	Slip-line existing culvert @ LM 8.491	Slip-line existing 18-in. CMP with a 14-in. smooth wall HDPE
2	Putnam	I40	Slip-line existing structure @ LM 34.59 (Milepost 301.8)	Slip-line a portion of the existing 72-in. CMP with a 63-in. HDPE culvert with internal baffles (culvert replacement not an option due to presence beneath Interstate 40)
2	Rhea	SR068	Rockfall @ LM 4.1, 4.4	Rockfall mitigation using trim blasting and scaling overhangs; mesh and shotcrete stabilization, rockfall drapes, road and drainage excavation.
2	Sequatchie	SR111	Jack and bore @ LM 4.47	Jack and bore new culvert through existing culvert from inlet side (existing end walls will not be impacted). Install Class C embedded riprap apron at outlet
2	White	SR136	Slip-line existing culvert @ LM 3.083	Washout and slip-line existing 18-in. CMP with 16-in. HDPE culvert
2	White	SR136	Open Cut and Replace Culvert or Pipe @ LM 0.62	Replace existing 24-in. box culvert with no defined channel of flow with new box culvert of the same dimensions, install new end walls, and install riprap apron only at outlet for protection.
3	Maury	SR166	Open Cut and Replace Culvert or Pipe @ LM 5.7	Remove and replace existing 18-in. culvert with new culvert

Region	County	Route	Project Name	Project Scope
3	Maury	SR373	Open Cut and Replace Culvert or Pipe @ LM 7.3	Remove and replace existing 24-in. culvert with new culvert
3	Montgomery	SR012	Open Cut and Replace Culvert or Pipe @ LM 5.4	Remove and replace existing 24-in. reinforced concrete pipe in poor condition with a new 30-in. reinforced concrete pipe. Install new end walls and riprap apron only at outlet for protection.
4	Benton	SR191	Open Cut and Replace Culvert or Pipe @ LM 10.057	Remove and replace existing culvert with new culvert. Currently on resurfacing list for FY2025.
4	Benton	SR191	Open Cut and Replace Culvert or Pipe @ LM 14.013	Remove and replace existing culvert with new culvert. Currently on resurfacing list for FY2025.
4	Benton	SR191	Open Cut and Replace Culvert or Pipe @ LM 15.076	Remove and replace existing culvert with new culvert. Currently on resurfacing list for FY2025.
4	Benton	SR191	Open Cut and Replace Culvert or Pipe @ LM 15.119	Remove and replace existing culvert with new culvert. Currently on resurfacing list for FY2025.
4	Carroll	SR077	Open Cut and Replace Culvert or Pipe @ LM 1.39	Remove and replace existing 16-in. culvert with new culvert
4	Carroll	SR077	Open Cut and Replace Culvert or Pipe @ LM 9.74	Remove and replace existing 30-in. culvert with new culvert
4	Crockett	SR221	Open Cut and Replace Culvert or Pipe @ LM 5.5	Remove and replace existing 96-in. galvanized metal pipe in poor condition with embedded, 16-ft. X 8-ft. reinforced concrete box culvert, including riprap apron only at outlet for protection. Install new end walls.
4	Gibson	SR077	Open Cut and Replace Culvert or Pipe @ LM 12.3	Remove and replace existing 69-in. CMP with new culvert. Currently on resurfacing list for FY2025.
4	Hardin	SR069	Replace existing structure @ LM 24.71	52’ of 15” CMP (Replace existing CMP with 18” polypropylene pipe with new FL raised to existing inlet and outlet ground level. Currently on resurfacing list for FY2025.
4	Tipton	SR054	Open Cut and Replace Culvert or Pipe @ LM 2.9	Remove and replace existing cross-drain with 24-in. RCP. Currently on resurfacing list for FY2025.
4	Tipton	SR059	Open Cut and Replace Culvert or Pipe @ LM 26	Remove and replace existing cross-drain with 24-in. RCP. Currently on resurfacing list for FY2025.

Region	County	Route	Project Name	Project Scope
4	Tipton	SR206	Open Cut and Replace Culvert or Pipe @ LM 5.1	Remove and replace existing CMP with 18-in. RCP (side drain). Currently on resurfacing list for FY2025.
4	Tipton	SR206	Open Cut and Replace Culvert or Pipe @ LM 1.7	Remove and replace existing CMP with 24-in. RCP. Currently on resurfacing list for FY2025.
4	Tipton	SR206	Open Cut and Replace Culvert or Pipe @ LM 7.05	Remove and replace existing cross-drain with 36-in. RCP. Currently on resurfacing list for FY2025.
4	Tipton	SR206	Open Cut and Replace Culvert or Pipe @ LM 7.35	Remove and replace existing cross-drain with 36-in. RCP. Currently on resurfacing list for FY2025.
4	Tipton	SR384	Open Cut and Replace Culvert or Pipe @ LM 1.5	Remove and replace existing CMP with 18-in. RCP (side drain). Currently on resurfacing list for FY2025.
4	Tipton	SR384	Open Cut and Replace Culvert or Pipe @ LM 3.01	Remove and replace existing cross-drain with 24-in. RCP. Currently on resurfacing list for FY2025.