



TDOT
Department of
Transportation



Integration of Resilience into TDOT Agency Practices

Research Final Report from 3 Sigma Consultants and the University of Tennessee | Mark
Abkowitz & Airton Kohls | October 17, 2022

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16. Abstract <p>At a time when transportation agencies are encountering more frequent and severe extreme weather events, greater emphasis is being placed on mainstreaming resilience into policies and practices. In response to the present and anticipated impact of extreme weather on transportation resilience within the state, the Tennessee Department of Transportation (TDOT) is considering how to facilitate the integration of resilience into agency decision-making processes and operating procedures. The ultimate objective is to mainstream extreme weather resilience into the way in which TDOT does business.</p> <p>This project was undertaken as an initial phase in pursuing that objective. It involved the following activities: 1) design and administer a resilience self-assessment survey for TDOT staff to complete, 2) analyze survey results, identify needs, and recommend next steps, and 3) design and implement a transportation resilience web site that could be used to serve as a knowledge resource for TDOT and its stakeholders.</p> <p>In addition to describing project activities, this report contains a discussion of findings and recommendations. Making significant strides in mainstreaming extreme weather resilience into TDOT policies and programs will require a comprehensive approach to meet the challenges associated with establishing and communicating agency resilience goals, objectives, performance measures and targets. Moreover, to successfully implement this approach, there is a need to provide knowledge awareness and training to TDOT staff, focused on learning and applying resilience concepts, analysis techniques, tools, and management processes. Concurrent with these activities is a need to institute a strong resilience culture within the agency.</p>			
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Executive Summary

At a time when transportation agencies are encountering more frequent and severe extreme weather events, greater emphasis is being placed on mainstreaming resilience into policies and practices. In response to the present and anticipated impact of extreme weather on transportation resilience within the state, the Tennessee Department of Transportation (TDOT) is considering how to facilitate the integration of resilience into agency decision-making processes and operating procedures. The ultimate objective is to mainstream extreme weather resilience into the way in which TDOT does business.

This project was undertaken as an initial phase in pursuing that objective. It involved the following activities: 1) design and administer a resilience self-assessment survey for TDOT staff to complete, 2) analyze survey results, identify needs, and recommend next steps, and 3) design and implement a transportation resilience web site that could be used to serve as a knowledge resource for TDOT and its stakeholders.

Technical Approach

The technical approach to performing this project involved the conduct of three sequential tasks, as described below.

Task 1: Design and Administer a Resilience Self-Assessment Survey

The purpose of this task was to enable TDOT staff to evaluate the current status of the agency's resilience efforts and to identify priority needs. The instrument for obtaining this information was the development of an online survey asking TDOT staff to respond to a series of questions relating to extreme weather resilience knowledge and awareness, resilience-related activities the agency had undertaken, and future activities that would enhance TDOT's ability to plan and operate a more resilience transportation system.

Task 2: Survey Analysis and Resilience Activities Development

This task focused on analyzing and reporting the survey results, resulting in the identification of areas where TDOT could strengthen agency extreme weather resiliency. It also involved developing a set of proposed short-term strategies and actions for TDOT to consider to assist with mainstreaming resilience activities into TDOT methods and practices.

Task 3: Develop TDOT Resilience Web Page

Towards building extreme weather resilience knowledge and awareness, this task involved the design and implementation of a web page containing useful sources of transportation extreme weather resilience information, both within and external to TDOT. Once populated, the intent is for this page to become part of TDOT's web site, as a menu selection therein.

Findings and Recommendations

The results of TDOT's extreme weather resilience self-assessment make it clear that while the organization has made some strides, it remains in the early stages of transformation. This is evident in terms of how respondents categorized the agency's resilience maturity level as well as the current level of resilience knowledge and skills among TDOT staff. Significant findings include:

- **The vast majority of survey respondents consider TDOT’s maturity level for incorporating resilience into its activities as being low or medium.**
- **There is a general lack of knowledge among survey respondents as to how TDOT is incorporating resilience concepts into its practices.**
- **TDOT faces a myriad of challenges in mainstreaming resilience into agency activities.**
- **A critical educational need involves staff understanding of agency resilience goals, objectives, performance measures and targets. Other needs include learning about resilience analysis techniques, tools, and management processes.**

Given the volume and trend of extreme weather events, it is critical and timely for TDOT to develop a focused strategy for mainstreaming extreme weather into agency policies and practices. This will require a comprehensive approach to meet the challenges associated with establishing and communicating agency resilience goals, objectives, performance measures and targets. Moreover, to successfully implement this approach, there is a need to provide knowledge awareness and training to TDOT staff, focused on learning and applying resilience concepts, analysis techniques, tools, and management processes. Concurrent with these activities is a need to institute a strong resilience culture within the agency.

It is therefore recommended as a next step that TDOT embark on an initiative to address these considerations. More specifically, the following actions should be undertaken:

1. **Form an Extreme Weather and Natural Hazards Resilience Task Force** – This task force should be comprised of senior TDOT staff with resilience portfolios representing various divisions within the agency. The mission of this group would be to guide and support ongoing engagement within and between TDOT staff and with outside partners. The responsibility for facilitating task force activities should be formally assigned to a specific entity within TDOT, the Long Range Planning Division being a desirable candidate.
2. **Establish a formal agency resilience policy and program** – TDOT should develop a formal agency policy on how it views resilience as part of its mission and establish a program with responsibility for carrying out that directive. To have the appropriate agency stature and influence, serious consideration should be given to naming a Chief Resilience Officer.
3. **Define resilience performance goals/metrics** – The resilience program should set achievable goals and have a basis for measuring whether they are being met.
4. **Develop and administer resilience training modules** – TDOT’s resilience self-assessment results make clear that agency staff feel a strong need to improve their resilience knowledge and awareness. This is best accomplished by developing and administering a series of resilience training modules, each targeted to specific TDOT staff based on their roles and responsibilities (e.g., planning, operations, maintenance, etc.).
5. **Identify and utilize best practice methods/tools for evaluating candidate and implemented resilience activities** – A comprehensive review should be performed to identify best practices in terms of management, assessment and communication methods being used by transportation entities in the public and private sectors to effectively mainstream resilience into organizational activities, including the tools and

techniques being applied. This will enable TDOT to implement proven approaches to strengthening resilience.

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Chapter 1 Introduction

At a time when transportation agencies are encountering more frequent and severe extreme weather, greater emphasis is being placed on mainstreaming resilience into policies and practices. The Tennessee Department of Transportation (TDOT) previously completed an extreme weather vulnerability assessment that included consideration of all major transportation infrastructure located within the state. That study enabled the agency to gain considerable knowledge regarding exposure of the state's overall transportation system to current and anticipated extreme weather events. In response to the present and anticipated impact of extreme weather on transportation resilience within the state, TDOT is considering how to facilitate the integration of resilience into agency decision-making processes and operating procedures. The ultimate objective is to mainstream extreme weather resilience into the way in which TDOT does business.

This project was undertaken as an initial phase in pursuing that objective. It involved the following activities: 1) design and administer a resilience self-assessment survey for TDOT staff to complete, 2) analyze survey results, identify needs, and recommend next steps, and 3) design and implement a transportation resilience web site that could be used to serve as a knowledge resource for TDOT and its stakeholders.

Engaging in this process can be impactful at several levels within TDOT. Of particular interest are opportunities to bring extreme weather resilience into agency methods and practices involving:

- Selection of capital and operating transportation investments
- Development of the State Transportation Improvement Program (STIP)
- Implementation of maintenance plans and procedures
- Design, construction and repair of roads and bridges
- Selection of materials for use in building roads and bridges
- Hazard mitigation planning and emergency management
- Informing the environmental review process
- Data collection activities to characterize and monitor the condition of vulnerable assets
- Collaboration with MPOs in updating their Long Range Transportation Plans

Project objectives are also closely aligned with several federal legislation and agency directives, including: 1) Risk-based Transportation Asset Management Plan (TAMP), and 2) FHWA Order 5520 (Transportation System Preparedness and Resilience to Climate Change and Extreme Weather Events), and 3) the Infrastructure Investment and Jobs Act (IIJA).

Chapter 2 Methodology

The technical approach to performing this project involved the conduct of three sequential tasks, as described below.

Task 1: Design and Administer a Resilience Self-Assessment Survey

The purpose of this task was to enable TDOT staff to evaluate the current status of the agency's resilience efforts and to identify priority needs. The instrument for obtaining this information was the development of an online survey asking TDOT staff to respond to a series of questions relating to extreme weather resilience knowledge and awareness, resilience-related activities the agency had undertaken, and future activities that would enhance TDOT's ability to plan and operate a more resilience transportation system.

Task 2: Survey Analysis and Resilience Activities Development

This task focused on analyzing and reporting the survey results, resulting in the identification of areas where TDOT could strengthen agency extreme weather resiliency. It also involved developing a set of proposed short-term strategies and actions for TDOT to consider to assist with mainstreaming resilience activities into TDOT methods and practices.

Task 3: Develop TDOT Resilience Web Page

Towards building extreme weather resilience knowledge and awareness, this task involved the design and implementation of a web page containing useful sources of transportation extreme weather resilience information, both within and external to TDOT. Once populated, the intent is for this page to become part of TDOT's web site, as a menu selection therein.

Chapter 3 Results and Discussion

3.1 TDOT Resilience Self-Assessment

A resilience self-assessment survey was administered to select TDOT staff, from which a total of nearly 50 survey completed responses were received. The survey consisted of a series of questions covering the following topics:

- Extent to which TDOT has established a resilience definition, policy, performance measures, and/or communication strategy
- Areas where TDOT has incorporated resilience into its programs and processes
- Identification of extreme weather resilience threats and vulnerability of transportation assets
- Greatest challenges TDOT faces in incorporating resilience into its roles and responsibilities
- Training needs to encourage resilience adoption
- Extent to which existing TDOT resilience activities are shared within the agency and with its partners
- TDOT's overall maturity level for incorporating resilience into its activities

The results of TDOT's resilience self-assessment make it clear that while the organization has made some strides in this direction, it remains in the early stages of this transformation. This is evident in terms of how respondents categorized the agency's resilience maturity level as well as the current level of resilience knowledge and skills among TDOT staff.

Appendix A contains the full survey results. What follows is a summary of the most important findings.

3.1.1 Overall Resilience Maturity Level

The vast majority of survey respondents consider TDOT's maturity level for incorporating resilience into its activities as being low or medium, with roughly an equal number of respondents associated with each of these categories. As shown in Figure 1, only 6% of respondents viewed TDOT as having a high level of resilience maturity.

What do you think is TDOT's overall maturity level for incorporating resilience into its activities?

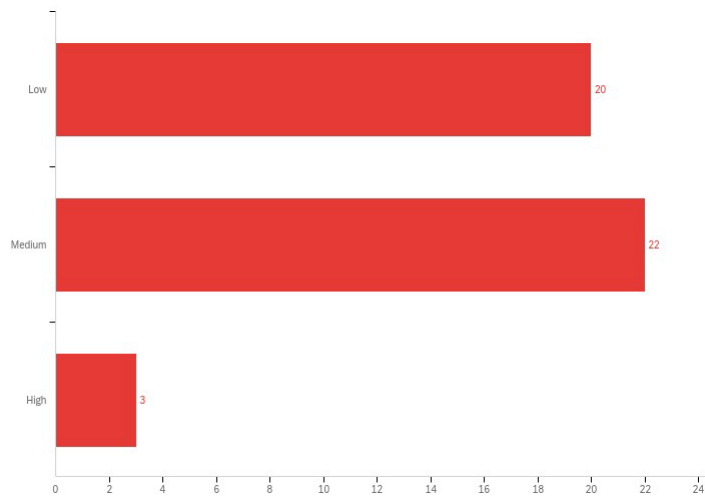


Figure 1 TDOT Maturity Level for Incorporating Resilience into its Activities

3.1.2 Where TDOT Is Incorporating Resilience Concepts

Delving a bit deeper into the context of this overall resilience maturity assessment, as shown in Figure 2, **there is a general lack of knowledge among survey respondents as to how TDOT is incorporating resilience concepts into its practices.** Among those who felt that some of this activity is occurring, such activity is dispersed among various stages in the process.

At what stage of the transportation planning process is TDOT incorporating resilience concepts (select all that apply)?

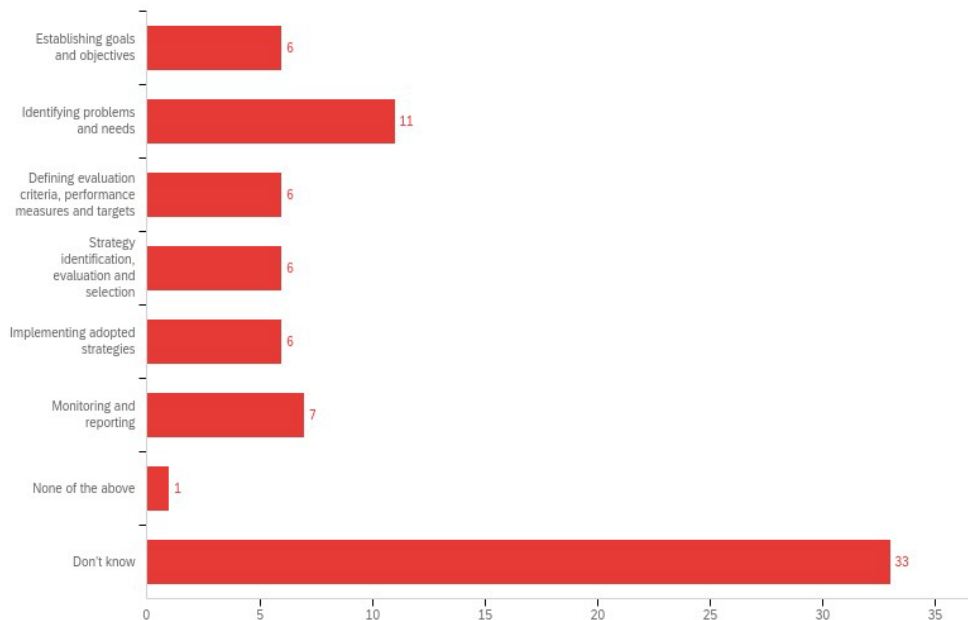


Figure 2 Status of TDOT Incorporation of Resilience Concepts into its Practices

3.1.3 Resilience Implementation Challenges

Given the aforementioned observations about the maturity level of TDOT's resilience programs and lack of knowledge about existing activities, it becomes important to understand the challenges TDOT faces in mainstreaming resilience into agency activities. Respondents cited a myriad of concerns (see Figure 3), foremost among them being:

- **Overall understanding of resilience**
- **Lack of established resilience performance goals/metrics**
- **Lack of established method/tools for measuring resilience**
- **Insufficient staffing levels or expertise**
- **Lack of adequate resilience training**

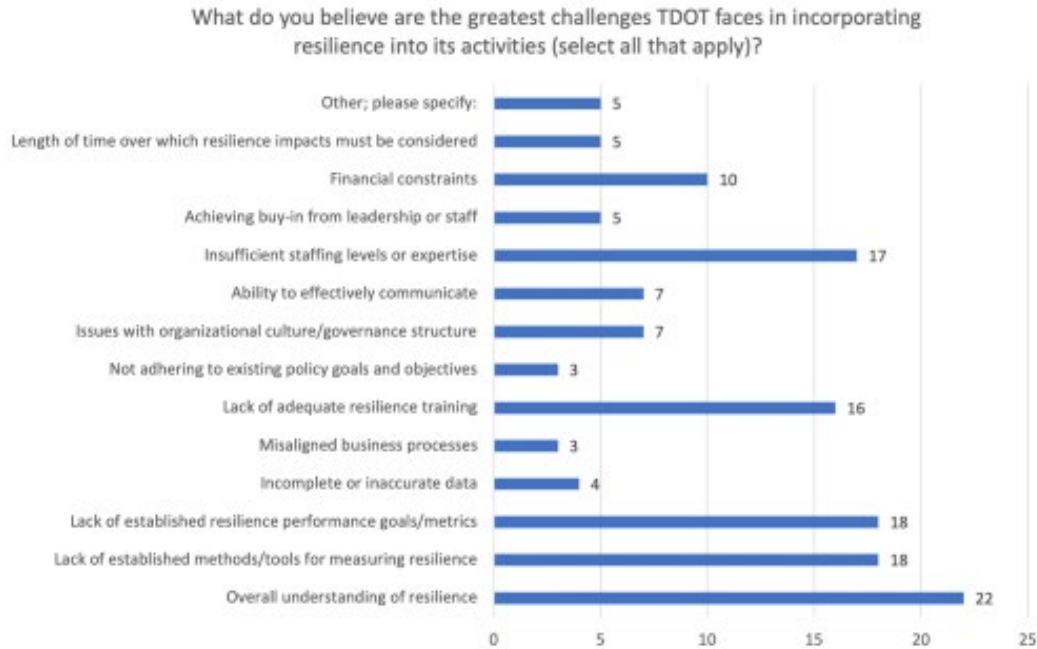


Figure 3 Challenges TDOT Faces in Incorporating Resilience into Agency Activities

3.1.4 Resilience Training Needs

To overcome these challenges, respondents identified several training needs (see Figure 4). **A critical educational need involves staff understanding of agency resilience goals, objectives, performance measures and targets. Other needs include learning about resilience analysis techniques, tools, and management processes.**



Figure 4 Resilience Training Needs

3.2 Resilience Workshop

The purpose of the workshop was to: 1) provide TDOT staff with information on current and expected extreme weather trends, 2) discuss the potential impact of these developments on TDOT roles and responsibilities, 3) share extreme weather resilience self-assessment survey results, 4) provide insight into how TDOT might integrate extreme weather resilience into its policies and programs, 5) propose next steps, and 6) entertain questions and open discussion. Over 80 TDOT staff participated in this videoconference session. Below is a summary of information provided in the workshop. Presentation slides are included as Appendix B in this report.

The location and topography of Tennessee make it somewhat unique in that it is defined by many different climate regions, each exposed to its own unique set of extreme weather events. These include damaging winds, drought, extreme heat, floods and flash floods, hail, tropical storms, sink holes, landslides and rockfalls, debris flow, thunderstorms and lightning, tornadoes, wildfires, snow and ice storms, and freeze-thaw cycles. In fact, every area of the state is threatened by some combination of these conditions.

These conditions cause disruptions that impact multiple modes (e.g., air, highways, marine, rail, pipeline), potentially affecting local, regional, national and international passenger and freight transport. The impacts can be episodic or chronic in nature, causing road closures and damage, bridge deterioration, destruction of embankments and slopes, diminished mobility, supply chain disruption, saturation of subgrade, illness/injury/death, environmental degradation, increased maintenance and reconstruction costs, and litigation from property owners. Importantly, these impacts create a negative public image of TDOT.

It is also clear that the situation is trending in a disturbing direction, as it is anticipated that temperatures will rise, precipitation levels may increase, precipitation intensity will increase, drought frequency will increase, we can expect higher wind speeds, and there will be more wildfires. Moreover, the impacts will be exacerbated by a growing U.S. population that is also becoming more diverse and elderly, and continued residential and business development. These will generate greater demand for transportation infrastructure and services.

Concurrently, public expectation will continue to be for adequate protection of critical transportation services when faced with the threat of extreme weather, and a quick and efficient transportation system recovery if loss and damage is incurred. This also comes at a time when transportation infrastructure will be facing increasing demands for reconstruction/rehabilitation over the next several decades. We are therefore at an inflection point where, depending on how TDOT acts, one can expect a deterioration in transportation services or, conversely, it presents an important opportunity for TDOT to improve transportation services by proactively incorporating resilience into its efforts. This is being encouraged by recent Federal legislation and directives.

Moving in this direction begins with establishing an agency definition for the concept of resilience. A suggested definition is, *"The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions with minimum damage to social wellbeing, the economy and the environment."* Thus, a resilient transportation agency is one that can deter problems before a disruption becomes disastrous, and is prepared and positioned to

take action, restore services and build back better or relocate assets where appropriate. When done successfully, this approach saves the state money and the public time, while earning TDOT greater respect and an enhanced reputation.

An important component to successful implementation of agency resilience policies and programs is a strong resilience culture. This is achieved by: 1) promoting the importance of resilience within TDOT and to external stakeholders, 2) demonstrating commitment to resilience in actions, 3) fostering preparedness and resilience efforts within and across departments, 4) capitalizing on a resilience theme in agency communications, and 5) leveraging technology through a resilience lens.

Concurrent with this activity is the establishment of a comprehensive and systematic resilience planning process. This is best achieved by implementing an incremental and iterative program consisting of the following steps:

- Identify current and future natural hazards
- Conduct inventory of infrastructure and assets
- Characterize risk of natural hazards on infrastructure
- Develop initial adaptation strategies
- Identify opportunities for coordination
- Link strategies to capital and rehabilitation cycles
- Prepare and implement adaptation plans
- Monitor and reassess

By adopting this approach, there is reason to believe that TDOT will identify and take actions to become more resilient to the extreme weather hazards threatening the state's transportation system. This is corroborated by transportation and utility studies conducted by the National Institute of Building Sciences that determined an overall benefit/cost of 4-to-1 associated with investment in natural hazard resilience actions, with an even higher return (8-to-1) when these investments are directed at riverine flooding.

One final workshop observation involved the relationship between resilience in response to extreme weather relative to other agency risks. It was noted that when investing in extreme weather resilience, there is likely to be crossover benefits associated with TDOT becoming more resilient to hazardous materials incidents, power service disruptions, financial crises, supply chain interruptions, cyberattacks, public health emergencies, structural failures, and civil unrest, among others.

The workshop concluded with discussion prompted by attendee questions and comments. This was supplemented by information shared via chat.

3.3 Resilience Web Site Development

To help organize information to enhance extreme weather resilience knowledge and awareness for TDOT staff and its transportation stakeholders, an effort was undertaken to design and implement a web site devoted to this purpose. This was accomplished by performing a comprehensive literature review of available extreme weather transportation resilience resources which provided relevant information. To organize this information, the web site was designed as a series of pages representing the following subject matter, respectively:

- Tools
- Webinars
- Workshops & Peer Exchanges
- Publications
- Regulations and Policy
- Related Links

Sample web pages are included as Appendix C in this report.

The web site has been successfully programmed and can be accessed at <https://tdotresilience.com/>. Although currently operating in a stand-alone mode, the expectation is that this url would be folded into TDOT's main web page as a selection option.

Chapter 4 Conclusion

The results of TDOT's extreme weather resilience self-assessment make it clear that while the organization has made some strides, it remains in the early stages of transformation. This is evident in terms of how respondents categorized the agency's resilience maturity level as well as the current level of resilience knowledge and skills among TDOT staff. Significant findings include:

- The vast majority of survey respondents consider TDOT's maturity level for incorporating resilience into its activities as being low or medium.
- There is a general lack of knowledge among survey respondents as to how TDOT is incorporating resilience concepts into its practices.
- TDOT faces a myriad of challenges in mainstreaming resilience into agency activities.
- A critical educational need involves staff understanding of agency resilience goals, objectives, performance measures and targets. Other needs include learning about resilience analysis techniques, tools, and management processes.

Given the volume and trend of extreme weather events, it is critical and timely for TDOT to develop a focused strategy for mainstreaming extreme weather into agency policies and practices. This will require a comprehensive approach to meet the challenges associated with establishing and communicating agency resilience goals, objectives, performance measures and targets. Moreover, to successfully implement this approach, there is a need to provide knowledge awareness and training to TDOT staff, focused on learning and applying resilience concepts, analysis techniques, tools, and management processes. Concurrent with these activities is a need to institute a strong resilience culture within the agency.

It is therefore recommended as a next step that TDOT embark on an initiative to address these considerations. More specifically, the following actions should be undertaken:

1. **Form an Extreme Weather and Natural Hazards Resilience Task Force** –This task force should be comprised of senior TDOT staff with resilience portfolios representing various divisions within the agency. The mission of this group would be to guide and support ongoing engagement within and between TDOT staff and with outside partners. The responsibility for facilitating task force activities should be formally assigned to a specific entity within TDOT, the Long Range Planning Division being a desirable candidate.
2. **Establish a formal agency resilience policy and program** – TDOT should develop a formal agency policy on how it views resilience as part of its mission and establish a program with responsibility for carrying out that directive. To have the appropriate agency stature and influence, serious consideration should be given to naming a Chief Resilience Officer.
3. **Define resilience performance goals/metrics** – The resilience program should set achievable goals and have a basis for measuring whether they are being met.
4. **Develop and administer resilience training modules** – TDOT's resilience self-assessment results make clear that agency staff feel a strong need to improve their resilience knowledge and awareness. This is best accomplished by developing and

administering a series of resilience training modules, each targeted to specific TDOT staff based on their roles and responsibilities (e.g., planning, operations, maintenance, etc.).

5. **Identify and utilize best practice methods/tools for evaluating candidate and implemented resilience activities** – A comprehensive review should be performed to identify best practices in terms of management, assessment and communication methods being used by transportation entities in the public and private sectors to effectively mainstream resilience into organizational activities, including the tools and techniques being applied. This will enable TDOT to implement proven approaches to strengthening resilience.

Appendix A- TDOT RESILIENCE SELF-ASSESSMENT SURVEY RESULTS

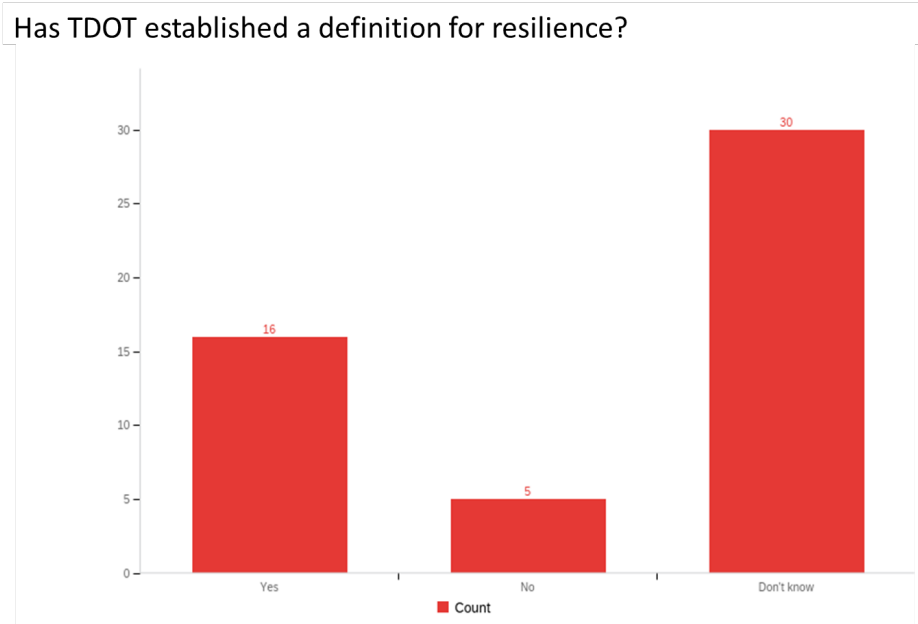


Figure A 1 Extent to Which TDOT has Established a Definition of Resilience

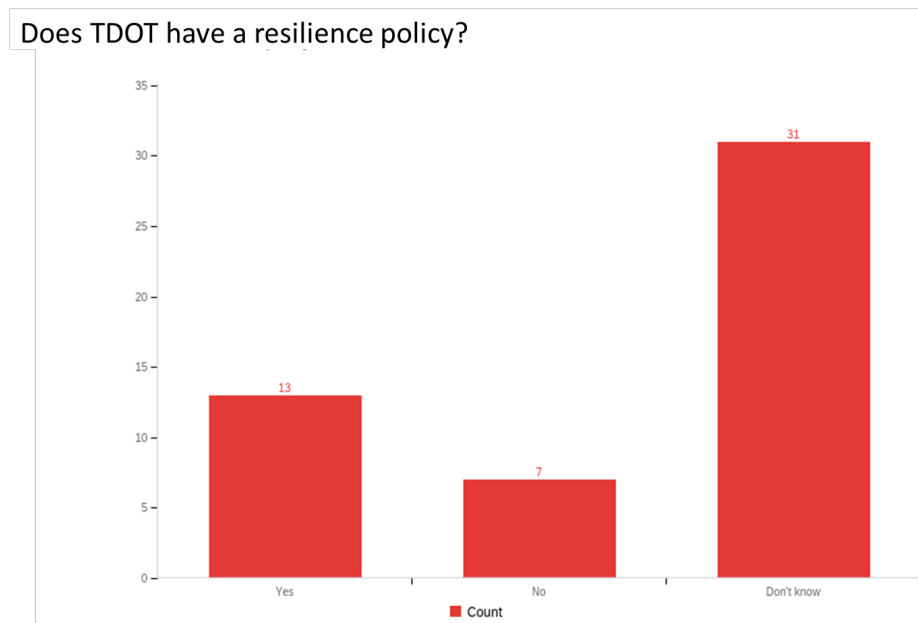


Figure A 2 Extent to Which TDOT has Established a Resilience Policy

Has TDOT established resilience metrics?

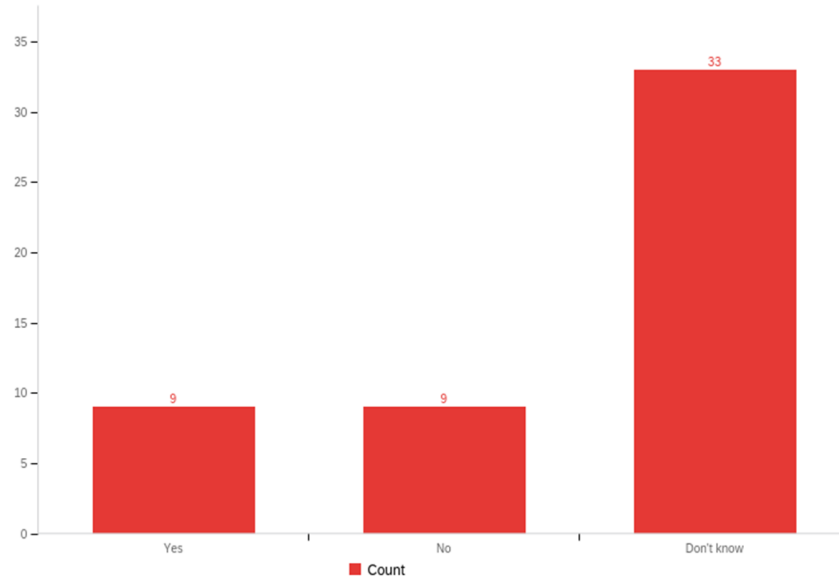


Figure A 3 Extent to Which TDOT has Established Resilience Metrics

Does TDOT have a process for communicating resilience activities?

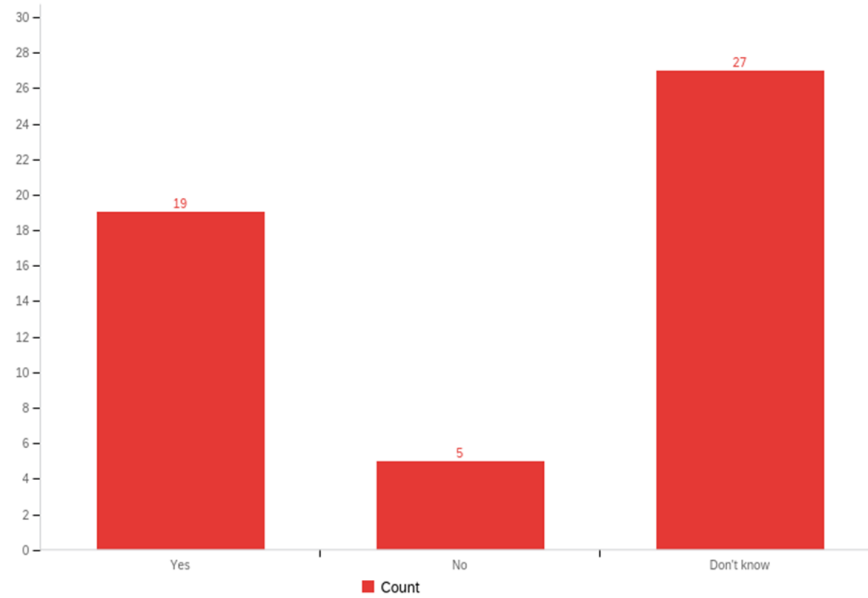


Figure A 4 Extent to Which TDOT has Established a Resilience Communication Process

In what areas has TDOT incorporated resilience into its programs (select all that apply)?

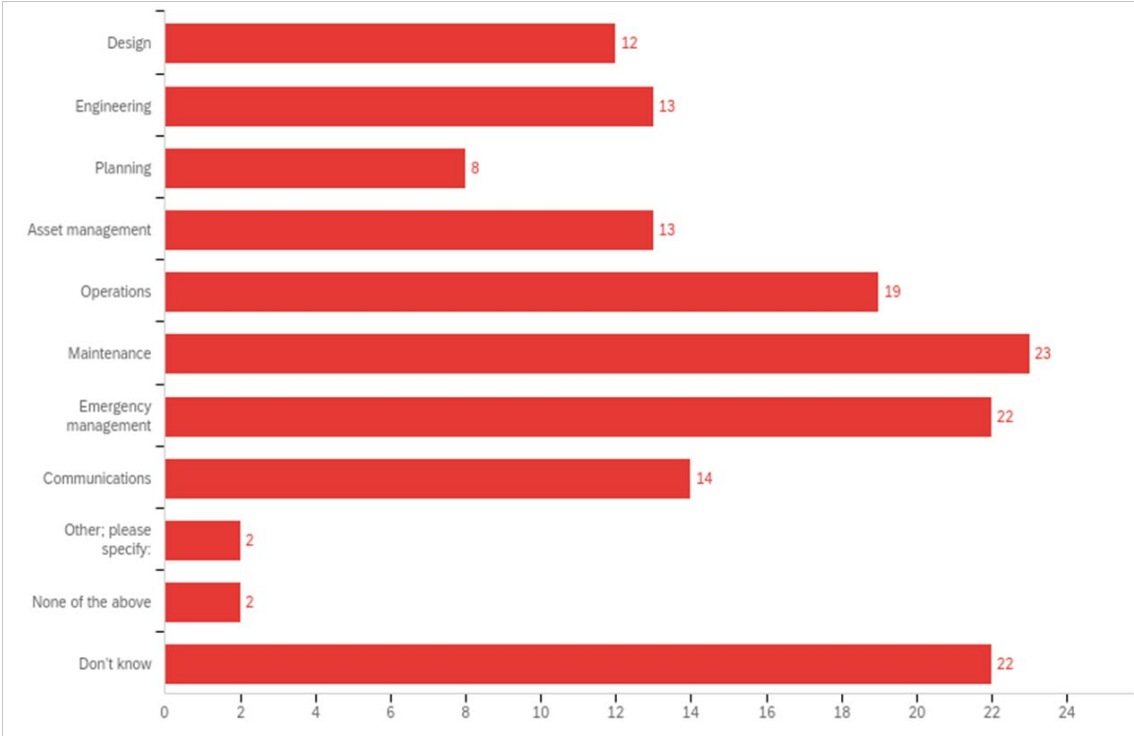


Figure A 5 Areas Where TDOT has Incorporated Resilience Into its Programs

What threats does TDOT include in its vulnerability assessments (select all that apply)?

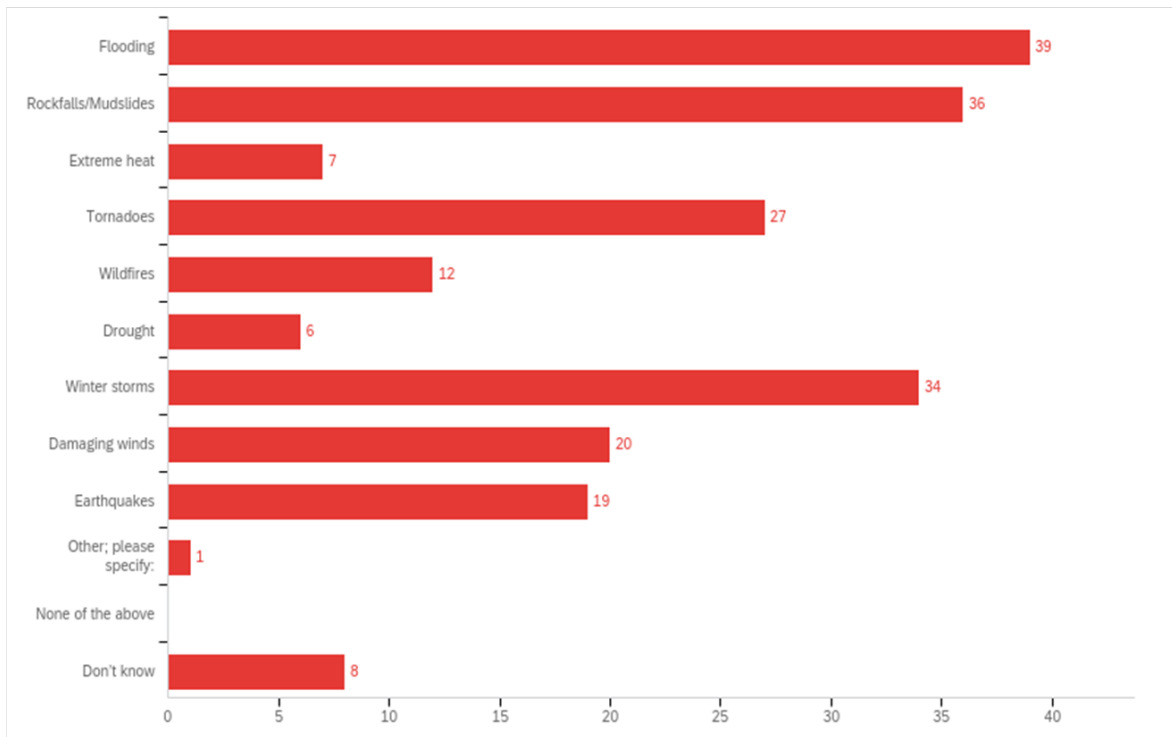


Figure A 6 Natural Hazard Threats TDOT Includes in its Vulnerability Assessments

Has TDOT developed a prioritized list of vulnerable transportation assets?

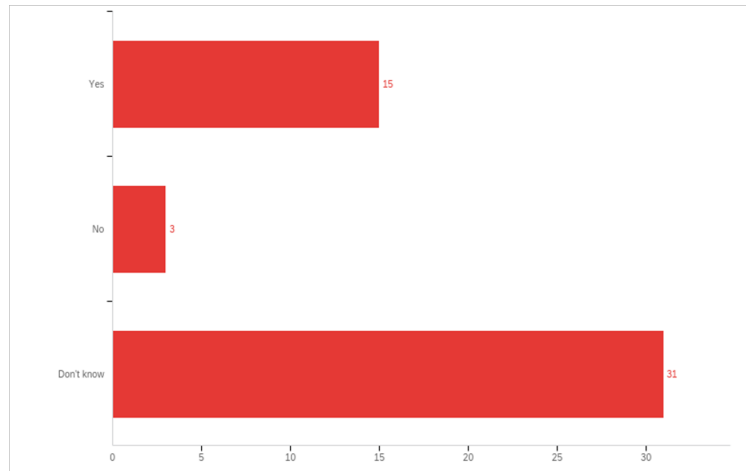


Figure A 7 Extent to Which TDOT has Identified Critical Transportation Assets

At what stage of the transportation planning process is TDOT incorporating resilience concepts (select all that apply)?

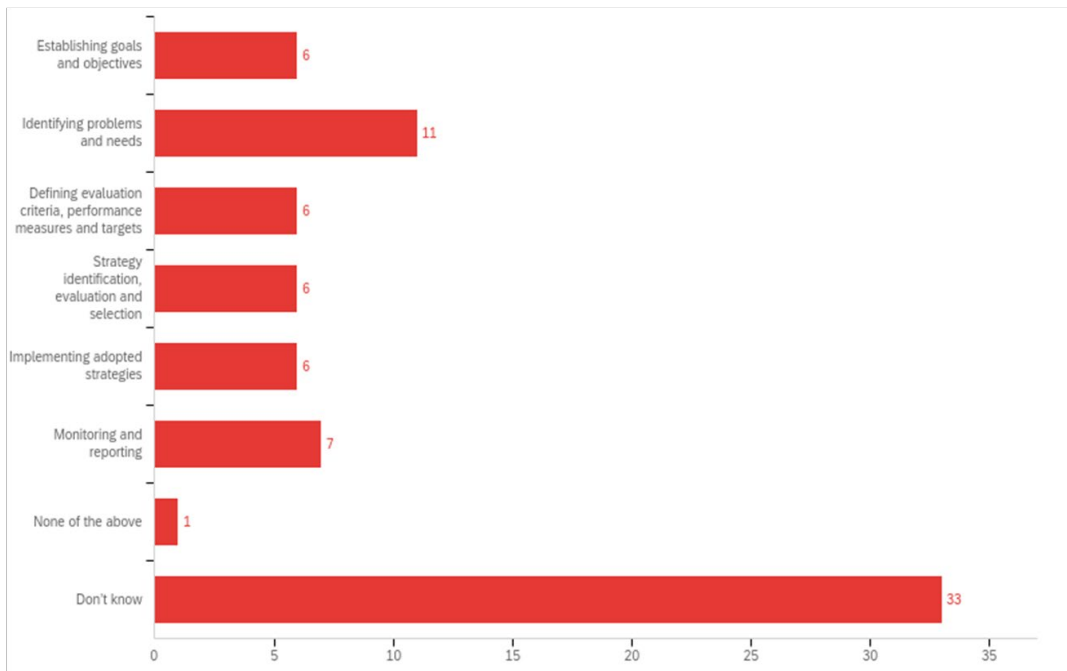


Figure A 8 Planning Process Stages Where TDOT is Utilizing Resilience Concepts

In which of the following is TDOT currently incorporating resilience (select all that apply)?

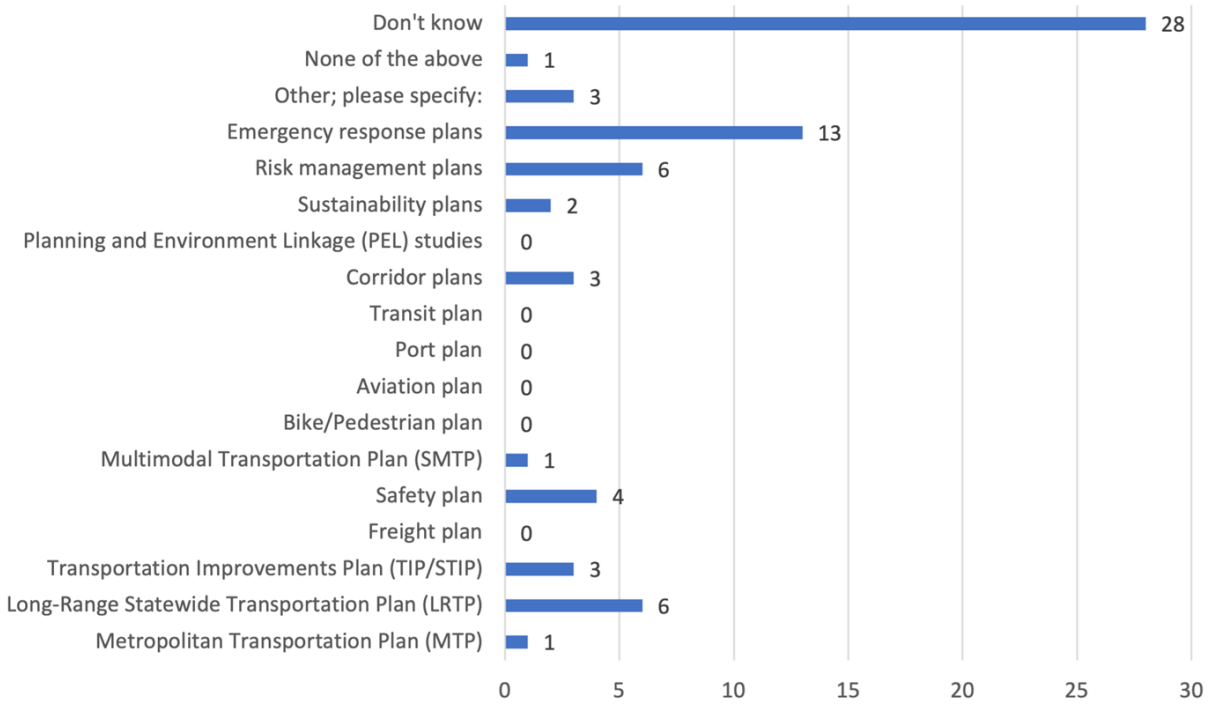


Figure A 9 Planning Activities Where TDOT is Currently Incorporating Resilience

What is the motivation for TDOT to incorporate resilience into its activities (select all that apply)?

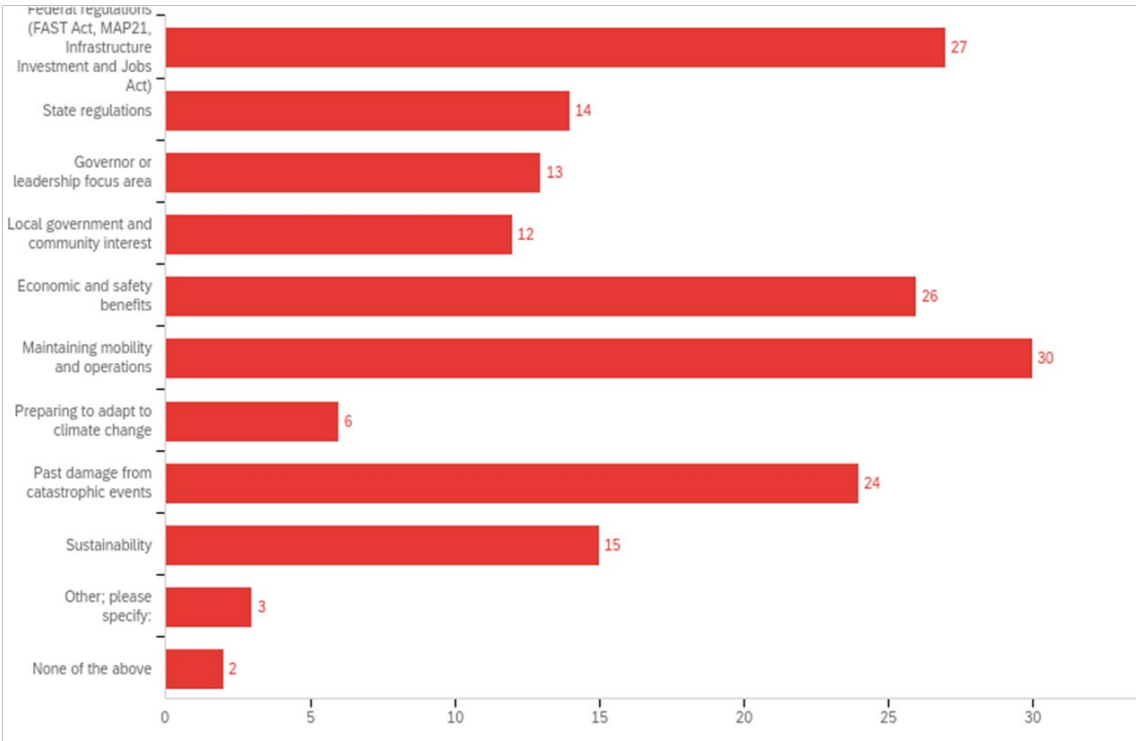


Figure A 10 Reasons Why TDOT Should Incorporate Resilience into its Activities

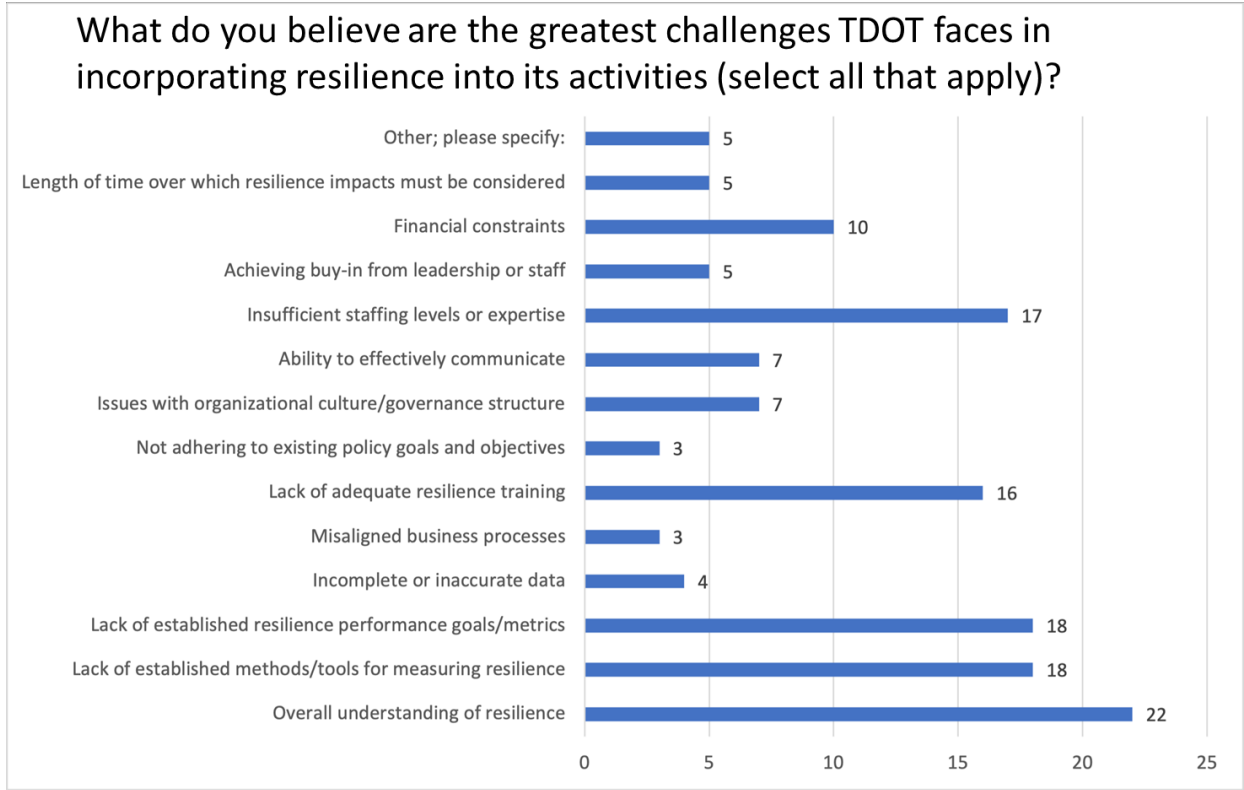


Figure A 11 Greatest Challenges TDOT Faces in Mainstreaming Resilience into its Activities



Figure A 12 TDOT Resilience Training Needs

How does funding uncertainty (federal, short-term extensions, continuing resolutions, etc.) affect TDOT’s ability to integrate resilience concepts and strategies?

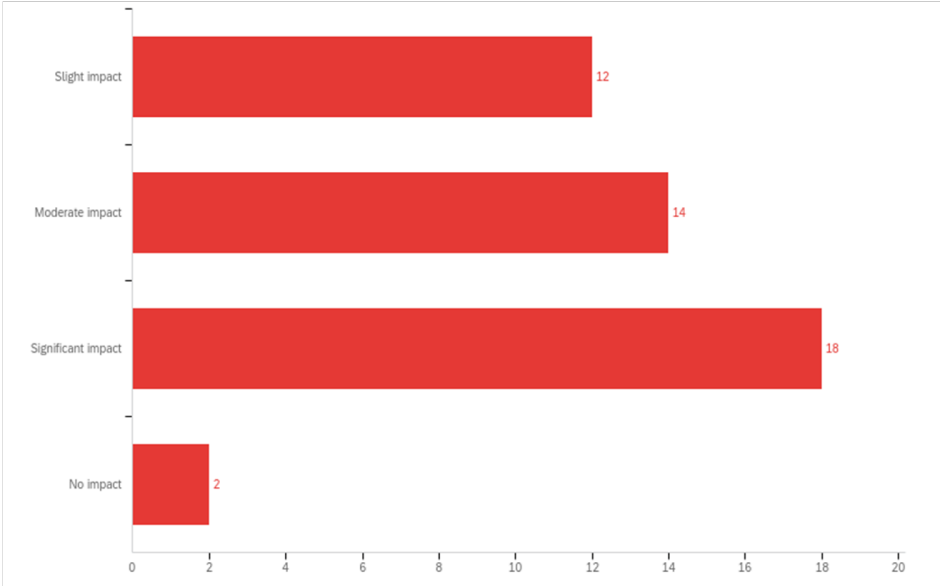


Figure A 13 Effect of Funding Uncertainty on Ability to Utilize Resilience Concepts & Strategies

Does TDOT share information between its divisions to help assess/incorporate resilience?

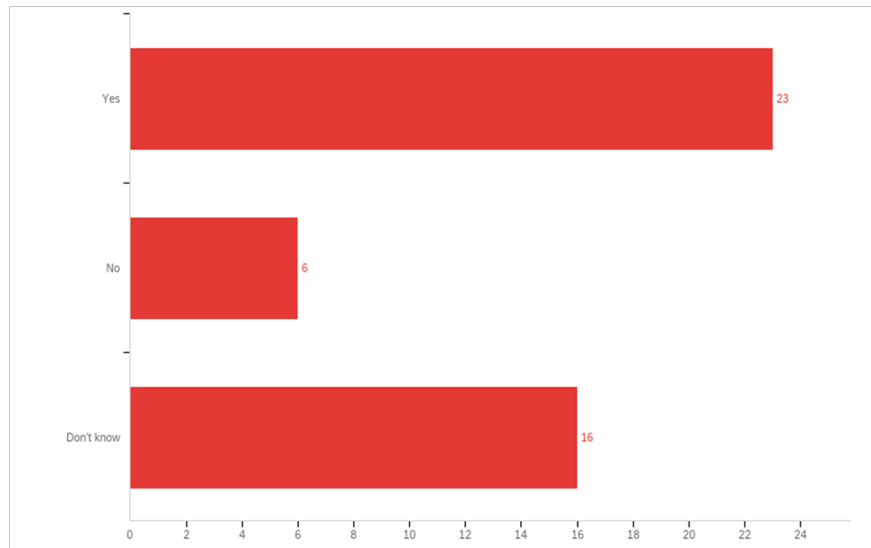


Figure A 14 Level of Internal Communication of Resilience Information

With which other agencies does TDOT share resilience data/strategies (select all that apply)?

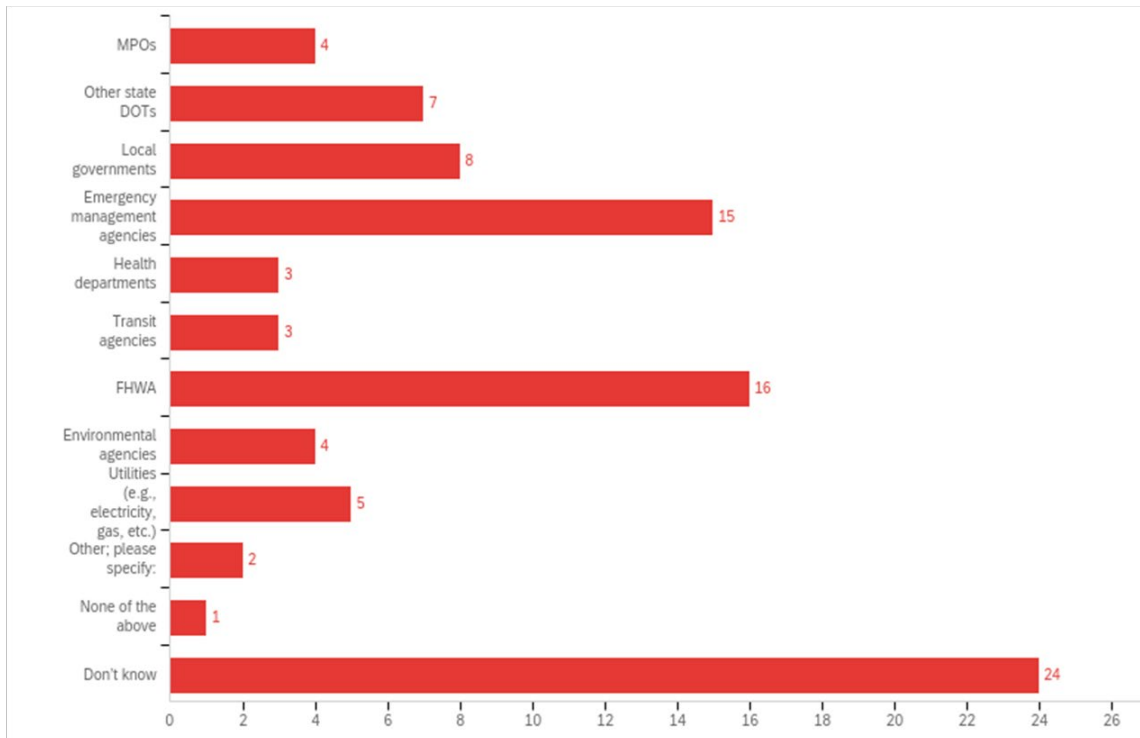


Figure A 15 Level of External Communication of Resilience Information

What do you think is TDOT's overall maturity level for incorporating resilience into its activities?

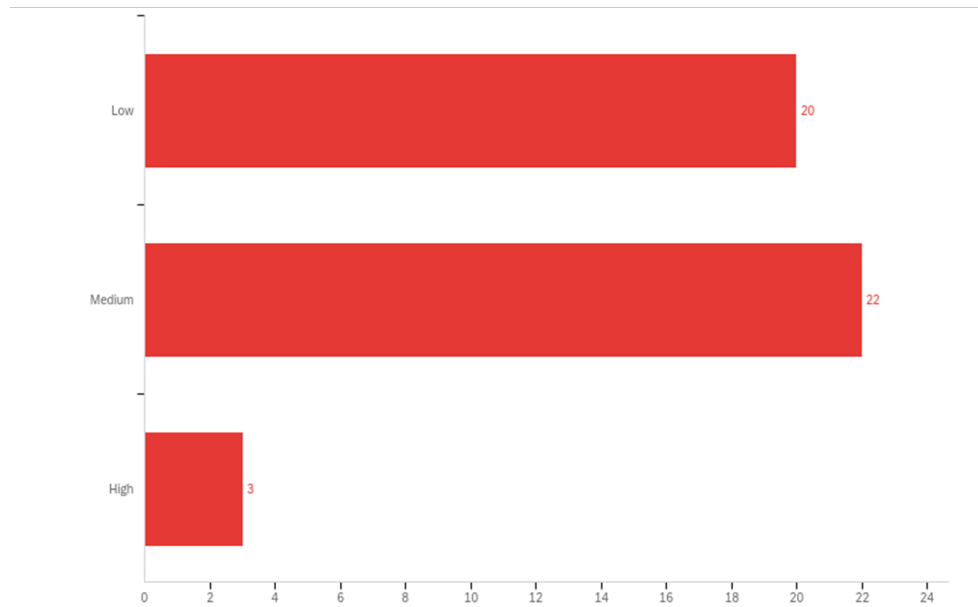


Figure A 16 TDOT's Overall Maturity Level for Incorporating Resilience into its Activities

Appendix B - WORKSHOP PRESENTATION SLIDES

Integrating Extreme Weather & Natural Hazard Resilience into TDOT Policies and Programs



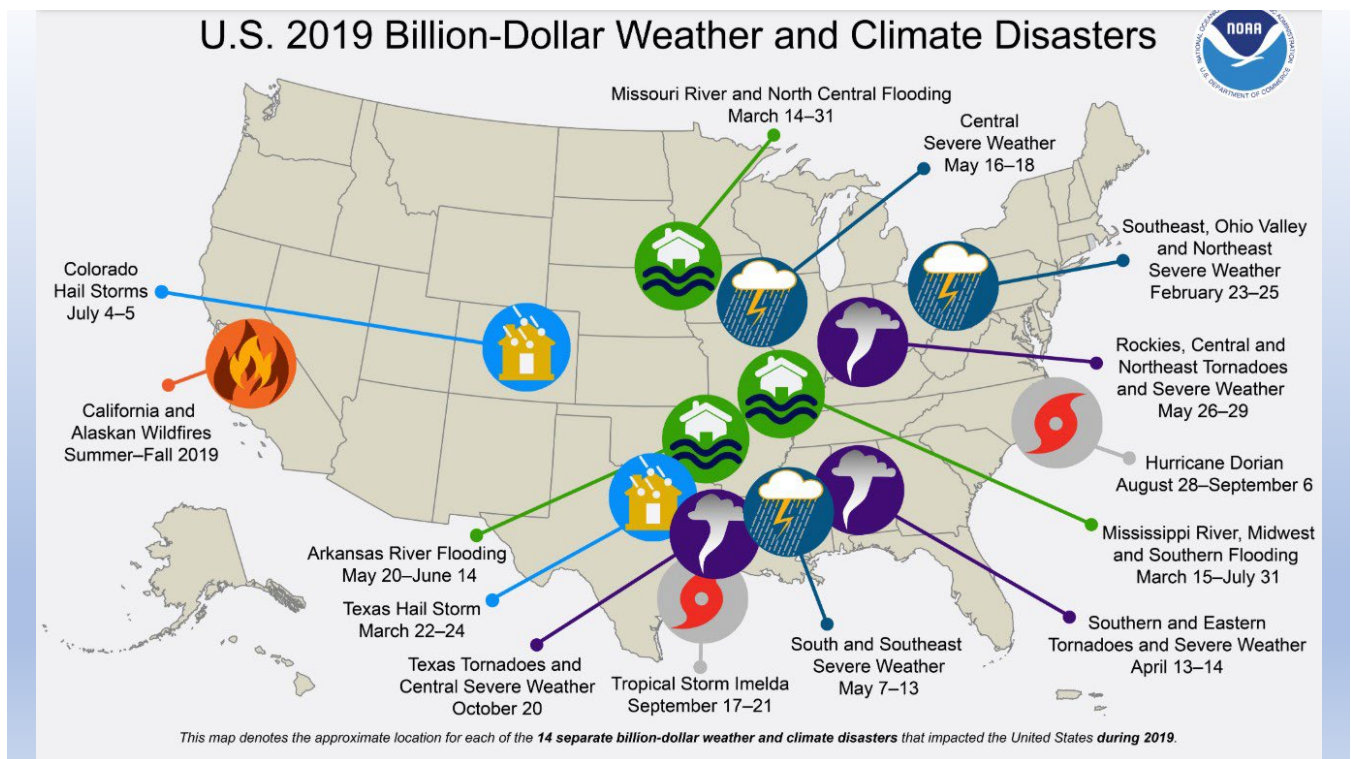
Dr. Mark Abkowitz
Professor of Civil & Environmental Engineering
Vanderbilt University

Mark Abkowitz – Background Information

- Professor of Civil & Environmental Engineering – Vanderbilt University
- Specializes in transportation systems analysis; community and infrastructure resilience; and risk assessment, management and communication.
- Principal investigator on TDOT Extreme Weather Vulnerability Study
- Consultant to Tennessee Advisory Commission on Intergovernmental Relations (TACIR) study on Natural Hazard Community Resilience in Tennessee
- Author of *Operational Risk Management - A Case Study Approach to Effective Planning and Response*
- Chair, TRB Committee on Extreme Weather and Climate Change, Resilience Section

Presentation Outline

- Current and expected extreme weather and natural hazard trends
- Impact on TDOT roles and responsibilities
- Results of TDOT resilience self-assessment
- Integrating extreme weather & natural hazard resilience into TDOT policies and programs
- Next steps
- Questions and discussion



Tennessee Climate Regions



Region Designations

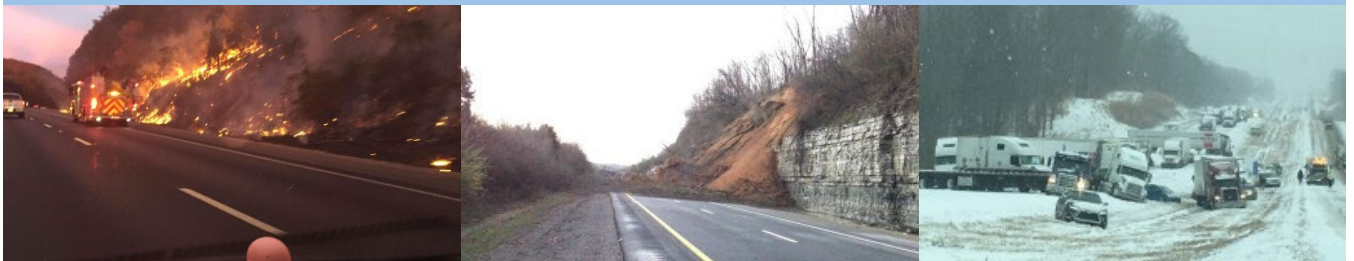
	Cumberland Plateau
	Highland Rim
	Inner Coastal Plain and Alluvial Plain
	Nashville Basin
	Ridge and Valley
	Unaka-Smokey Mountains

Extreme Weather & Natural Hazards in TN

- Damaging Winds
- Drought
- Extreme Heat
- Floods and Flash Floods
- Hail
- Tropical Storms
- Sink Holes
- Landslides and Rockfalls
- Debris Flow
- Thunderstorms and Lightning
- Tornadoes
- Wildfires
- Snow and Ice Storms
- Freeze-Thaw Days
- Earthquakes

Average Annual Natural Hazard Events in TN: 1996-2018

Average Annual Frequency: 1996-2018							
Hazard	Cumberland Plateau	Highland Rim	Inner Coastal & Alluvial Plain	Nashville Basin	Ridge & Valley	Unaka-Smokey Mountains	TOTAL
Cold	0.0	1.8	0.4	0.1	0.1	0.0	2.4
Dry	5.7	21.7	14.0	6.0	1.0	0.5	48.8
Frozen Precipitation	46.8	122.3	88.1	49.0	82.7	38.0	427.0
Heat	0.0	3.7	20.9	0.5	0.2	0.0	25.3
Hydrologic	13.7	47.9	32.5	23.0	24.3	8.6	150.0
Lightning	1.6	5.2	4.3	5.4	1.7	0.3	18.5
Rotational Winds	3.2	15.7	7.4	7.6	5.8	2.2	41.8
Straight Winds	59.4	167.4	81.5	94.8	160.3	54.7	618.1

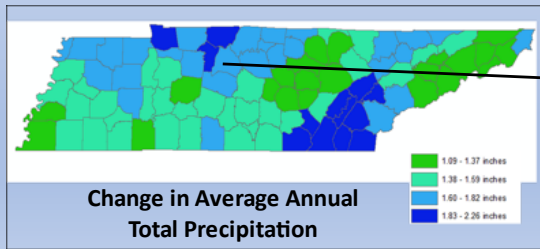
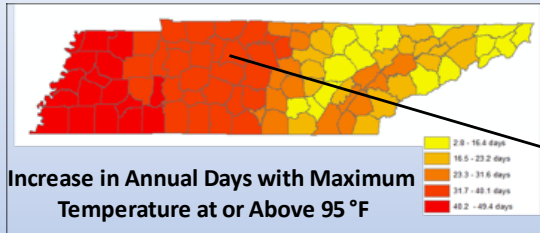


Anticipated Weather and Climate Changes

- Temperatures will rise (min and max)
- Precipitation levels may increase
- Precipitation intensity will increase
- Drought frequency will increase
- Higher wind speeds
- More wildfires



Mid-Century Climate Projections



Nashville Basin - RCP 8.5	Projected (2035-2055)	Change From Observed
Avg. # days above 95°F	43.4	+34.5
Avg. # of days per year below freezing	55.7	-24.9
Avg. # times low temps fluctuate around freezing (freeze-thaw cycle)	41.4	-4.7
Avg. # of "very heavy" (95 th percentile precipitation) events per year	14.0	+2.2

Future Considerations

- U.S. population will continue to grow, mostly in urban areas.
- A more diverse and elderly population.
- Significant growth in residential and business land use.
- Increased population will generate new demand for transportation infrastructure and services.
- Public expectation will continue to be for a quick and efficient transportation system recovery.
- Transportation infrastructure will be facing increasing demands for reconstruction/rehabilitation over the next several decades, *which provides an opportunity to incorporate resilience into these efforts.*

Source: *Climate Change and the Highway System: Impacts and Adaptation Approaches*, NCRHP 2083.

Classifying Transportation System Disruptions

Modes Impacted

- Airports
- Bridges/Tunnels
- Highways
- Ports/Terminals
- Locks/Rivers
- Channels/Harbors
- Rail Line Haul
- Rail Terminals/Stations
- Pipelines

Geographical Scope

- Local
- Regional
- National
- International

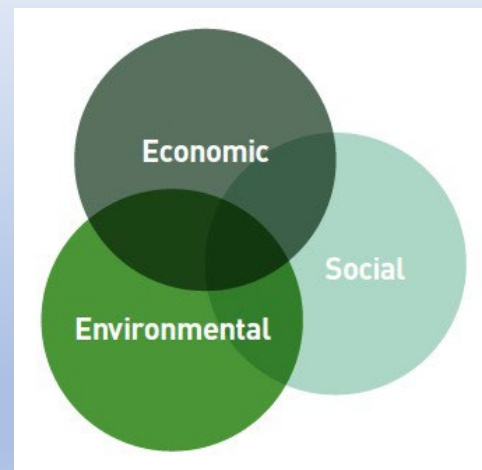
Duration

- Episodic
 - Short-Term
 - Long-Term
- Chronic
 - Slow Onset



How Does This Impact TDOT?

- Road closure and damage
- Bridge deterioration
- Destruction of embankments and slopes
- Diminished mobility
- Supply chain disruption
- Saturation of subgrade
- Illness/injury/death
- Environmental degradation
- Increased maintenance/reconstruction costs
- Litigation from private property owners
- Negative public image



What is Resilience?

“The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions such as significant multi-hazard threats with minimum damage to social wellbeing, the economy and the environment.”



Source: Federal Transit Administration, Emergency Relief Organization Final Rule

Resilience Legislation & Directives

- **FHWA Order 5520** - FHWA shall ensure that its programs, policies, and activities integrate consideration of climate change and extreme weather event impacts and adaptation into its planning, operations, policies and programs... that address risk and promote resilience at both the project and systems levels.
- **Risk-Based Transportation Asset Management Plan (TAMP)**
Each state department of transportation shall develop a risk-based TAMP for its highways and bridges, although states are encouraged to include other infrastructure assets as well.

TDOT Transportation Asset Management Plan (TAMP): Top 2019 Risk Scores

Flood



Rock Slides & Slope Failure

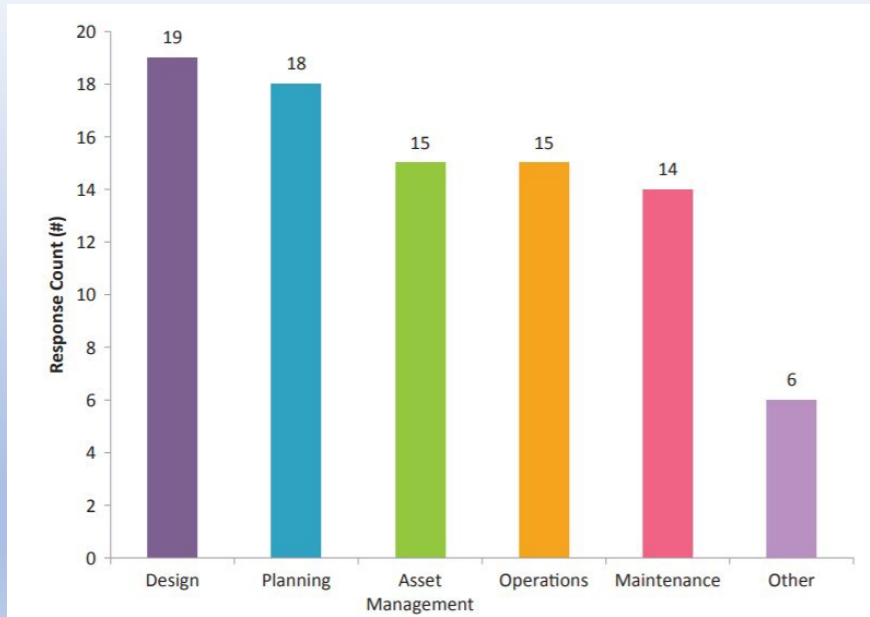


A Resilient Transportation Agency.....

- ...is prepared and positioned to take action, restore services, and build back better or relocate assets where appropriate.
- ...can deter problems and take action before a disruption becomes disastrous.
- ...saves the state money, the public time, and the agency its respect and reputation.

Source: NCHRP 20-59(55) – Transportation System Resilience: CEO Primer and Engagement.

Survey of State DOT Resilience Programs



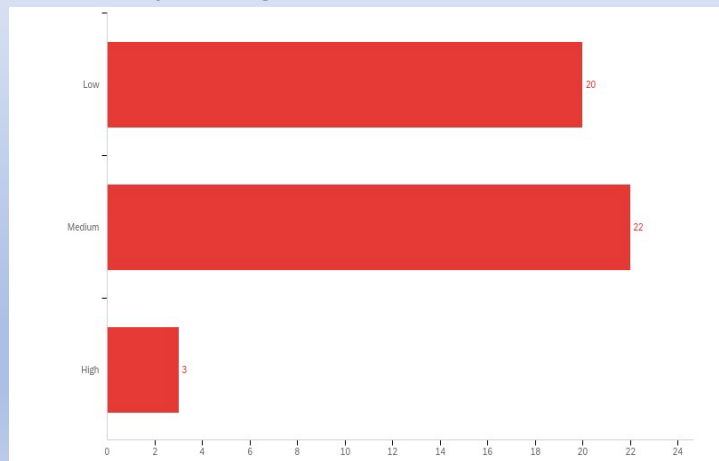
Source: NCHRP Synthesis 527

TDOT Resilience Self-Assessment: Key Findings

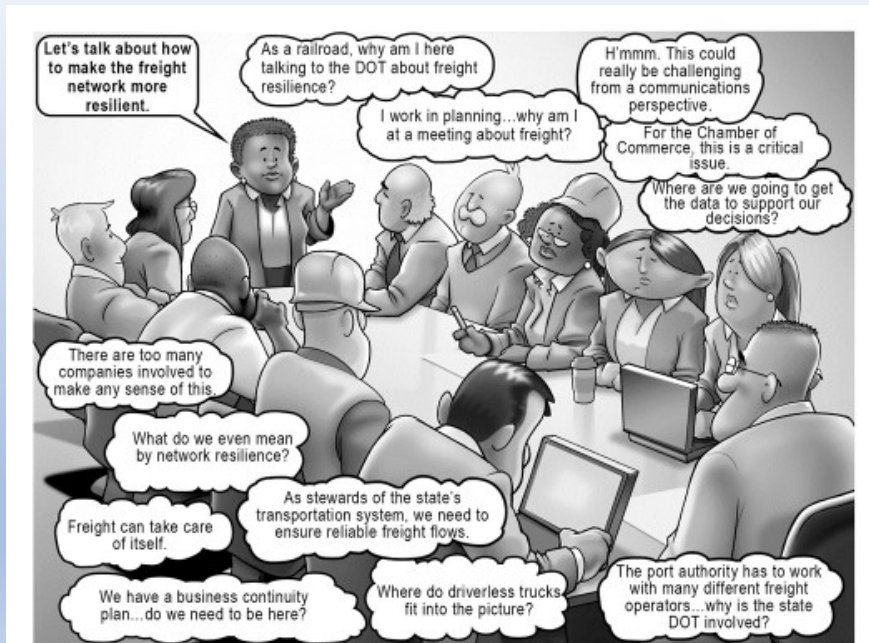
Primary Concerns

- Overall understanding of resilience
- Lack of established resilience performance goals/metrics
- Absence of method/tools for measuring resilience
- Insufficient staffing levels or expertise
- Need for resilience training

TDOT's overall maturity level for incorporating resilience into its activities



Stakeholder Resilience Perspectives



Building a Resilience Culture

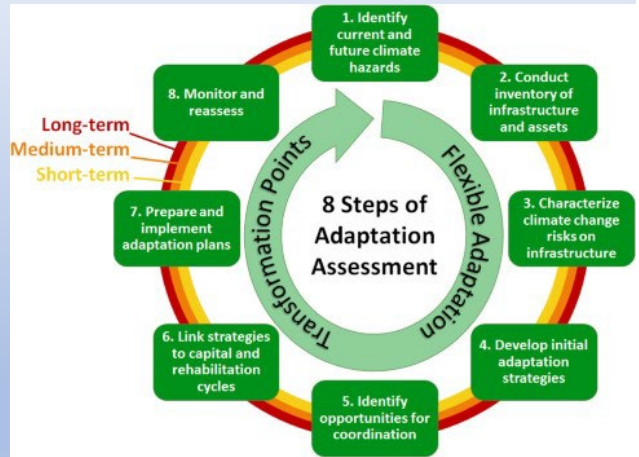
- Promote the importance of resilience within TDOT and to external stakeholders
- Demonstrate commitment to resilience in actions
- Foster preparedness and resilience efforts within and across departments
- Capitalize on resilience theme in agency communications
- Leverage technology through a resilience lens

Source: *Resilience: A DOT Imperative*, NCHRP, 2018.



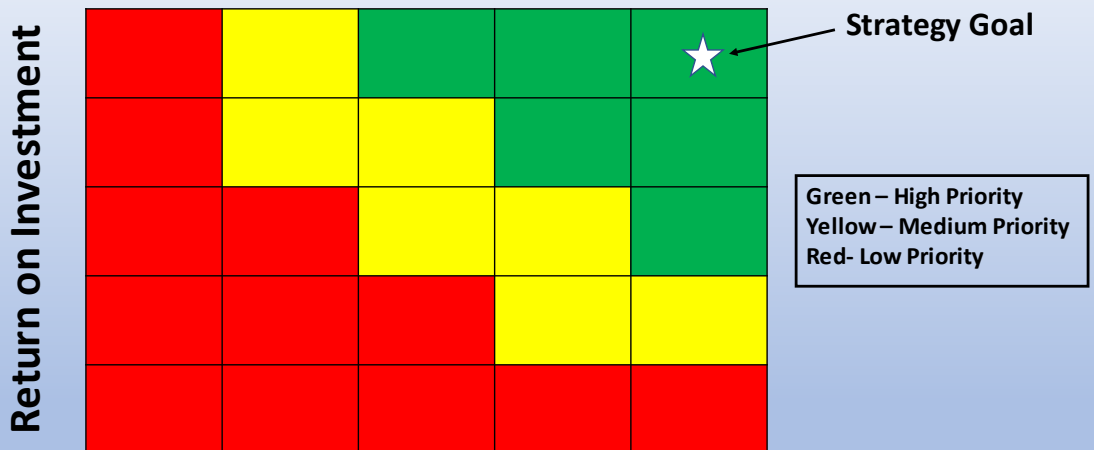
Resilience Planning Steps

- Identify current and future natural hazards
- Conduct inventory of infrastructure and assets
- Characterize risk of natural hazards on infrastructure
- Develop initial adaptation strategies
- Identify opportunities for coordination
- Link strategies to capital and rehabilitation cycles
- Prepare and implement adaptation plans
- Monitor and reassess



Source: New York City Panel on Climate, Adaptation Assessment Guidebook

Resilience Initiative Prioritization Heat Map



Achievability

(available resources, desired time frame, cultural/institutional acceptance)

Benefit/Cost by Hazard and Resilience Action

	Utilities & Transportation Case Studies
Overall Hazard B/C Ratio	4:1
Riverine Flood	8:1
Wind	7:1
Earthquake	3:1
Wildland-Urban Interface Fire	N/A

Source: National Institute of Building Sciences. (2018). Natural Hazard Mitigation Saves: 2018 Interim Report.

Resilience Is Also About Man-Made & Technological Threats

- Hazardous materials incidents
- Power service disruptions
- Financial crises
- Supply chain interruptions
- Cyber attacks
- Public health emergencies
- Structural failures
- Civil unrest



Source: restoreyoureconomy.org

TDOT Next Steps?

- Form an Extreme Weather and Natural Hazards Resilience Task Force
 - Comprised of senior TDOT staff with resilience portfolios
 - Facilitated by Long Range Planning Division
 - Guide/support ongoing engagement within/between TDOT units and with outside partners
- Establish a formal agency resilience policy and program
- Define resilience performance goals/metrics
- Develop and administer resilience training modules
- Identify and utilize best practice methods/tools for evaluating candidate and implemented resilience activities
- Create a resilience information clearinghouse



Questions and Discussion



Mark Abkowitz

mark.abkowitz@vanderbilt.edu

Appendix C – RESILIENCE CLEARINGHOUSE WEB PAGES

[TDOT Resilience Hub](#)

[Home](#) [Tools](#) [Webinars](#) [Workshops & Peer Exchanges](#) [Publications](#) [Regulations and Policy](#) [Related Links](#)

Homepage

TDOT Resilience

Having recognized the present and future effect of extreme weather on transportation resilience within the state, TDOT is embarking on an initiative to instill this knowledge and experience into agency decision-making processes and operating procedures. Part of this process involves the creation of this extreme weather resilience clearinghouse to serve as a knowledge resource for TDOT and its stakeholders.




Figure C 1 TDOT Resilience Home Page

Tools



Data available to perform resilience activities, including a brief description and opportunity to access/download

[European Road Authorities' Climate Risk Assessment Tools: RIMAROCC and ROADAPT Projects](#)

[New York's Expanded USGS StreamStats Tool](#)

[Transportation Climate Change Sensitivity Matrix](#)

[U.S. DOT CMIP Climate Data Processing Tool](#)

[U.S. DOT Vulnerability Assessment Scoring Tool](#)

Figure C 2 Tools Page

Webinars



Prior webinars that have occurred with links to access/download those recordings and presentation material

[FHWA CMIP Climate Data Processing Tool: Using future climate data for more resilient infrastructure design](#)

Figure C 3 Webinars Page

Workshops & Peer Exchanges



Prior workshops and peer exchanges that have occurred with links to access/download those recordings and presentation material

[Climate Resilience and Planning Peer Exchange: Atlanta Regional Commission](#)

[Integrating Extreme Weather & Natural Hazard Resilience into TDOT Policies and Programs](#)

[Resilience and Transportation Planning and Project Development Peer Exchange: U.S. EPA Region 5](#)

[Texas Resilience and Planning Workshop: Summary Report](#)

Figure C 4 Workshops and Peer Exchanges Page

Publications



Relevant reports from within and outside TDOT, with a brief description and opportunity to access/download

Transportation and Resilience Basics

[Climate Change Adaptation for Pavements – FHWA TechBrief](#)

[FHWA Resources for the Asset Management Practitioner](#)

[Fourth National Climate Assessment – Chapter 12: Transportation](#)

[Lessons Learned from Irene: Climate Change, Federal Disaster Relief and Barriers to Adaptive Reconstruction](#)

[Understanding Transportation Resilience: A 2016–2018 Roadmap](#)

[Transportation Resilience 2019 – 2nd International Conference on Resilience to Natural Hazards and Extreme Weather Events](#)

[Transportation System Resilience: Research Roadmap and White Papers](#)

Figure C 5 Publications Page – Transportation and Resilience Basics Selections

Guidelines & Frameworks

[Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance](#)

[FDOT Resilience Quick Guide: Incorporating Resilience in the MPO Long Range Transportation Plan](#)

[FHWA Transportation Engineering Approaches to Climate Resiliency \(TEACR\) Study](#)

[Guidelines to Incorporate the Costs and Benefits of Adaptation Measures in Preparation for Extreme Weather Events and Climate Change](#)

[Highways in the River Environment – Floodplains, Extreme Events, Risk, and Resilience](#)

[Improving the Resilience of Transit Systems Threatened by Natural Disasters, Vol. 1: A Guide](#)

[Incorporating the Costs and Benefits of Adaptation Measures in Preparation for Extreme Weather Events and Climate Change Guidebook](#)

[International Climate Change Adaptation Framework for Road Infrastructure](#)

[Mainstreaming System Resilience Concepts into Transportation Agencies: A Guide](#)

[Massachusetts Port Authority Resiliency Program and Floodproofing Design Guide](#)

[New York City Climate Resiliency Design Guidelines](#)

[The Innovative DOT: A Handbook of Policy and Practice \(Focus Area 7: Integrate Transportation and Land Use Decision-Making – Climate Change Resilience and Long-Range Planning Section\)](#)

[Transportation Research Board \(TRB\) NCHRP: A Pre-Event Recovery Planning Guide for Transportation](#)

[Vulnerability Assessment and Adaptation Framework – Third Edition](#)

[Washington State DOT \(WSDOT\) Guidance for Project-Level Climate Change Evaluation](#)

Figure C 6 Publications Page – Guidelines and Frameworks Selections

Impact Assessment

[Assessing Criticality in Transportation Adaptation Planning](#)

[Assessing the Vulnerability of Tennessee Transportation Assets to Extreme Weather](#)

[Atlanta, Georgia Transit Asset Management System Pilot Project](#)

[Caltrans District Climate Change Vulnerability Assessments](#)

[Central Texas Extreme Weather and Climate Change Vulnerability Assessment of Regional Transportation Infrastructure](#)

[Climate Change Vulnerability Assessment and Adaptation Options Study for Oregon](#)

[Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: The Gulf Coast Study, Phase 2](#)

[Post-Hurricane Sandy Transportation Resilience Study of NY, NJ, and CT](#)

[Potential Impacts of Climate Change on Transportation Infrastructure in New Hampshire](#)

Figure C 7 Publications Page – Impact Assessment Selections

Implementation

[Arizona DOT Resilience Pilot Program](#)

[FTA and Climate Change Adaptation: Synthesis of FTA-Funded Pilots](#)

[Deploying Transportation Resilience Practices in State DOTs](#)

[Freight Transportation Resilience in Response to Supply Chain Disruptions](#)

[Incorporating Resilience into Transportation Planning and Assessment](#)

[Resilience in Transportation Planning, Engineering, Management, Policy, and Administration](#)

[Integrating Resilience into the Transportation Planning Process](#)

[Synthesis of Approaches for Addressing Resilience in Project Development](#)

Figure C 8 Publications Page - Implementation Selections

Strategy & Planning

[California Climate Adaptation Strategy](#)

[California Extreme Heat Adaptation Final Guidance Document –
Transportation Recommendations](#)

[Central New Mexico Climate Change Scenario Planning Project and Long
Range Metropolitan Transportation Plan](#)

[Danish Road Directorate – Blue Spot](#)

[FHWA Synthesis of Approaches for Addressing Resilience in Project
Development](#)

[Hawaii Highways Climate Adaptation Action Plan](#)

[Maryland State Highway Administration Climate Change Adaptation Plan with
Detailed Vulnerability Assessment](#)

[Minnesota DOT Flood Mitigation Program](#)

[North Carolina 2020 Climate Risk Assessment and Resilience Plan](#)

[Sacramento Region Transportation Adaptation Plan and Regional
Transportation Plan](#)

Figure C 9 Publications Page – Strategy & Planning Selections

Federal Policy and Regulations



Federal policy frameworks and regulations

[FHWA Order 5520 – Transportation System Preparedness and Resilience to Climate Change and Extreme Weather Events](#)

[FHWA – Eligibility of Activities to Adapt to Climate Change and Extreme Weather Events Under the Federal-Aid and Federal Lands Highway Program](#)

[FHWA – Resilience and Transportation Planning](#)

[FHWA’s Risk-Based Asset Management Planning Rule](#)

Figure C 10 Federal Policy and Regulations Page

Related Links



Links of other organizations where relevant information may reside

[American Association of State Highway and Transportation Officials \(AASHTO\)](#)

[Data.gov Climate](#)

[Georgetown Climate Center](#)

[NOAA Climate.gov](#)

[Rockefeller Foundation – 100 Resilient Cities](#)

[Transportation and Climate Change Clearinghouse \(TCCC\)](#)

[U.S. Federal Highway Administration](#)

[Vanderbilt Climate Change Initiative](#)

Figure C 11 Related Links Page

References

Federal Highway Administration, *Transportation System Preparedness and Resilience to Climate Change and Extreme Weather Events*, FHWA Order 5520, December 2014.

Gordon Proctor & Associates, *Risk-Based Transportation Asset Management Literature Review*, Report No. FHWA-HIF-12-036, June 2012.

Major, D.C., and M. O'Grady, *Adaptation Assessment Guidebook - New York City Panel on Climate Change*, Ann. New York Acad. Sci., 1196, 229-292, 2010.

National Cooperative Highway Research Program, *Climate Change and the Highway System: Impacts and Adaptation Approaches*, Project No. NCHRP 20-83, August 2013.

National Cooperative Highway Research Program, *Transportation System Resilience: CEO Primer and Engagement*, NCHRP 20-59(55), March 2017.

National Cooperative Highway Research Program, *Resilience in Transportation Planning, Engineering, Management, Policy, and Administration*, Synthesis 527, 2018.

National Institute of Building Sciences, *Natural Hazard Mitigation Saves: Interim Report*, 2018.