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Integrating Natural Hazard Resilience into the Transportation Planning Process

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16. Abstract This handbook provides information on integrating climate change resilience into transportation agencies' transportation planning processes. This handbook is primarily focused on long-range plans and transportation improvement plans, but many of the approaches are applicable to other plans, such as transportation asset management plans and corridor plans, which are also discussed briefly in this handbook. The handbook provides approaches to build resilience to natural disasters, extreme weather events, climate change, mitigation of stormwater, and other natural hazards for each step in the transportation planning process. This handbook is designed to meet agencies where they are and includes a quick start guide to help agencies assess their progress and identify appropriate next steps. For each step in the planning process, the handbook provides examples and resources to assist agencies in identifying resilience challenges and implementing resilience integration actions.		
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FOREWORD: Resilience Improvement Plans

The Bipartisan Infrastructure Law (BIL, Public Law 117-58) established the Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) Program, codified at 23 U.S.C. 176, to help make surface transportation more resilient to natural hazards including climate change, sea level rise, flooding, extreme weather events, and other natural disasters. This forward explores basic components of Resilience Improvement Plans, a key part of the PROTECT program.

What is a Resilience Improvement Plan?

A Resilience Improvement Plan is a voluntary plan that demonstrates a systemic approach to transportation system resilience and includes a risk-based assessment of vulnerabilities of transportation assets and systems to current and future weather events and natural disasters, consistent with 23 U.S.C. 176(e)(2). A Resilience Improvement Plan can be developed by a State Department of Transportation (DOT) or Metropolitan Planning Organization (MPO) for short and long-range planning activities and investments with respect to the resilience of surface transportation within the boundaries of the State or MPO, as applicable.

What are the Benefits of Developing a Resilience Improvement Plan?

Resilience Improvement Plans can improve the resilience and reliability of the transportation system by better incorporating resilience considerations within existing transportation planning and programming processes. Resilience Improvement Plans are an important tool to inform risk-based asset management decisions. Benefits to developing a Resilience Improvement Plan are summarized below:

Figure 1- Benefits to Developing a Resilience Improvement Plan

Benefits to developing a Resilience Improvement Plan	
	Improved system reliability
	Incorporation of resilience into transportation planning and programming activities
	Support for the resilience planning factor
	7% and 3% potential reductions in required non-Federal share match for *PROTECT Formula** and *PROTECT Discretionary Grant Program* projects

**State DOTs are the only eligible entities under the PROTECT Formula Program.*

BIL introduced several incentives tied to Resilience Improvement Plan development within the PROTECT program. A Resilience Improvement Plan developed by a State DOT or MPO can reduce the non-Federal share required for use of PROTECT funding in two ways:

- A 7-percent reduction in the non-Federal share can be applied if a project has been prioritized on the eligible entity's Resilience Improvement Plan. (23 U.S.C. 176(e)(1)(B)(i)).
- A 3-percent reduction in non-Federal share can be applied if the State incorporates the Resilience Improvement Plan into the long-range statewide transportation plan (LRSTP) under 23 U.S.C. 135, or an MPO incorporates the Resilience Improvement Plan into its metropolitan transportation plan (MTP) under 23 U.S.C. 134. (23 U.S.C. 176(e)(1)(B)(i)).

Under the PROTECT Formula Program, the 3-percent and 7-percent reductions only apply to projects in State DOT-developed Resilience Improvement Plans. However, in the PROTECT Discretionary Grant Program, any entity with a funded grant project may use these non-Federal share reductions in cases where the project is located within an area where there is either an MPO or State Resilience Improvement Plan, and the project is prioritized on that plan (for the 7-percent non-Federal share reduction), or the plan has been incorporated into the LRSTP or MTP (for the 3 percent non-Federal share reduction).

Coordination among parties is important. There is no one-size-fits-all approach. For example, a State DOT may choose to incorporate multiple MPO Resilience Improvement Plans into the State Resilience Improvement Plan to strengthen the State plan.

In summary, Resilience Improvement Plans are a tool that States, MPOs, and other entities can use to inform risked-based asset management decisions and the transportation planning process. They also provide additional financial incentives to undertake resilience projects.

Resilience Improvement Plan Requirements

The following Resilience Improvement Plan aspects are detailed in 23 U.S.C. 176(e)(2):

Table 1- Resilience Improvement Plan Requirements

Resilience Improvement Plan Component	**Statutory Requirement** (emphases added)
Timeframe	A Resilience Improvement Plan "shall 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 ..." 23 U.S.C. 176(e)(2)(A).
Geographic Coverage	Shall be for planning activities and investments "**within the boundaries** of the State or metropolitan planning organization, as applicable." 23 U.S.C. 176(e)(2)(A).
Methodology	A Resilience Improvement Plan shall:

	- Demonstrate a "**systemic approach** to surface transportation system resilience and 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)." 23 U.S.C. 176(e)(2)(B). - 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)(C).
Other required components	A Resilience Improvement Plan shall, *as appropriate*: - Include a description of how the plan will improve the ability of the State or metropolitan planning organization to: o "**respond promptly** to the impacts of weather events and natural disasters;" and o "be prepared for changing conditions, such as sea level rise and increased flood risk". - Describe the "**codes, standards, and regulatory framework**, if any, adopted and enforced to ensure resilience improvements within the impacted area of proposed projects" that are included in the plan. - Consider the "benefits of combining hard surface transportation assets, and **natural infrastructure**, through coordinated efforts by the Federal Government and the States." - Assess the "resilience of other **community assets**, including buildings and housing, emergency management assets, and energy, water, and communication infrastructure." - "[I]nclude such other information as the State or metropolitan planning organization considers appropriate." 23 U.S.C. 176(e)(2)(E).

Optional components	A Resilience Improvement Plan *may*: - Designate "**evacuation routes and strategies**, including multimodal facilities, designated with consideration for individuals without access to personal vehicles." - 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." - 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." - 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;" - Use "**science and data** and indicate the source of data and methodologies." 23 U.S.C. 176(e)(2)(D).

For more information on Resilience Improvement Plans, access FHWA's PROTECT website here.

Executive Summary

What is this handbook and how can it help me?

FHWA developed *Integrating Natural Hazard Resilience into the Transportation Planning Process* to help transportation professionals build resilience to natural disasters, extreme weather events, and climate change, and to address the mitigation of stormwater. Natural hazards may threaten lives, property and other assets. Often, natural hazards can be predicted. They tend to occur repeatedly in the same geographical locations because they are related to weather patterns or physical characteristics of an area.[1]

This handbook provides options for improving transportation system resilience by weaving it throughout the long-range transportation planning process. Figure 0-1 shows the major steps of the planning cycle covered in this handbook.

Figure 0-1. The transportation planning process consists of eight major steps that reiterate as a (frequently non-linear) cycle. Stakeholder engagement occurs at every stage of the transportation planning process.

[1] FEMA. (2020). *Are You Ready? – A Citizens Guide to Preparedness*.

Who is the handbook intended for?

This handbook is designed primarily for transportation planners at State departments of transportation (DOTs), metropolitan planning organizations (MPOs), public transportation operators, Federal land management agencies (FLMAs), Tribal governments, and regional transportation planning organizations (RTPOs) or other affected nonmetropolitan local officials with responsibility for transportation.

Why is it important to consider resilience in long-range transportation planning?

Resilience is defined as the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions.[2] Building upon and integrating resilience into existing decision-making processes allows for a more seamless and effective transition to a resilient system than developing a separate stand-alone process. By taking steps to mitigate risks during the planning processes, your agency can protect its investments, reduce maintenance costs, enhance safety, and recover more quickly when disaster strikes.

How do I get started?

Transportation planning agencies (defined in this handbook as State DOTs, MPOs, public transportation operators, FLMAs, Tribal government agencies responsible for transportation planning, and RTPOs) and affected nonmetropolitan local officials with responsibility for transportation can take actions both to reduce risks before an event and to prepare to improve their recovery times after an event. Table 0-1 helps you identify steps to integrate resilience into the planning process and directs you to the most appropriate sections of the handbook for your specific needs. There is something here for everyone – agencies that are very large or very small, those that have already started considering resilience, and those just starting out. In addition, although the handbook is organized linearly based on the steps of

Which strategies should my agency work on and how many do we need to complete?

Your agency can prioritize strategies based on your current capacity to address them, current position in the planning cycle, or internal goals and objectives. The list of strategies is not meant to be exhaustive or prescriptive; different strategies will be applicable and feasible to different agencies.

Just starting: If your agency is new to resilience planning, consider the actions on the left of the list. Especially for small agencies, those strategies can efficiently and effectively help you to consider resilience in planning.

Looking to do more: If your agency has checked off some of the recommended strategies and has the capacity to do more, consider the strategies farther to the right that build on the work you have already done. You can address more strategies across the table with each new planning cycle.

[2] FHWA. (2014). *Order 5520.*

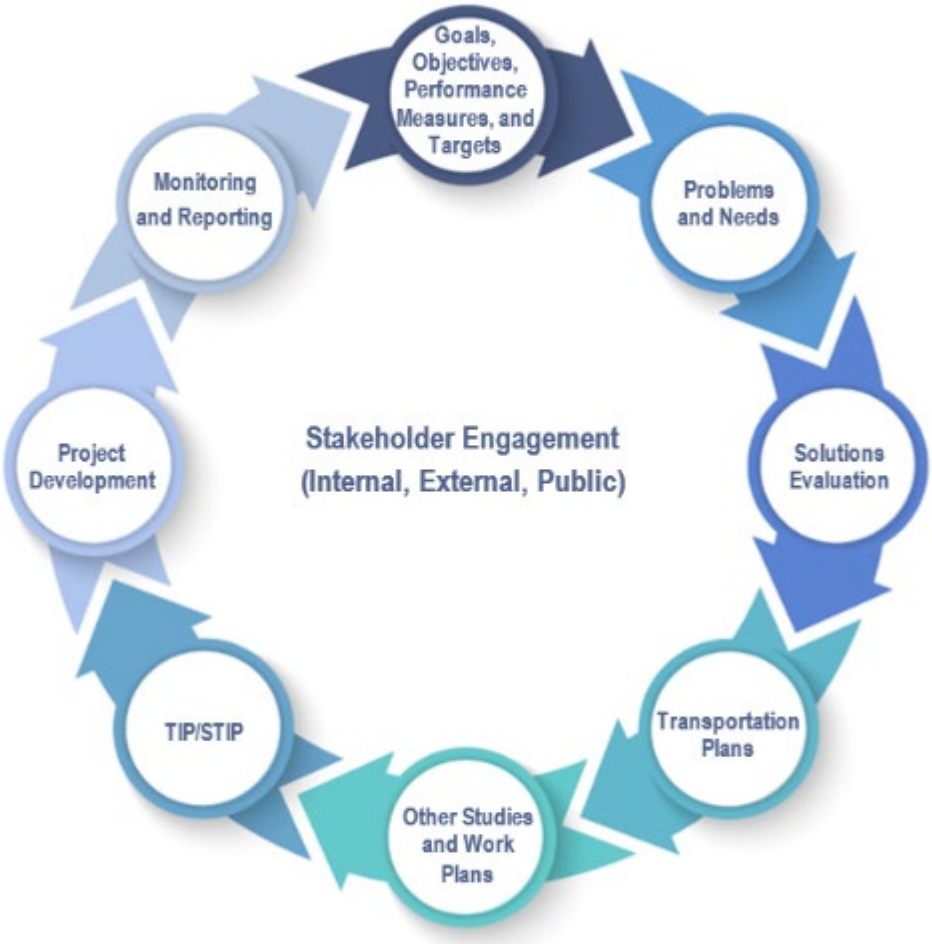
the transportation planning process, your agency can begin integrating resilience at any step in the process.

Table 0-1. Checklist of Potential Resilience Integration Actions

Planning Step	Potential Resilience Integration Actions		
Stakeholder Engagement (Internal, External, Public) (Chapter 2)	☐ Identify a resilience champion (Section 2.1) ☐ Enhance internal communication and build support across disciplines (Section 2.2)	☐ Coordinate with and solicit information from external agencies, institutions, or other stakeholders (Section 2.3)	☐ Communicate effectively with the public (Section 2.4)
Developing Goals, Objectives, Performance Measures, and Targets (Chapter 3)	☐ Determine if natural hazards and climate change will affect existing goals, objectives, performance measures, and targets (Section 3.1)	☐ Develop a resilience goal (Section 3.2) ☐ Develop resilience objectives (Section 3.3)	☐ Develop performance metrics and targets to measure resilience (Section 3.4)
Defining Problems and Needs (Chapter 4)	☐ Identify known risks and vulnerabilities because of natural hazards and climate change through existing studies (Section 4.1)	☐ Conduct a natural hazard exposure screen (Section 4.2)	☐ Conduct a natural hazard vulnerability assessment (Section 4.3)
Evaluating Solutions (Chapter 5)	☐ Add resilience considerations to evaluation criteria (Section 5.1) ☐ Gather relevant resilience strategies identified in existing studies or plans (Section 5.2)	☐ Request resilience ideas in calls for projects (Section 5.3)	☐ Evaluate and prioritize among resilience solutions (Section 5.4)
Developing Transportation Plans (Chapter 6)	☐ Include resilience when establishing priorities and evaluation criteria (Section 6.1)	☐ Identify funding for improving resilience (Section 6.2)	☐ Use scenario planning to increase system resilience (Section 6.3) ☐ Identify vulnerabilities in the preferred scenario (Section 6.4)

Other Studies and Work Plans (Chapter 7)	☐ Integrate resilience into asset management plans (Section 7.4)	☐ Integrate resilience into short-term work plans (Section 7.1) ☐ Integrate resilience into longer term strategic plans or capital improvement plans (Section 7.2)	☐ Integrate resilience into corridor planning studies or other sub-area studies (Section 7.3)
Developing the Statewide Transportation Improvement Program (STIP) and Transportation Improvement Program (TIP) (Chapter 8)	☐ Screen projects to identify facilities repeatedly requiring repair and reconstruction because of emergency events (as consistent with the requirements of 23 CFR part 667) and those facilities at risk of damage from future events (Section 8.2)	☐ Identify funds available for resilience improvements (Section 8.1)	☐ Prioritize projects using one or more resilience evaluation criteria (Section 8.3)
Project Development (Chapter 9)	☐ Build awareness of the need for resilience considerations in project design (Section 9.1)	☐ If appropriate, recommend incorporating resilience into the project purpose and need (Section 9.4) ☐ Discuss resilience at public outreach meetings (Section 9.3)	☐ Recommend natural hazard risk screening as part of project initiation forms (Section 9.2) ☐ Provide relevant planning documentation to streamline environmental review (Section 9.5)
Monitoring and Reporting (Chapter 10)	☐ Track resilience over time (Section 10.1)	☐ Report on performance of resilience measures and progress to policymakers, stakeholders, and the public (Section 10.2)	☐ Use adaptive management to make adjustments to increase resilience (Section 10.3) ☐ Integrate monitoring and reporting results into agency practices (Section 10.4)

Chapter 1
Introduction



Chapter 1 Introduction

Resilience

"The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions" (FHWA, Order 5520, 2014)

A well-functioning transportation system is the lifeblood of our national and local economies, but a vast array of natural disaster events—such as landslides, wildfires, ice storms, and floods—can disrupt the transportation system with little to no warning. Communities are often caught off guard by these disasters. Natural hazards planning considers the potential risks and effects of a natural disaster event so that agencies can implement strategies to increase resiliency. Transportation planning agencies, (defined in this handbook as State DOTs, MPOs, public transportation operators, FLMAs, Tribal government agencies responsible for transportation planning, and RTPOs) and affected nonmetropolitan local officials with responsibility for transportation, can take actions to reduce risks before an event and to prepare and improve their recovery times after an event. This handbook provides options for improving your transportation system's resilience—the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions – by integrating resilience to extreme weather and climate change into your transportation planning process.[3]

1.1 Reasons for integrating resilience into transportation planning

Key Resources for Understanding the Transportation Planning Process

- FHWA's The Transportation Planning Process Briefing Book provides an overview of transportation planning and related resources for those involved in the transportation planning process.
- FHWA's PlanWorks provides resources for every step in the planning process as well as other processes, such as environmental review.

Transportation agencies nationwide are taking action to make themselves and their transportation systems more resilient. By taking steps to mitigate risks during your planning processes, you can protect your investments, reduce maintenance costs, enhance safety, and recover more quickly when disaster strikes.

Every community might be struck by disaster at some point, and resilience preparations can help a community to both withstand and recover from the disaster. Communities nationwide are preparing for and experiencing increases in the frequency and severity of natural hazards, such as flood events and heat waves. Many of the agencies that are now proactively considering resilience began to do so as a reaction to a severe event, such as following a catastrophic storm. These events have spurred agencies to take a proactive approach to prepare for future risks, including

[3] This document uses "metropolitan transportation plan" (MTP) for MPO long-range plans and "long-range statewide transportation plan" (LRSTP) for statewide long-range plans. Specific agencies may refer to their long-range plans by other names, but these terms, which are used in Federal Highway Administration and Federal Transit Administration joint planning regulations at 23 CFR part 450, have been used for clarity and consistency throughout this document.

hurricanes, extreme precipitation, flash flooding, wildfire, droughts, sea level rise, loss of permafrost, and high heat.

Resilient transportation agencies consider short-term and long-term risks and preparations they need to make to prepare for those risks. Preparations for short-term risks might involve scheduling more frequent cleaning of culverts in areas that are currently experiencing flooding during rain events. Preparations for long-term risks may involve updating design methods for bridges that are built within the 100-year flood plain or that may be exposed to sea level rise. Long-term preparations can also involve planning how to respond in the immediate aftermath of a disaster.

Communities expect transportation agencies to keep the transportation system working efficiently day-to-day, and to return the system to full operations as soon as possible after any disruption. Delays in restoring operations can inflict significant damage to the economy by blocking freight movement and customers' and employees' access to work and businesses. Where the disruption is extensive and prolonged enough to significantly limit access to medical care and services, some communities have even seen their mortality rate rise (Kishore, et al., 2018).

Example Long-Range Plan Definition of Resilience

"Resiliency is a risk-based and life-cycle process for addressing the vulnerabilities of critical infrastructure systems, making the system work smarter and better able to adapt to unexpected challenges. Resiliency is not just about a post-disaster capability for rapid recovery. Nor is resiliency only about protecting assets. Resiliency is derived from the fundamental principles of layered defense and risk mitigation. As such, a resiliency framework takes an adaptive life-cycle approach to tackling the dynamic challenges that confront today's complex infrastructure systems. Embedded in it is the capability to protect its assets, anticipate and detect threats, prevent risks of known failures, withstand unanticipated disruptions, and respond and recover rapidly when the worst does happen." (NOACA, 2017a)

Finally, the transportation system represents a significant investment of taxpayer dollars. Agencies have begun integrating resilience into their planning to protect their investments, reduce long-term maintenance costs, and be strategic in their investment decisions.

1.1.1 Federal Requirements and Policy

The 2021 enactment of the Bipartisan Infrastructure Law (BIL, Public Law 117-58) introduced several new programs, new eligibilities under existing programs, and updated references under existing programs to build upon the success of resilience-related provisions from earlier statutes. In 2015, Congress enacted provisions in the FAST Act that directed agencies to consider resilience in their transportation planning processes.[4] The statute and implementing regulations direct transportation agencies to consider resilience in their transportation planning processes, but generally permit agencies

[4] FAST Act, Pub. L. No. 114-94, §§ 1201(6)(A), 1202(2)(A) (2015) (codified at 23 U.S.C. 134(h)(1)(I), 135(d)(1)(I)).

decide how to do that.[5] This handbook provides a toolbox of approaches and options for addressing these requirements.

Bipartisan Infrastructure Law (BIL)

On November 15, 2021, President Biden signed the Infrastructure Investment and Jobs Act (IIJA) (Public Law 117-58, also known as the "Bipartisan Infrastructure Law" (BIL)) into law. The BIL is the largest long-term investment in our infrastructure and economy in our Nation's history. It provides $550 billion over fiscal years 2022 through 2026 in new Federal investment in infrastructure, including in roads, bridges, and mass transit, water infrastructure, resilience, and broadband.

Additional guidance and information about the implementation of the BIL can be found at FHWA's Bipartisan Infrastructure Law webpage. Several new programs, new eligibilities under existing programs, and updated references under existing programs specifically address resilience in the BIL. One notable example of a new program addressing resilience introduced under the BIL is the Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) Program (23 U.S.C. 176), which provides for both formula and discretionary funding for resilient infrastructure.

Table 1-1 on the following page shows the Federal regulations relevant to resilience considerations for State DOTs and MPOs and provides the regulatory source and context in which the regulation applies.

[5] See Table 1-1 on following page.

Table 1-1. Federal Regulations Relevant to Resilience Considerations

Agency	Regulatory Text	Source and Context
State DOT	"(a) Each State shall carry out a continuing, cooperative, and comprehensive statewide transportation planning process that provides for consideration and implementation of projects, strategies, and services that will address the following factors: . . . (9) Improve the resiliency and reliability of the transportation system and reduce or mitigate stormwater impacts of surface transportation"	23 CFR 450.206(a)(9) As a Factor in the 3C (continuing, cooperative, and comprehensive) Planning Process
State DOT	"(c) The long-range statewide transportation plan shall reference, summarize, or contain any applicable short-range planning studies; strategic planning and/or policy studies; transportation needs studies; management systems reports; emergency relief and disaster preparedness plans; and any statements of policies, goals, and objectives on issues . . . that were relevant to the development of the long-range statewide transportation plan."	23 CFR 450.216(c) Long-Range Statewide Transportation Plan
State DOT	667.1 - "Each State, acting through its department of transportation (State DOT), shall conduct statewide evaluations to determine if there are reasonable alternatives to roads, highways, and bridges that have required repair and reconstruction activities on two or more occasions due to emergency events." 667.7 - "(a) Not later than November 23, 2018, the State DOT must complete the statewide evaluation for all NHS roads, highways and bridges. The State DOT shall update the evaluation after every emergency event to the extent needed to add any roads, highways, or bridges subject to this paragraph that were affected by the event. The State DOT shall review and update the entire evaluation at least every 4 years. In establishing its evaluation cycle, the State DOT should consider how the evaluation can best inform the State DOT's preparation of its asset management plan and STIP. (b) Beginning on November 23, 2020, for all roads, highways, and bridges not included in the evaluation prepared under paragraph (a) of this section, the State DOT must prepare an evaluation that conforms with this part for the affected portion of the road, highway, or bridge prior to including any project relating to such facility in its STIP." 667.9 - "(a) The State DOT shall consider the results of an evaluation prepared under this part when	23 CFR 667.1, 667.7(a)-(b), and 667.9(a) Facilities Repeatedly Damaged in Emergency Events Planning, Asset Management Plans, Project Development

	developing projects. State DOTs and metropolitan planning organizations are encouraged to include consideration of the evaluations during the development of transportation plans and programs, including TIPs and STIPs, and during the environmental review process under part 771 of this title."	
State DOT	515.7 – "(b) A State DOT shall establish a process for conducting life-cycle planning for an asset class or asset sub-group at the network level (network to be defined by the State DOT)…the State DOT should include future changes in demand; information on current and future environmental conditions including extreme weather events, climate change, and seismic activity; and other factors that could impact whole of life costs of assets." "(c) A State DOT shall establish a process for developing a risk management plan. This process shall, at a minimum, produce the following information: (1) Identification of risks that can affect condition of NHS pavements and bridges and the performance of the NHS, including risks associated with current and future environmental conditions, such as extreme weather events, climate change, seismic activity, and risks related to recurring damage and costs as identified through the evaluation of facilities repeatedly damaged by emergency events carried out under part 667… (2) An assessment of the identified risks in terms of the likelihood of their occurrence and their impact and consequence if they do occur; (3) An evaluation and prioritization of the identified risks; (4) A mitigation plan for addressing the top priority risks;	23 CFR 515.7(b), (c), and 515.9(h) Transportation Asset Management Plan[6]

[6] BIL amended the requirements for Transportation Asset Management Plans' risk management and lifecycle cost analyses to take into consideration extreme weather and resilience. See 23 U.S.C. 119(e)(4)(D).

	(5) An approach for monitoring the top priority risks; and (6) A summary of the evaluations of facilities repeatedly damaged by emergency events carried out under part 667 of this title that discusses, at a minimum, the results relating to the State's NHS pavements and bridges." 515.9 - "(h) A State DOT shall integrate its asset management plan into its transportation planning processes that lead to the STIP..."	
MPO	"(b) The metropolitan transportation planning process shall be continuous, cooperative, and comprehensive and provide for consideration and implementation of projects, strategies, and services that will address the following factors: . . . (9) Improve the resiliency and reliability of the transportation system and reduce or mitigate stormwater impacts of surface transportation;"	23 CFR 450.306(b)(9) As a Factor in the 3C (continuing, cooperative, and comprehensive) Planning Process
MPO	"(b) In developing metropolitan transportation plans and TIPs, the MPO should consult with agencies and officials responsible for other planning activities within the MPA that are affected by transportation (including State and local planned growth, economic development, tourism, natural disaster risk reduction, environmental protection, airport operations, or freight movements) or coordinate its planning process (to the maximum extent practicable) with such planning activities."	23 CFR 450.316(b) Interested parties, participation and consultation
MPO	"(f) The metropolitan transportation plan shall, at a minimum, include: . . . (7) Assessment of capital investment and other strategies to preserve the existing and projected future metropolitan transportation infrastructure, provide for multimodal capacity increases based on regional priorities and needs, and reduce the vulnerability of the existing transportation infrastructure to natural disasters."	23 CFR 450.324(f)(7) Metropolitan transportation plan contents

Other Federal laws and policies that emphasize the importance of considering resilience, but do not place requirements on State DOTs and MPOs, include:

- Congress established a goal of the National Highway Freight Program to "improve the . . . resiliency of freight transportation in rural and urban areas." (23 U.S.C. 167(b)(2)).
- FHWA's 2014 *Order 5520 Transportation System Preparedness and Resilience to Climate Change and Extreme Weather Events* directs the agency to encourage State DOTs and MPOs to integrate resilience into transportation planning.

- The *USDOT Strategic Plan for FY 2022-2026* commits DOT to "Improve the resilience of at-risk infrastructure."
- 44 CFR part 201 directs all States to prepare and submit to the Federal Emergency Management Agency (FEMA) a State hazard mitigation plan which identifies vulnerabilities, develops long-term strategies for risk reduction, and communicates implementation approaches and priorities. A FEMA approved hazard mitigation plan is a requirement for receiving non-emergency disaster assistance, including funding mitigation projects.[7]
- The Department of Homeland Security's National Infrastructure Protection Plan prioritizes funding efforts where they can have the biggest effect on the Nation's resilience to risk.

1.1.2 State-Level Requirements and Policy

Your State may have its own requirements for integrating resilience into transportation planning processes. Some MPOs cite their State-level executive orders and related guidance as their reason to integrate resilience into system and project planning, investment decisions, and project design. Examples of some of the State-level orders that influence MPOs in that State include the following:

- **California.** In 2008, the Governor of California issued Executive Order S-13-08, directing California agencies to begin considering a range of sea level rise scenarios when planning construction projects in areas vulnerable to rising sea levels. In 2011, Caltrans (the State DOT) issued *Guidance on Incorporating Sea Level Rise: For use in the planning and development of Project Initiation Documents* to help planning staff and project development teams to determine how to proceed.
- **Delaware.** In response to Executive Order 41, issued by the Governor of Delaware in 2013, the State prepared *Avoiding and Minimizing Risk of Flood Damage to State Assets: A Guide for Delaware State Agencies* (2016). This guidance provides step-by-step instructions for avoiding and minimizing flood risk to State assets, including by considering those risks during the planning and design of infrastructure projects.
- **Maryland.** Since 2007, Maryland's governors and legislatures have issued a series of directives ordering State agencies to prepare for potential impacts of climate change. In 2015, the State issued *Climate Change and Coast Smart Construction Infrastructure Siting and Design Guidelines*, (updated in 2020) which includes recommendations for the siting and design of State structures and infrastructure, institutionalizing resilience into State policies and programs, and technical tools and resources.

1.2 Handbook purpose

This handbook provides approaches for integrating natural hazard resilience into your transportation planning processes. Although the handbook focuses on long-range plans and transportation improvement programs, some of the approaches could apply to other plans you develop, such as corridor plans. Building upon and integrating resilience into existing decision-making processes allows

[7] More information on the purpose and requirements of State hazard mitigation planning is available on FEMA's website.

for a more seamless and effective transition to a resilient system than developing a separate stand-alone process.

This handbook is designed to help you develop approaches to improve your system's resilience to natural disasters, extreme weather events, and stormwater that can result from natural hazards and climate change. It does not address security hazards, such as crime, cybersecurity, and terrorism; however, those other threats are also important considerations for the development of a resilient transportation system.

Finally, this handbook is intended to encourage a consistent vernacular on integrating resilience into transportation planning and to facilitate collaboration and coordinated action across agencies and between jurisdictions, which will help increase resilience system-wide. These approaches also offer options for coordinating across different departments within an agency.

Figure 1-1. This handbook is meant to help transportation planners consider resilience to natural hazards, such as this flood, in planning (MnDOT, 2014).

1.3 Handbook audience

This handbook is designed primarily for transportation planning agencies. However, it may also be of interest to others involved in aspects of transportation system design, operation, and maintenance. The transportation planning process offers coordination and consultation with many other aspects of planning, and transportation operations and maintenance that may benefit from resilience considerations. This handbook points out some of these overlaps, such as with transportation asset management plans.

This handbook is also designed to assist agencies of any size (from 1 to 2 people, up to thousands) and with any level of experience with resilience (from beginners to experts). For small agencies or those just starting to address resilience, this handbook will help identify effective practices to get started. For others, this handbook will provide new ideas for further integrating resilience into your work. There is no one-size-fits-all approach to integrate resilience into the transportation planning process—each agency will develop their own path—but this handbook can help illuminate some of the options for moving forward.

1.4 Handbook background

This handbook includes a toolbox of options based on extensive research, including a review of the state of the practice, agency interviews and case studies, and additional research to fill any gaps. Earlier products developed as input to this project include:

- **Integrating Resilience into the Transportation Planning Process: White Paper on Literature Review Findings** (FHWA, 2018a): This white paper provides a baseline level of understanding of how DOTs and MPOs are beginning to integrate resilience into their long-range plans and programming documents. The white paper was based on an online literature review of 52 State DOTs (all States, Puerto Rico, and the District of Columbia) and 101 MPOs to understand how these agencies' long-range plans, transportation improvement programs, and corridor plans include concepts relevant to resilience, such as addressing recurrent flooding issues. The 101 MPOs selected for review represented a variety of sizes, geographic areas and States, and progress toward integrating resilience.
- **Case studies:** Ten case studies highlighting agencies' existing efforts to integrate resilience into their planning processes were developed as input to this handbook based on online research and interviews with agency staff. The case study agencies also represent a range of sizes, geographic areas, and technical capacity:
  - Boston Region MPO
  - California DOT (Caltrans)
  - Colorado DOT
  - Delaware DOT
  - Fayette Raleigh Metropolitan Planning Organization
  - Massachusetts DOT
  - Miami Dade Transportation Planning Organization
  - North Jersey Transportation Planning Agency
  - Northeast Ohio Areawide Coordinating Agency
  - Rockingham Planning Commission

As the research team developed this handbook, they conducted additional research as needed to fill remaining gaps. This research looked at other resources on transportation planning and on resilience planning.

1.5 How to use this handbook

This handbook provides approaches, strategies, and examples of integrating resilience into the transportation planning process. Although each agency's planning process varies, the handbook is organized around a modified version of the eight-step cycle that FHWA often uses to illustrate the transportation planning process. Figure 1-2 shows the major steps, including stakeholder engagement at the center, which occurs at every step of the cycle. Although the handbook is organized linearly based on these steps of the planning cycle, you can begin integrating resilience at any step in the process.

The remainder of this chapter provides a roadmap to the rest of the handbook.

The **Executive Summary** provides a quick start guide to help assess your agency's current level of resilience planning experience. You can identify which resilience integration actions you have already taken, and review the remaining actions for new ideas. Based on the results of this exercise and the remaining actions of interest, you can then go to the most relevant sections of the handbook.

Chapters 2-10 provide options for integrating resilience into each major step of the transportation planning process. The handbook uses the following icon to draw your attention to key content in each chapter:

Key resilience integration action: This handbook will use a star icon to bring your attention to actions that are good starting points for integrating resilience into that step in the planning cycle.

Within each chapter, specific examples from agencies illustrate the actions.

- **Chapter 2** – **Stakeholder engagement.** This chapter focuses on communicating about resilience and working with stakeholders. You can apply these strategies throughout your planning process.
- **Chapter 3** – **Developing goals, objectives, performance measures, and targets**. Find options here for incorporating resilience into the goals and objectives that guide the development of the plans and programs. You can also find options for measuring progress toward achieving those goals and objectives.
- **Chapter 4** – **Defining problems and needs**. This chapter provides options for understanding your transportation system's vulnerabilities to current and future environmental conditions.

  Chapter 5 – **Evaluating solutions.** This chapter provides options for adding resilience considerations to evaluation criteria and identifying, evaluating, and prioritizing among resilience solutions to be included in the long-range plan.
- **Chapter 6** – **Developing transportation plans**. Learn about approaches to incorporate resilience into your transportation plans.
- **Chapter 7** – **Other studies and work plans**. Between the long-range plan and programming, agencies often start scoping out projects. This chapter provides options for integrating resilience into other agency studies and work plans like asset management plans and corridor plans.
- **Chapter 8 – Developing the Statewide Transportation Improvement Program (STIP) and Transportation Improvement Program (TIP)**. The transportation system can only become more resilient if resilience activities influence your investments and programming.
- **Chapter 9** – **Project development.** Look here for ideas on how to make sure resilience ideas developed during the planning process influence the design and implementation of projects.

- **Chapter 10** – **Monitoring and reporting**. See this chapter for ideas on how to track the resilience of your system and how to report on that progress in a way that is useful for influencing future planning cycles.

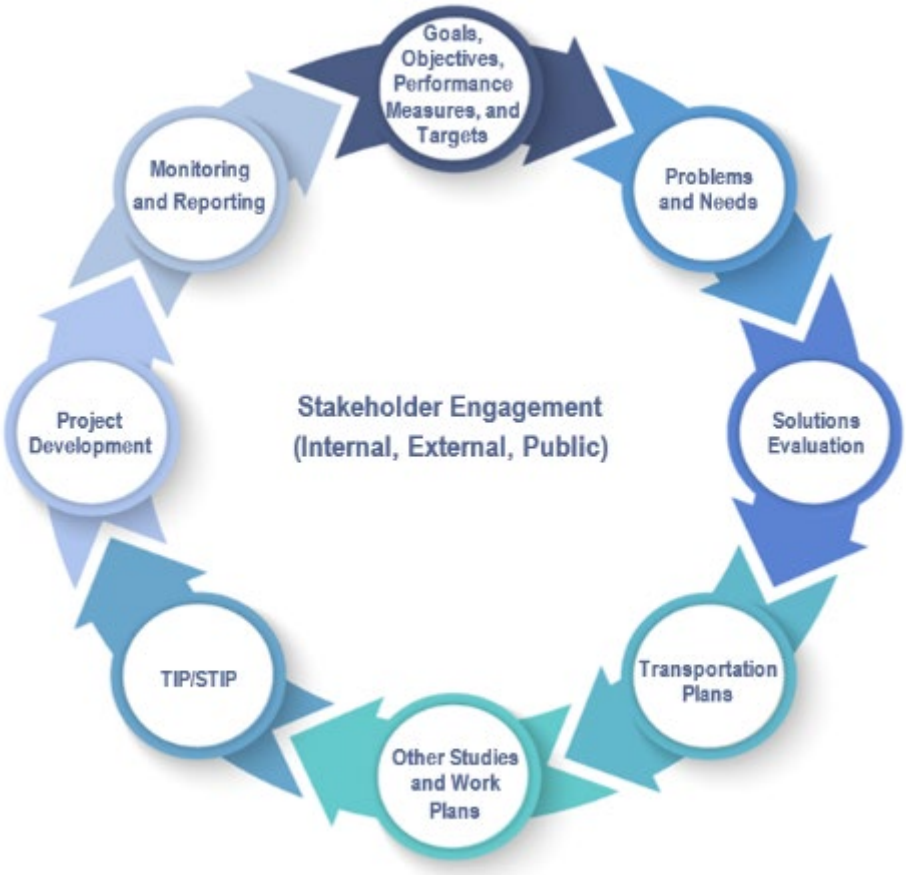


Figure 1-2. The transportation planning process consists of eight major steps that reiterate as a (frequently non-linear) cycle. Stakeholder engagement occurs at every stage of the transportation planning process.

The handbook includes the following appendices:

- **Appendix A: Glossary** provides a glossary of key terms used throughout the handbook.
- **Appendix B: Acronym List** provides a list of acronyms used throughout the handbook.
- **Appendix C**: **Acknowledgements** recognizes those that supported the development of this handbook.

Chapter 2
Stakeholder Engagement

Chapter 2 Stakeholder Engagement (Internal, External, Public)

Engaging stakeholders – whether they are internal or external, including members of the public – can help your planning efforts by providing support, insight, and resources. In many cases, ensuring buy-in from stakeholders is an important component of the success of your efforts. You likely already have connections with existing groups and activities, so starting your engagement with these connections is cost-efficient and shows respect for their time. Figure 2-1 shows possible stakeholders grouped by how closely related they are to your efforts, starting with your department and working out towards the public.

- **Your planning department** may know which groups or staff to consult to identify your system needs and vulnerabilities.
- **Other internal stakeholders and departments** can both benefit from and contribute support to your resilience efforts. Involving other members of your agency in the resilience planning process can raise awareness on resilience issues, educate staff on how resilience can be integrated into their roles, and build capacity across your agency. Gaining broad internal support can help drive resilience efforts forward and ensure they are a priority.

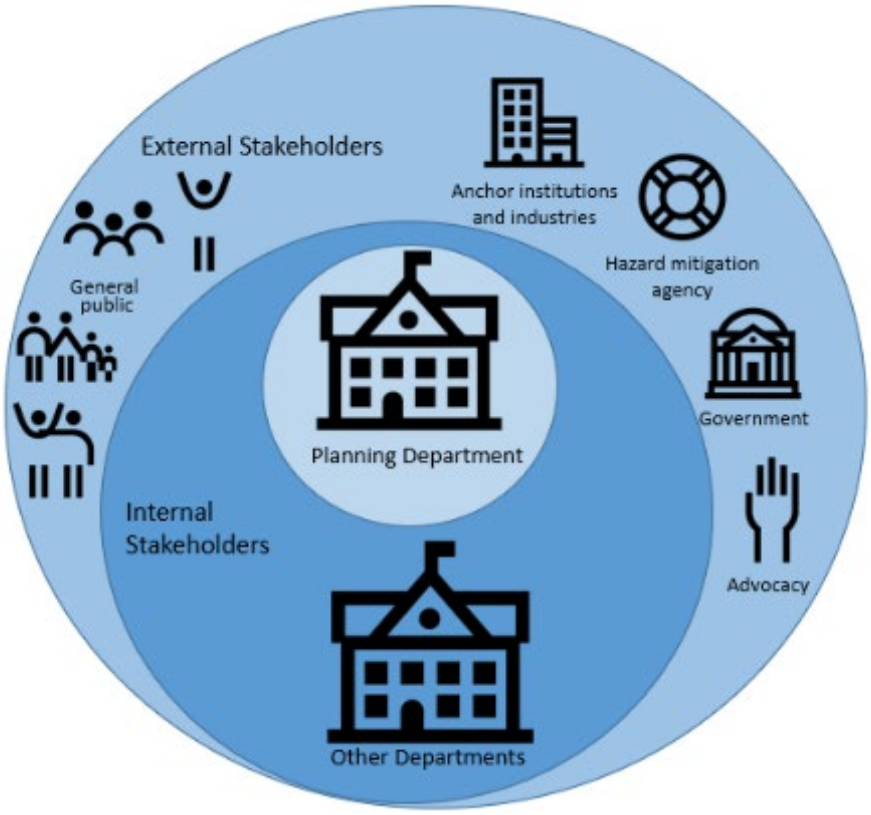


Figure 2-1. Possible stakeholders for engagement.

- Involving **external stakeholders** allows you to tap into the broader context of resilience efforts, gaining lessons learned from others. It can also enhance the capacity of your agency by pooling resources and bringing more people to the table.
- Including **the public** can ensure that their needs and perspectives are being incorporated into your plans. Public outreach efforts can also educate your community members about resilience concerns and why your agency is taking action.

The remainder of this chapter outlines the benefits and types of engagement that you might use for internal, external, and public stakeholders. The proposed strategies can form a general foundation that will help your agency be successful as you proceed through the planning cycle.

2.1 Identify a Resilience Champion

Resilience efforts may be more successful when there is a specific individual or team that rallies support. This is especially true if resilience is a new concern for your agency and has not previously been included in planning efforts or discussions. You can also use existing relationships and lines of communication within your agency to gather support and build a culture of resilience.

You can identify a champion(s) to lead resilience efforts at your transportation planning agency. This designation of a "champion" does not have to result in a formal job title – in many cases, a "champion" is someone already within the department or agency with some knowledge of and interest in resilience. This person can adopt their role as "champion" in addition to their other duties, assuming they have the support of their leadership team. A champion can serve as a voice for resilience efforts, a central resource for all work related to resilience, and a project manager to keep resilience efforts on track.

Who Can Be a Resilience Champion?

Anyone! Examples include:

- Existing teams or individuals who are already involved in resilience work.
- Staff interested in natural hazards, future changes, or adaptation and resilience.
- Department or agency leadership.

You can also make use of existing relationships and communicate the importance of resilience to other departments and agency leadership. The benefits of having support from leadership include increasing buy-in among decision makers, increasing the visibility of your efforts, and having another champion at a higher level of your agency who can communicate directly with leaders in other agencies and departments.

2.2 Enhance internal communication and build support across disciplines

Clear, strong internal communication facilitates coordination efforts and information exchange. As resilience is a relatively new topic in the transportation field, different people may have different definitions or ways of thinking of resilience. Internal communication can help ensure that everyone is on the same page and is supporting a cohesive effort. Internal communication can also educate your staff members on resilience issues and build capacity within your agency.

2.2.1 Whom to engage within your agency

Resilience is a cross-cutting issue and all disciplines have a role to play. The following types of disciplines would likely benefit from and be a resource for resilience planning efforts:

- Communications
- Environment and Stormwater
- Hydraulic Engineers
- Bridge and Other Engineers
- Emergency Operations
- Project Development
- Maintenance and Operations
- Facility Managers
- Sustainability
- Planning

Beyond these disciplines, personnel with experience in grant applications, geographic information systems (GIS), education, and public land and government-owned properties might be able to contribute their expertise to your efforts.

2.2.2 How to engage internally

Using internal communications, trainings, discussion groups, or other methods, you can educate staff members about how resilience fits in to their work and what actions they can take to account for resilience. Internal communication is also important for raising awareness, building capacity, and garnering support. Within your department, you can develop internal communications to convey information about your resilience efforts (e.g., what resilience is, why it is important, and how the agency is working to achieve those initiatives). All of this can be done via existing lines of communication and collaboration.

Engaging Internally via Existing Pathways

You likely already have connections within your agency with those whom you'd like to engage on resilience. Making use of these existing pathways streamlines your efforts and strengthens your connections.

For starters, you can include resilience in existing recurring meetings or committees, send out information on existing newsletters or listservs, and add resilience to existing trainings.

Clearly defining roles and responsibilities can be a component of strong internal communication. Actions that can help to define responsibilities include:

- **Delegating tasks according to expertise**: The actions described in chapters 4-11 require a diverse skillset and will involve collaboration among different parties within your agency and with external parties. Identifying the people or groups that are suited to perform and support these various actions can increase efficiency and effectiveness.
- **Establishing resilience goals, objectives, performance measures, and targets** (as detailed in Chapter 3): Goals and objectives can help ensure that your team members are aligned in their purpose and actions. Performance measures and targets can clearly communicate the results

everyone is working towards and create milestones for the team. The goals and objectives for those working on resilience might be more specific than the high-level long-range plan goals, and this specificity can help give clear direction to staff.

- **Planning for and scheduling collaboration efforts**: Holding space on people's calendars for resilience work can make sure that it remains a priority and that progress continues to be made. This can be done via pre-existing meetings, or if necessary, by establishing new resilience-specific meetings. Regular check-ins can allow team members to share their actions and progress while staying abreast of resilience work being done by others throughout the agency.
- **Setting up committees**: If applicable, you can integrate resilience items into the agendas of existing committees, subcommittees, or ad hoc committees. If not, you can also set up new resilience committees to provide a regular venue for resilience discussions. The champion for resilience (discussed in Section 2.1) can be a voice for resilience in these settings.

2.3 Coordinate with and solicit information from external agencies, institutions, and other stakeholders

Stakeholder input is important at every step of the transportation planning process. External , agencies, and institutions, and other stakeholders can be valuable sources of knowledge and resources. While coordinating outside of your agency may initially take additional effort, it can make overall resilience planning efforts more efficient and effective. Involving stakeholders from outside your agency can help pool resources (e.g., time, knowledge, funding), ensure that everyone's efforts support and learn from one another, and make sure that resilience initiatives across organizations complement each other and are working towards similar goals.

2.3.1 Engaging External Stakeholders

Since MPOs and DOTs do not own, build, operate, or maintain all transportation infrastructure, engaging with external stakeholders is a way to ensure that they are willing to use the results of your planning efforts to influence how they spend their limited time and money on the broader transportation system. Starting with existing lines of communication and collaboration can streamline the engagement process.

To identify potential stakeholders, consider whether other agencies are undertaking resilience work that may influence the status of your own planning. Is someone else implementing resilience measures that will then protect the transportation system? Is there another organization whose systems and assets are likely to experience the same hazards as mine? If the answer is yes, then it could be useful to coordinate with such organizations.

Figure 2-2. New York's Metropolitan Transportation Council working group on freight transportation brought in Metropolitan Resilience Network for a presentation at one of their meetings (NYMTC, 2017).

Examples of groups that may be pursuing resilience work you can seek to coordinate with include: utilities (energy, water, telecommunications), Chief Resilience Officers or similar staff within cities,

universities, local transportation agencies, and hazard mitigation planners/emergency management groups. Table 2-1 includes agencies and organizations in addition to FHWA and FTA and other DOT operating administrations that may be appropriate to coordinate with, grouped by their role in resilience planning. This list is not comprehensive but, rather, a sampling of possible agencies for you to consider. See Section 4.1 for further resources on climate data.

Table 2-1. Possible Organizations for Consultation

Type	Example	Possible Role
Data Providers	Army Corps of Engineers (USACE)	Conduct flood studies, including flood plain management and flood risk management.
	Federal Emergency Management Agency (FEMA)	Provides flood hazard information.
	National Aeronautics and Space Administration (NASA)	Provides general climate science.
	National Oceanic and Atmospheric Administration (NOAA)	Provides detailed past climate data as well as maps, data, and other resources for projected conditions.
	U.S. Geological Survey (USGS)	Provides a variety of data sets, including spatial data for observed and projected conditions.
	U.S. Global Change Research Program (USGCRP)	Sponsors the U.S. Climate Resilience Toolkit, a useful resource for any resilience practitioner. Publishes the National Climate Assessment (2014, 2017-2018, and 2023), with information on a variety of hazards and on specific regions.
Implementation Stakeholders	Federal Land Management Agencies	Undertake resilience planning.
	U.S. Army Corps of Engineers (USACE)	Building climate resilience is part of USACE's Sustainability Mission.
	Counties, cities	Own and maintain infrastructure.
	Silver Jackets (State-led multi-agency collaborative teams focusing on reducing risks from flooding and other natural disasters)	Bring together multiple state, federal, and other agencies to learn from one another in reducing risks from floods and other natural disasters.
Federal Grant Providers	FEMA	FEMA provides Resilience, Hazard Mitigation, and Preparedness Grants.
State Agencies or Organizations	Emergency response	Your State's emergency response organization likely has information, resources, and expertise related to hazards and resilience.

	State climatologists	Almost all states in the U.S. have a State climatologist who can serve as a resource for projects.
	State hazard mitigation planners	Personnel involved in drafting the State hazard mitigation plan will likely have information on key hazards and specific resilience strategies.
Local Government	Evacuation/ emergency planners	As with State-level emergency planners, local-level evacuation and emergency planners are key resilience stakeholders.
	Local hazard mitigation planners	As with the State hazard mitigation plan, staff involved in this effort at the local level can likely provide information and opportunities for coordination on hazards and resilience.
	Land use planners	Land use planners can provide valuable information on how areas may be used in the future.
	Local/county transportation departments, public works, and public transit	These organizations typically own and maintain roads.

2.3.2 How to engage externally

Using pre-existing collaborations such as interagency workgroups or ad hoc lines of communication, you can streamline your engagement efforts with external stakeholders and know that you already have built a relationship with these stakeholders. You can also implement new, resilience-specific lines of communication with external stakeholders where warranted. Engaging externally can expand your resource base, help you coordinate with implementing agencies and transportation asset owners/managers, help you connect with possible funding sources, and allow you to act as a resource.

Some transportation agencies are already participating in interagency workgroups on resilience:

- **Miami-Dade Transportation Planning Organization (TPO)** (FL) is one of many key stakeholders involved in the Southeast Florida Regional Climate Change Compact. The TPO benefits from the pooled resources and expertise of multiple county and regional organizations and the expanded capacity to address resilience issues in Southeast Florida (Southeast Florida Regional Climate Change Compact, 2018).
- **Massachusetts DOT (MassDOT)** is an ex-officio member of Massachusetts's Commission on the Future of Transportation in the Commonwealth. The commission brings agencies to the table that would not typically be involved in transportation planning, furthering resilience efforts by incorporating unique perspectives. (Commission, 2018)

Coordinating with and soliciting information from external stakeholders can also be done outside of a formal committee and on an as-needed basis. For example, in conducting their *Extreme Weather At-Risk Roadway System Analysis* (FRMPO, 2016), the Fayette Raleigh Metropolitan Planning Organization (WV) asked representatives of local jurisdictions to identify flood-prone transportation assets that GIS analyses might miss.

In addition, you might work with local agencies (such as cities) to fund resilience work. It's possible that these local agencies already have funds (or are expecting funds) for resilience work, or have knowledge of available grants.

You can also serve as a resource to your external stakeholders. It will likely benefit the community at large if you share the results of your resilience work. The knowledge you gather can inform further resilience efforts and help to align practices throughout your region.

PlanWorks

Resilience is a concern for planners across a variety of sectors. Coordinated planning can help achieve common goals across various planning efforts (e.g., hazard mitigation planning).

PlanWorks is a decision-support and web resource from FHWA that helps local practitioners more effectively collaborate and create plans (FHWA, 2015c). The tool can help your agency pinpoint how to engage with stakeholders at various decision points within the transportation planning process.

2.4 Communicate effectively with the public

Communicating effectively with the public is important both for building support for your resilience efforts as well as for gaining valuable community input. Public input can be useful throughout the transportation planning process. For example, community members can make their priorities known to help develop goals and objectives and evaluate solutions, and can help identify concerns to define problems and needs. You can also use your resilience planning as an opportunity to increase awareness of resilience in your community. Your agency is likely already pursuing public outreach, so resilience can easily be integrated into this facet of engagement.

2.4.1 Whom to engage in the public

Under the Statewide and Nonmetropolitan Transportation Planning and Metropolitan Transportation Planning processes, States are required to have a public involvement process and MPOs are required to develop Public Participation Plans (PPPs), part of which entails discussing how they will reach out to communities traditionally underserved by existing transportation systems. [8] Since these plans are already in place and States and MPOs are already engaging with a wide swath of the population, agencies can take advantage of these existing outreach strategies and integrate resilience into the messaging and conversation at pre-planned public engagement events.

[8] See 23 CFR 450.210(a) and 450.316(a). For provisions regarding a process for seeking out and considering the needs of communities traditionally underserved by existing transportation systems, see 23 CFR 450.210(a)(1)(viii) and 23 CFR 450.316(a)(1)(vii). See also Executive Order 12898 "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations" and title VI of the Civil Rights Act of 1964.

2.4.2 How to engage with the public

Transportation agencies can engage with community members in a variety of ways, some of which your agency may already be implementing. You can also tailor communication initiatives to your resilience needs. There are several community engagement strategies, including virtual public involvement, that make use of project visualization techniques, virtual meetings, mobile applications, web-based polling, games, art, or other creative ideas to encourage interaction and participation. FHWA has further resources on their Public Involvement web page for transportation planners.

2.5 Recap of approaches to considering resilience while engaging stakeholders

This chapter presented four core approaches to considering resilience while conducting stakeholder engagement (see Table 2-2). The approaches include strategies for building a culture of resilience within your own agency and engaging with internal and external stakeholders as well as the public. Many of these approaches are likely already being practiced by your agency, so integrating resilience into engagement may be a relatively low-effort process.

Why Consider Resilience When Engaging Stakeholders?

By including resilience in stakeholder engagement, your agency can raise awareness of resilience concerns while building support and expanding your network of resilience partners.

Table 2-2. Stakeholder Engagement Recap

Integration Action	Key Action?	Potential Approaches
Identify a resilience champion	✓	▪ Build a culture of resilience. ▪ Garner support from leadership.
Enhance internal communication and build support across disciplines	✓	▪ Delegate tasks according to expertise. ▪ Establish resilience goals, objectives, performance measures, and targets. ▪ Plan for and schedule collaboration efforts. ▪ Set up committees.
Coordinate with and solicit information from external stakeholders, agencies, or institutions		▪ Establish formal avenues of coordination (e.g., interagency workgroups). ▪ Utilize ad hoc avenues of coordination. ▪ Serve as a resource to external stakeholders.

Communicate effectively with the public		▪ Use avenues already in place in your agency. ▪ Pursue creative engagement strategies and educational efforts. ▪ Ensure meaningful involvement of underserved populations.

Chapter 3
Developing Goals, Objectives, Performance Measures, and Targets

Chapter 3 Developing Goals, Objectives, Performance Measures, and Targets

Goals and objectives help set the tone and strategic direction for the rest of the planning process, as all other actions in the planning cycle can build on this step. You can then use performance measures and targets to track and measure progress on achieving goals and objectives. Public and stakeholder engagement is critical to developing goals and objectives that address the values and priorities of your agency's jurisdiction. Engagement is also important for identifying existing and future challenges that your agency may need to address.

Importance and benefits of integrating resilience: Integrating resilience into goals, objectives, or performance measures and targets can help your agency prioritize and track resilience actions throughout the other steps of the planning cycle and make clear to staff, stakeholders, and the public that resilience is important. Many transportation planning agencies integrate resilience into their goals and objectives to (FHWA, 2018a):

- Ensure resilience is considered throughout the planning process.
- Prioritize resilience alongside other key considerations.
- Justify investments in resilience.
- Improve system performance in the face of natural hazards and climate change.

The following sub-steps provide opportunities for resilience:

- **Review existing goals, objectives, performance measures, and targets** – This step provides an opportunity to reflect on your previous goals, objectives, performance measures, and targets and gather new data and input on priorities from staff, stakeholders, and the public. As part of this process, your agency can assess whether natural hazards and climate change will affect the ability to meet your goals, objectives, performance measures, and targets.
- **Establish goals** – Goals serve as the foundation of the transportation planning process and influence actions throughout the planning cycle. Your agency can consider revising existing goals or developing new goals to account for resilience.
- **Establish objectives** – Objectives build on and support the achievement of big-picture goals and influence the development of performance measures (FHWA, 2013a). Your agency can consider revising existing objectives or developing new objectives to account for resilience to help your agency prioritize resilience-related goals.
- **Establish performance measures and targets** – Performance measures and targets are designed to measure progress on goals and objectives to assess the implementation of projects and strategies. As a result, these metrics aid decision making regarding investments and management and can also inform the next planning cycle.

Figure 3-1 illustrates the key steps and possible resilience integration actions for developing goals, objectives, and performance measures. The following sections provide detailed information about each resilience integration action, including resources and tools.

Developing Goals, Objectives, Performance Measures, and Targets

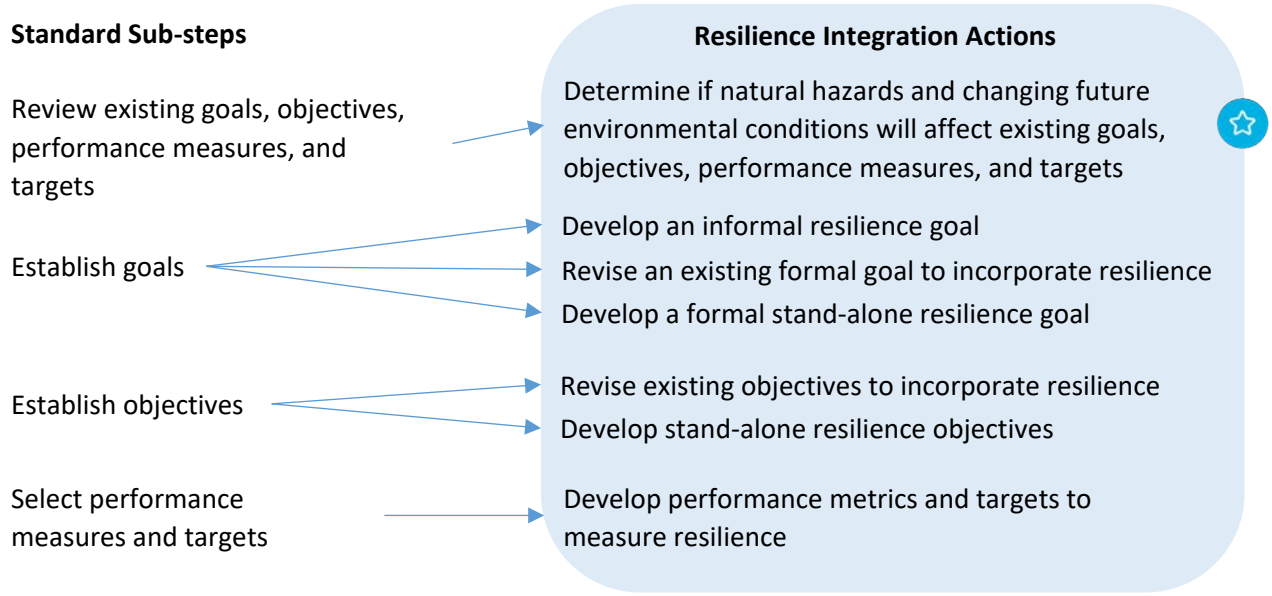


Figure 3-1. Key steps and resilience integration actions for developing goals, objectives, performance measures, and targets.

3.1 Determine if natural hazards and climate change will affect existing goals, objectives, performance measures, and targets

Determining if natural hazards and climate change will affect existing goals, objectives, performance measures, and targets is a key resilience integration action. Before establishing goals, objectives, performance measures, and targets for this planning cycle, reflect on whether natural hazards and climate change will affect your agency's ability to meet current ones. For example, your reliability, safety, and state-of-good-repair goals might be more challenging to achieve as a result of natural hazard and climate change impacts, including:

- Loss of roadway capacity.
- Loss of alternative routes.
- Loss of situational awareness (because of power/communications outages).
- Inability to evacuate.

- Loss of service life (because of faster deterioration).
- Increased safety risk.
- Loss of economic productivity.
- Reduced mobility.

To facilitate the review of existing goals, objectives, performance measures, and targets, your agency first needs to develop a baseline understanding of local hazards. Natural hazards and climate change impacts are not geographically uniform; therefore, identify what hazards exist (or are projected to exist in the future) for your system. See the textbox for potential sources to help you gather and use relevant data.

Key Resources for Understanding Natural Hazards and Climate Change

- Chapter 4 of FHWA's Vulnerability Assessment and Adaptation Framework for information on obtaining climate data.
- Chapter 4 of Synthesis of Approaches for Addressing Resilience in Project Development for information on collecting and using climate data.
- National Oceanic and Atmospheric Administration (NOAA) Climate Maps and Data for historical and current temperature and precipitation data and trends, including extreme events.
- NOAA Tides and Currents for historical and current local water level and tidal gauge data as well as sea level rise predictions.

In addition, local resources and institutions (i.e., State/local governments, non-governmental organizations (NGOs), universities) may be especially useful for gathering localized information and data. Your agency may also choose to conduct a needs assessment (see textbox) or vulnerability assessment (see Chapter 4) to develop a more robust understanding of your transportation system's vulnerabilities and risks to natural hazards and climate change.

Using the information gathered, determine the key risks and how the hazards may affect your ability to meet existing goals and objectives, considering the following questions modified from FHWA's *Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance* (FHWA, 2015a):

Example of Utilizing a Needs Assessment

For each four-year MTP planning cycle, the Boston Region MPO conducts a needs assessment to evaluate new data from a variety of sources and revisit its goals and objectives. The2015 needs assessment identified transportation infrastructure in hazard areas and emphasized the need for system preservation, which the MPO then made a focus of its goals and objectives (Boston Region MPO, 2015b).

- Do these risks have a direct effect on the ability to meet your goals and objectives? Performance measures and targets?
- Do these risks affect the underlying assumptions upon which your goals, objectives, performance measures, and targets are founded?
- Are these risks likely to change during the time horizon of your existing goals, objectives, performance measures, and targets? Should your existing goals, objectives, performance measures, and targets be modified to account for these changes?
- Are there any specific thresholds for these risks at which decision making becomes sensitive that could be considered in your goals, objectives, performance measures, and targets?

Understanding these impacts will inform your agency's approach to continuing to meet existing goals, objectives, and targets or lead to the development of new or modified goals, objectives, and targets.

The remainder of this chapter explores integrating resilience into your goals, objectives, performance measures, and targets to address natural hazards and climate change.

3.2 Develop a resilience goal

A goal is defined as a broad, outcome-oriented statement that describes a desired end state and reflects both agency and community priorities (FHWA, 2013a). Revising existing goals or developing new performance-based or outcome-driven resilience goals (see textbox) will help your agency prioritize resilience throughout the other steps of the planning cycle.

In the early stages of goal development, determine whether a resilience-related or focused goal is appropriate for your agency in the context of the current and future natural hazards and climate data gathered in Section 3.1. Gather a wide array of inputs from transportation planners, community leaders, citizens, environmental specialists, landscape architects, resource agencies, public works officials, design engineers, and elected officials to discuss whether resilience is a priority for your agency.

If you determine that the existing goals sufficiently cover your agency's resilience needs, move to Section 3.3. If not, consider whether resilience can be addressed through the development of an informal goal, modifying an existing goal, or developing a new goal. Each of these approaches are discussed in more detail, below.

As stated in Section 3.1, your agency faces unique threats depending on localized natural hazards and environmental conditions as well as the particular assets and priorities of your agency. Although examples are provided, keep in mind that how your agency defines and addresses resilience may differ depending on your unique hazards and priorities.

Key Resources and Tools for Developing Resilience Goals

- Performance Based Planning and Programming Guidebook for information on developing performance-based goals.
- Appendix C of Integrating Resilience into the Transportation Planning Process: White Paper on Literature Review Findings provides additional examples of DOT and MPO resilience goals.

Performance-based or Outcome-oriented Goals

Key questions to consider when developing performance-based or outcome-oriented goals are ((FHWA, 2013a):

- What are the priorities of your agency and community?
- What outcome are you trying to achieve?
- How can your agency support the outcome?
- What goals will help your agency achieve the outcome?

3.2.1 Develop an informal resilience goal

Developing an informal resilience goal or theme is a good first step to navigating your resilience challenges and may lead to a formal resilience goal in a future planning cycle. It can also be encompassed in a broader vision for your agency rather than a specific goal. The benefits of developing an informal goal/theme include:

- Informal goals/themes are relatively easy to develop and do not need to go through the formal long-range transportation planning process. It may be easier to gain buy-in and acceptance of

an informal goal, especially if there are any public or political sensitivities, with less wordsmithing.

- Informal goals/themes can be developed at any time. An informal goal is useful if you are in the middle of your transportation planning process and want to begin integrating resilience now rather than waiting until the next planning cycle.

However, an informal goal or theme is likely to carry less weight throughout the transportation planning process than a formal goal.

Strategies for implementing an informal resilience goal include:

- **Proactively discuss resilience:** You may already be taking resilience-related actions or recognize the need to start addressing resilience more directly. Hold an internal meeting to present the local hazards, discuss priorities, and obtain buy-in for establishing an informal goal.
- **Hold a conversation following an extreme weather event:** An informal resilience goal may evolve in response to a catalyst such as a natural hazard event. To facilitate the development of the goal and to obtain buy-in across your agency, you could hold a meeting following the event to discuss what happened and what actions could be taken to better prepare for or mitigate damage in a future event. You could also discuss whether resilience planning is a priority at that point in time and something your agency can be actively working toward. The likelihood of the event to occur again in the near-future may influence whether resilience planning is an immediate priority.

Figure 3-2. Pennsylvania DOT snow plow responding to winter storm (PennDOT, 2019).

Resilience has been integrated into informal goals and visions by transportation planning agencies over the years:

- In 2016, California DOT (Caltrans) included resilience in its then-current LRTP as part of the overall vision rather than in a formal goal. The vision of that plan was to “reduce long-run repair and maintenance costs by using ‘fix-it first’, smart asset management, and life-cycle costing, to maintain our transportation infrastructure in good condition – this should include developing a comprehensive assessment of climate-related vulnerabilities, and actions to ensure system resiliency and adaptation to extreme events” (Caltrans, 2016).

- In 2017, the North Jersey Transportation Planning Authority (NJTPA) chose to integrate themes (competitive, efficient, livable, resilient) from a broader regional plan (Together North Jersey, 2015) throughout their then-current LRTP, *Plan 2045* (NJTPA, 2017a). These themes were developed through extensive public outreach and discussions at the local level, with the NJTPA playing a leading role in Together North Jersey's organization and efforts. Although NJTPA did not develop a resilience-specific goal for this LRTP, the accompanying *Regional Capital Investment Strategy for the NJTPA Region*, which outlines investment principles and guidelines to inform project selection and policy direction for this LRTP does include increasing regional resilience as an investment principle (NJTPA, 2017b). See Section 7.2 for additional details.

Figure 3-3. Themes from Together New Jersey regional plan (Together North Jersey, 2015).

3.2.2 Revise an existing formal goal to incorporate resilience

A formal resilience goal establishes resilience as a known priority throughout your agency and transportation planning cycle that is on par with other issues (e.g., safety, reliability). A formal goal also helps to make resilience a visible priority to the public.

Your agency likely already has a number of goals loosely related to resilience such as infrastructure reliability, environmental, or safety goals. It may be increasingly more challenging to reach these goals as a result of climate change unless you plan for resilience. This is particularly true in the case of infrastructure reliability and asset management.

To evaluate the effectiveness and appropriateness of your existing goals, gather input internally or externally on your existing goals in the context of the information gathered in Section 3.1 on natural hazards and climate change. Your agency may choose to conduct a survey or hold a meeting or workshop to gather and discuss these findings. Based on these discussions, your agency may decide to revise your existing goals to incorporate resilience considerations. You could also add resilience-related objectives, performance measures, and targets under these goals to more explicitly incorporate resilience, although the resilience component itself is not a requirement.

Concepts of resilience have already been integrated into existing formal goals by transportation planning agencies, such as safety or system performance, without explicitly establishing a resilience goal. Resilience may instead come through specific objectives or performance measures that reflect regional priorities.

Table *3-1* demonstrates some examples.

Table 3-1. Examples of Integrating Resilience into Existing Goals

Existing goal	Examples of integration
Safety	**Arkansas DOT**: "Improve statewide safety by funding projects reducing fatal and serious injury crashes, reducing vulnerability (the magnitude of impact on the system because of events such as major traffic incidents, flooding, lane closures, bridge failures, and seismic activity), and improving resiliency of the system (the ability of the system to recover from these events)" (Arkansas DOT, 2016).
System Performance	**Colorado DOT**: "Improve the resiliency and redundancy of the transportation system to address the potential effects of extreme weather and economic adversity, emergency management, and security" (Colorado DOT, 2015).* **Florida DOT:** "Provide agile, resilient, and quality transportation infrastructure" (Florida DOT, 2016).

*Colorado DOT identifies this text as a strategic policy action to simultaneously address all four of their official goals: safety, mobility, economic vitality, and maintaining the system.

3.2.3 Develop a formal stand-alone resilience goal

Your agency may decide to develop a formal stand-alone resilience goal, if integrating resilience into your existing goals does not directly or adequately address your agency's resilience challenges. This strategy greatly increases the visibility of the issue and makes resilience a clear priority, both internally and externally. A stand-alone goal and associated objectives also make it easier to develop performance measures that directly measure progress.

Whenever adding new goals, it is important to maintain a manageable number of goals. FHWA's *Performance Based Planning and Programming Guidebook* recommends no more than twelve goals (FHWA, 2013a). If your agency already has a significant number of goals, it may be more appropriate to integrate resilience considerations into an existing goal or remove older goals that are no longer as relevant to your agency.

Examples of stand-alone resilience goals that agencies have established include:

- Rockingham Planning Commission (NH) previously included resilience as part of its environmental goals, but in 2017, created a standalone resilience goal for its 2040 LRTP: "The region's transportation system is adaptive and resilient to climate change and natural and other hazards". (Rockingham Planning Commission, 2017)
- In 2014, Hawaii DOT included a goal in its LRTP to "promote long-term resiliency, relative to hazard mitigation, namely global climate change, with considerations to reducing contributions to climate change from transportation facilities, and reducing the future impacts of climate change on the transportation system" and to "improve resiliency of the state through the transportation system" (FHWA, No Date).

- In 2017, the New York Metropolitan Transportation Council included a goal in its LRTP to "improve the resiliency of the regional transportation system." The MPO stated that the goal will be supported by projects and actions that focus on "hardening" the transportation system and by evolving partnerships among agencies to help reduce impacts of disasters on the movement of goods and people (New York Metropolitan Transportation Council, 2017).
- In 2017, the Madison Area Transportation Planning Board (WI) had a goal to "develop a transportation system that is resilient in the face of climate change and rising fuel prices in the future" and to "reduce vulnerability of the public and the region's transportation infrastructure to crime and natural hazards" (Madison Area Transportation Planning Board, 2017).
- The Delaware DOT (DelDOT) established "Resiliency and Reliability" as one of the 10 total goals for their *Innovation in Motion* LRTP. The resiliency and reliability goal is defined as: "Provide a resilient and reliable transportation system that offers predictable travel times under normal conditions as well as efficient and safe use during emergency situations" (DelDOT, 2018).

3.3 Develop resilience objectives

Revising existing objectives or developing new objectives to account for resilience will help you prioritize and better measure progress towards resilience goals. In performance-based planning and programming, it is important to develop specific and measurable objectives that support your big-picture goals.

Key Resources and Tools for Developing Resilience Objectives

- Performance Based Planning and Programming Guidebook for information on developing performance-based objectives.
- Appendix C of Integrating Resilience into the Transportation Planning Process: White Paper on Literature Review Findings for additional examples of DOT and MPO resilience objectives.

In the early stages of developing objectives, reflect on your goals and existing objectives in the context of current and future natural hazards and climate data gathered in Section 3.1. Discuss how key resilience challenges could be addressed through modified or new objectives. This conversation will also be influenced by any resilience-related goals developed in Section 3.2. If you determine that your existing objectives are appropriate as is, move to Section 3.4. If you determine that changes are needed, the following sections provide examples for either revising existing objectives or developing new objectives to account for resilience.

3.3.1 Revise existing objectives to incorporate resilience

Similar to goals, your agency may already have infrastructure reliability, environmental, or safety objectives in place that could be revised to incorporate resilience. Revising existing objectives and associated performance measures likely involves less effort than developing new objectives. Table 3-2 includes examples of resilience-related objectives that support existing goals.

Table 3-2. Examples of Integrating Resilience into Existing Objectives

Goal Category	Goal	Objective
System Performance	**Fayette Raleigh MPO** (WV): Preserve and maintain the existing transportation system (FRMPO, 2015)	Set aside adequate funds for maintenance before expanding the system, and give priority to projects that upgrade substandard infrastructure (FRMPO, 2015) [*note: this could include upgrading infrastructure to meet current precipitation levels].* Extend road and sidewalk life through preventive measures, and improve stormwater management along roads through the addition (or more frequent maintenance) of ditches, culverts, storm drains, and curb and gutter in urban areas (FRMPO, 2015).
	Minnesota DOT: System stewardship (MnDOT, 2017)	Strategically build, manage, maintain, and operate all transportation assets. Rely on system data and analysis, performance measures and targets, agency and partners' needs, and public expectations to inform decisions. Use technology and innovation to get the most out of investments and maintain system performance. Increase the resiliency of the transportation system and adapt to changing needs (MnDOT, 2017).

Aligning objectives across multiple planning documents may also be advantageous for facilitating a more comprehensive understanding and commitment to core objectives. For example, the Northeast Ohio Areawide Coordinating Agency (NOACA) (OH) used identical objectives across its Strategic Plan, LRTP, and Water Quality Strategic Plan to integrate resilience throughout the agency's work (NOACA, 2017a; NOACA, 2017b; NOACA, 2015). See Chapter 7 for more information on coordinating resilience efforts with other studies and work plans. Although these objectives do not explicitly use the term resilience, they are all aligned with resilience-related goals.

For example, under NOACA's goal of building a sustainable multimodal transportation system, the three plans included a natural hazard-related objective to "provide funding priority and other preferences with scoring criteria to projects that integrate the control of stormwater, protection and improvement of water quality, and control of development in floodplains" (NOACA, 2017a; NOACA, 2017b; NOACA, 2015). NOACA also includes an objective to "consider strategic abandonment or alternative provision of service for infrastructure elements that are underutilized or whose maintenance or reconstruction costs may exceed their benefit" (NOACA, 2017a; NOACA, 2017b; NOACA, 2015).

3.3.2 Develop stand-alone resilience objectives

Your agency may also decide to develop a stand-alone resilience objective. This strategy clearly establishes resilience as a priority and ensures the development of direct and measurable objectives for achieving resilience or resilience-related goals.

The benefits of developing stand-along resilience objectives are that the objectives can be crafted directly to the needs and goals of your agency. The textbox details qualities of "SMART" objectives to help you develop actionable resilience objectives.

"SMART" Objectives

Developing "SMART" objectives is an increasingly common practice in performance-based planning and programming (FHWA, 2013a). The "SMART" characteristics identified in FHWA's *Performance Based Planning and Programming Guidebook* include (FHWA, 2013a):

- **Specific** – The objective provides sufficient specificity to guide formulation of viable approaches to achieving the objective without dictating the approach.
- **Measurable** – The objective facilitates quantitative evaluation, saying how many or how much should be accomplished.
- **Agreed** – Planners, operators, and relevant planning participants come to a consensus on a common objective.
- **Realistic** – The objective can reasonably be accomplished within the limitations of resources and other demands.
- **Time-bound** – The objective identifies a timeframe within which it will be achieved.

These characteristics are equally applicable to revising or developing new objectives related to resilience. A "SMART" resilience objective will be better able to inform decision making.

The Boston Region MPO (MA) demonstrates the development and evolution of resilience objectives over time. The MPO first developed resilience objectives in its 2011 LRTP (Boston Region MPO, 2011). Under a climate change goal, the MPO included an objective "to invest in adaptations that protect critical infrastructure from effects resulting from climate change" (Boston Region MPO, 2011). The motivation behind the decision to include resilience as a planning objective were the findings from the MPO's past studies on greenhouse gas emissions and reduction strategies and State requirements. The MPO shifted the focus of its resilience objectives from climate adaptation in the 2011 LRTP to system preservation in the 2015 LRTP (Boston Region MPO, 2011; Boston Region MPO, 2015a). The 2015 objectives under the system preservation goal for maintaining the transportation system included (Boston Region MPO, 2015a):

- "Prioritize projects that support planned response capability to existing or future extreme conditions (sea level rise, flooding, and other natural and security-related man-made hazards).":
- "Protect freight network elements, such as port facilities, that are vulnerable to climate change impacts."

The Miami-Dade Transportation Planning Organization (TPO) (FL) has also developed a number of objectives tailored to the specific needs of Miami-Dade County, including one stand-alone resilience objective. The goal of maximizing and preserving the existing transportation system, includes a clear resilience objective to "reduce the vulnerability and increase the resilience of critical infrastructure to the impacts of climate trends and events" (Miami-Dade TPO, 2019).

Other stand-alone resilience objectives include:

- **Palm Beach MPO** (FL): Increase the percentage of facilities that can accommodate a two-foot sea level rise (Palm Beach MPO, 2019).

- The **Northern Middlesex MPO** (MA): Protect transportation infrastructure from climate change, and more specifically address stormwater runoff and flooding concerns (Northern Middlesex MPO, 2019).
- **Cape Cod MPO** (MA): Improve the transportation system's resiliency to the effects of sea level rise, under the goal of supporting livable communities that strengthen the long-term resilience of the region (Cape Cod MPO, 2020).

3.4 Develop performance metrics and targets to measure resilience

The development of performance measures and targets related to resilience is a more advanced and action-oriented element of resilience planning. Resilience metrics and targets are important for measuring your progress towards improving resilience and for making informed investment or management decisions.

Key Resources and Tools for Developing Performance Metrics and Targets to Measure Resilience

- Performance Based Planning and Programming Guidebook for information on developing performance-based measures and targets.

A key consideration when developing metrics and targets is whether the necessary data is available to measure and monitor progress. For targets in particular, it is important to collect existing conditions data to establish a baseline value so that you can track trends in performance and develop appropriate targets (FHWA, 2013a). Obtaining current and future data to quantify and track progress is one challenge to developing useful performance measures, which will be discussed in more detail in Chapter 10 (FHWA, 2013a). With each iteration of the planning cycle, your agency will have more data and a better understanding of what factors affect performance (FHWA, 2013a).

Determining the appropriate metric or target also depends on many factors such as the timeframe, future environmental conditions, or funding availability. While resilience tends to be considered on a longer time-horizon, you could also establish shorter-term resilience metrics and targets as intermediate steps to achieving long-term resilience goals and objectives. In addition, you may also consider making modifications to metrics or methods of tracking to account for future environmental conditions. Furthermore, certain performance measures or targets may be costlier to implement than others, depending on the implementation strategies involved in achieving those measures and targets and the monitoring and reporting process.

Performance measures and targets can be *outcomes* (e.g., bridges are more resilient by a specified factor) or *outputs* (e.g., a specified percentage of investments in projects in the 100-year floodplain will incorporate design elements to increase resilience to climate change). Your agency typically has more control over achieving output measures than outcome measures. Table 3-3 lists examples of resilience-related performance measures and targets.

Table 3-3. Examples of Resilience-related Performance Measures and Targets

DOT or MPO	Goal or Objective	Performance Measures or Targets
Cape Cod MPO (MA) (Cape Cod MPO, 2020)	Improve the transportation system's resiliency to the effects of sea level rise.	▪ Evaluate potential impacts of sea level rise for all TIP projects during the 25% design review and adjustments to projects are made as warranted.
Miami-Dade MPO (FL) (Miami-Dade, MPO, 2014)	Reduce the vulnerability and increase the resiliency of critical infrastructure to the impacts of climate trends and events.	▪ Number of highway lane and centerline miles within the 100-year floodplain.
Mid-Region Council of Governments (Mid-Region COG) (NM) (Mid-Region COG, 2015)	Environmental resilience: Prepare for climate uncertainties.	▪ Development in high flood risk areas: Number of housing units and number of employees located in Federal Emergency Management Agency (FEMA) 100-Year floodplains. ▪ Development in forest fire risk areas: Number of housing units and number of employees located in wildland-urban intermix areas.
Palm Beach MPO (FL) (Palm Beach MPO, 2019)	Provide an efficient and reliable vehicular transportation system.	▪ Increase the percentage of facilities that accommodate two feet sea level rise; the performance target is 90% for the strategic intermodal system network in 2025.

Other potential performance measures and targets include:

- Hours of roadway lane miles closed because of flooding or other weather conditions.
- Number of roadway closures because of flooding or other weather conditions.
- Percentage of culverts that are hydraulically adequate for current and future precipitation events.
- Percent of facilities that are highly vulnerable to climate change, as determined by an indicator-based vulnerability assessment.
- Frequency of sweeping of roads at frequently flooded locations.

Similar to objectives, it is also important to limit the number of metrics or targets to a meaningful and manageable set. Collecting and analyzing data can be time-consuming and expensive so it is important to prioritize key metrics and targets that inform goals and objectives.

3.5 Recap of approaches to considering resilience while developing goals, objectives, performance measures, and targets

This chapter presented four core approaches to considering resilience while developing goals, objectives, performance measures, and targets (see Table 3-4). The key step is to first determine if and how natural hazards and climate change will affect your agency's goals, objectives, performance measures, and targets. Understanding existing and future conditions will help your agency determine whether to develop resilience goals, objectives, performance measures, or targets. The approaches range from developing an informal resilience goal to developing specific performance metrics or targets to measure resilience.

Why Consider Resilience When Developing Goals, Objectives, Performance Measures, and Targets?

Your agency's goals, objectives, performance measures, and targets are the foundation of the transportation planning process. Considering resilience at this stage will prioritize resilience and influence/guide the rest of the planning process. In addition, integrating resilience at this step will make clear to staff, stakeholders, and the public that resilience is a key focus of your agency.

Table 3-4. Developing Goals, Objectives, Performance Measures, and Targets Recap

Integration Action	Key Action?	Potential Approaches
Determine if natural hazards and climate change will affect existing goals, objectives, performance measures, and targets	✓	▪ Collect information from a variety of sources (e.g., Federal, state/local, NGOs, universities) on current and future natural hazards and climate conditions with a focus on local conditions. ▪ Conduct a needs assessment or vulnerability assessment to develop a more robust understanding of the transportation system's vulnerabilities to natural hazards and climate change. ▪ Determine key threats and consider how the hazards may affect your agency's ability to meet existing goals and objectives.
Develop a resilience goal		▪ Develop an informal resilience goal (e.g., hold an internal meeting to discuss your agency's response to a recent extreme weather event). ▪ Revise an existing formal goal to incorporate resilience (e.g., conduct a survey to evaluate the effectiveness and appropriateness of your existing goals in the context of resilience). ▪ Develop a formal stand-alone resilience goal.
Develop resilience objectives		▪ Revise existing objectives to incorporate resilience. ▪ Develop stand-alone resilience objectives.

Develop performance metrics and targets to measure resilience		▪ Determine the appropriate metric or target based on timeframe, funding availability, or future climate conditions.

Chapter 4
Defining Problems and Needs

Chapter 4 Defining Problems and Needs

This step in the planning process focuses on defining the problems and needs of your agency's transportation system such as aging infrastructure, traffic congestion, safety concerns, or weather-related risks and vulnerabilities. A strong understanding of your agency's problems and needs can help you identify key areas of concern to target throughout the subsequent steps of the planning process. Even focusing on only a subset of your problems and needs is meaningful progress.

Importance and benefits of integrating resilience: Understanding exposure and vulnerability as well as the consequences of natural hazards and climate change to your transportation system is key to successfully building resilience. With such knowledge, your agency can identify high-priority problems and resilience needs.

Figure 4-1 illustrates the key sub-steps and possible resilience integration actions for defining problems and needs. The following sections provide detailed information about each resilience integration action, including resources and tools to help your agency integrate resilience into your transportation planning processes.

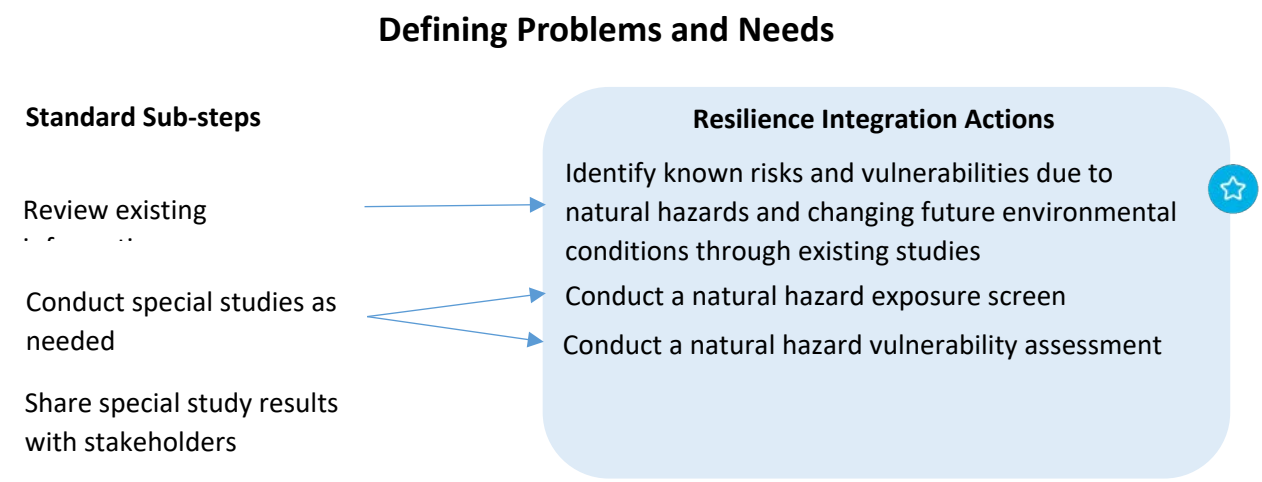


Figure 4-1. Key steps and resilience integration actions for defining problems and needs.

Your agency can implement any one of the resilience integration actions to define problems and needs. The actions outlined in this chapter generally follow the FHWA Vulnerability Assessment and Adaptation Framework (see Vulnerability Assessment Framework Conceptual Diagram - Adaptation Framework - Resilience - Sustainability - Environment - FHWA (dot.gov)) and focus specifically on assessing exposure, conducting a vulnerability assessment, and assessing risk and consequences (FHWA, 2017f). The major components of the *Vulnerability Assessment and Adaptation Framework* include:

- **Articulate objectives and define study scope:** Set the parameters of your vulnerability assessment, including determining which natural hazards and assets to analyze. Local planning documents such as hazard mitigation plans, risk maps, exposure screens, or risk screens may be useful for identifying which hazards are particularly relevant to your agency. Your agency's

resilience-related goals, objectives, performance measures, and targets from Chapter 3 may also help to shape the scope of the assessment.

- **Obtain asset data** (Section 4.2): Collect a variety of asset data from both internal and external sources, including your asset management inventory, maintenance records, and GIS datasets.
- **Obtain climate data** (Sections 4.1 and 4.2): Collect both existing and projected future climate data for the hazards relevant to your agency. Local or regional reports from government agencies, NGOs, or universities may be useful for gathering climate data.
- **Assess vulnerability** (Sections 4.2 and 4.3): First evaluate the exposure of your assets. Then, if desired, consider the sensitivity, and adaptive capacity of individual assets or your transportation system as a whole using one of three approaches: stakeholder input, indicator-based desk review, or engineering-informed assessment. Using this information, identify and prioritize your vulnerabilities (FHWA, 2017f).
- **Consider risk** (Section 4.3.4): Evaluate the likelihood and consequences of an asset experiencing a particular impact to better understand impacts and inform decision-making.
- **Analyze adaptation options** (Chapter 5 and Chapter 6): Identify and analyze potential adaptation options to address vulnerabiltiies and increase resilience.
- **Incorporate results into decision-making**: Integrate the vulnerability assessment results into various exsiting transportation processes, such as transportation planning, environmental review, engineering design, transportation systems management and operations, and asset management.

4.1 Identify known risks and vulnerabilities because of natural hazards and climate change through existing studies

Identifying known risks and vulnerabilities to the transportation system because of natural hazards and climate change is a key resilience integration action and the first step to defining resilience-related problems and needs. Gathering this information from existing reports and studies (for example, reports evaluating records of past damage, analysis done for compliance with 23 CFR part 667, or climate change vulnerability assessments) can help you streamline the data collection process, ensure regional consistency, and identify any gaps in current knowledge to inform the scope or future studies. As a result, this method is often less expensive and time-intensive than pursuing new studies.

Local and regional reports, planning documents, and risk and vulnerability assessments are particularly helpful for understanding the local context of natural hazards and climate change. Any resources that pull together information on natural hazard exposure can be useful to your agency even if the resource is focused on a different set of assets. Ideally, however, your agency can find transportation-focused resources on exposure and vulnerability. These resources may include:

- **Government agency reports and assessments** – Local or regional government agencies may have completed their own reports or assessments on how natural hazards and climate change are affecting your area, including impacts to critical infrastructure. Federal agencies such as USGS or the Army Corps of Engineers also conduct relevant studies in select locations. Other planning documents such as hazard mitigation plans, asset management plans, or risk maps may also be helpful in identifying applicable hazards. For example, the Tri-Cities Area MPO (VA)

utilized data from an existing multi-jurisdictional hazard mitigation plan to determine that hurricanes, tornadoes, high winds, floods, and mass evacuations often occur simultaneously. Using these findings, the MPO decided to focus its resilience efforts on hurricane events (Tri-Cities Area MPO, 2017).

- **University research** – Universities may be conducting studies in your area on local or regional natural hazards and climate change. These studies could be broader than resilience, but still relevant to your agency's understanding of risks and vulnerabilities.
- **Non-governmental organization (NGO) reports and assessments** – NGOs often produce reports and assessments on specific topics tailored to their expertise, which may include the local impacts of natural hazards and climate change.

4.2 Conduct a natural hazard exposure screen

To gain a better understanding of the exposure of the transportation network to natural hazards and address knowledge or data gaps from Section 4.1, your agency can conduct a natural hazard exposure screen.

Select hazards: Potential hazards to consider include: temperature, precipitation, drought, sea level rise, storm surge and waves, permafrost thaw, streamflow, wind, earthquakes, wildfires, tornadoes, and hurricanes, though there may be additional or different hazards in your region (FHWA, 2017f). To narrow the list for your region, identify natural hazards your agency has experienced in the past and how they affected your transportation system. Your agency may have records on the effects of past natural hazard events, such as operational disruptions, asset conditions, and costs of maintenance or repair.

Obtain geospatial hazard data: Collecting geospatially refined data and information on climate change (e.g., temperature and precipitation trends) is important to better understand local risks and vulnerabilities. Your agency may obtain geospatial hazard data through internal data collection and knowledge of past damage locations or through external sources such as Federal Emergency Management Agency (FEMA) flood hazard maps (see textbox for additional resources). Local or regional resources such as statewide data portals or sea level rise scenarios and maps may also be a source of exposure data.

Key Resources for Conducting a Natural Hazard Risk Screen

- Chapter 4 of the FHWA Vulnerability Assessment and Adaptation Framework for information on obtaining and understanding data, including temperature, precipitation, riverine hydrology, sea level rise and storm surge.

Overlay hazards and assets: With the geospatial hazard information, your agency can compare the location of key assets to hazard data maps to understand which assets may be exposed to that hazard. For example:

- The Fayette Raleigh MPO (WV) used GIS software to assess whether proposed projects are in FEMA's 100-year floodplain (FRMPO, 2015). While the MPO used this strategy to assess proposed projects, a similar approach could also be taken during the problems and needs phase of the planning process to quickly identify any assets located within the floodplain.

- The Boston Region MPO (MA) uses its own interactive All-Hazards Planning application tool (see Figure 4-3) to map the transportation network in relation to natural hazard zones, including flooding, hurricane storm surges, earthquake liquefaction, and sea level rise (Boston Region MPO, No date). Visualizing exposure helps make the information easily accessible for the MPO and the public. Although the MPO primarily uses this tool to assess the exposure of TIP projects, a similar tool could be used at the problems and needs phase of the planning process to quickly identify potentially vulnerable locations/assets.

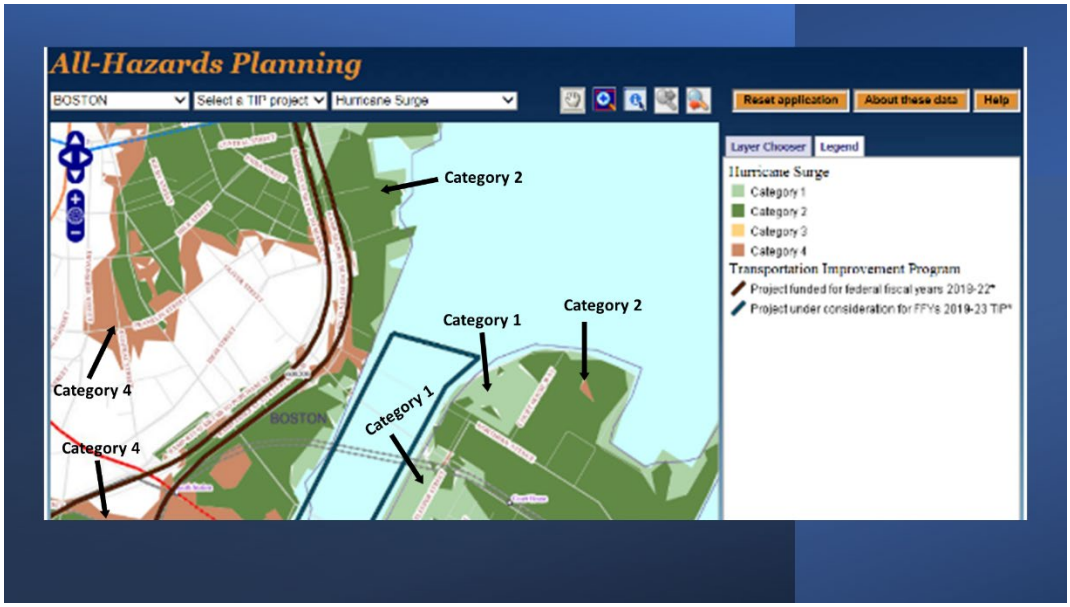


Figure 4-2. Screenshot of the All-Hazards Planning Application Tool showing hurricane surge in relation to TIP projects in Boston (Boston Region MPO, No date).

Key questions to consider when compiling exposure data and conducting a natural hazard exposure screen include:

- What locations are exposed to hazards? What locations have a high number of exposed assets? What assets are
- exposed to multiple hazards?
- Are there any information gaps that require further analysis? What additional information is needed?
- Could you conduct a vulnerability assessment for more detailed information? If so, what assets or locations do you prioritize for further analysis?

Figure 4-3. Flood damage to US 301 in South Carolina following Hurricane Florence in September 2018 (SCDOT, 2018).

4.3 Conduct a natural hazard vulnerability assessment

Conducting a vulnerability assessment can help your agency build on the exposure screen and develop a more robust understanding of your transportation system's vulnerabilities to natural hazards and climate change. Vulnerability is defined as a transportation system's (or individual asset's) exposure, sensitivity, and adaptive capacity to natural hazards and climate change (FHWA, 2017f):

- **Exposure:** degree to which an asset or system experiences the direct effects of the hazard.
- **Sensitivity:** how an asset or system fares when exposed to the hazard.
- **Adaptive capacity:** degree to which an asset or system is able to adjust to or cope with the hazard.

Key Resources for Assessing Vulnerabilities and Risks

- FHWA Vulnerability Assessment and Adaptation Framework for detailed step-by-step information on three methods for conducting a vulnerability assessment.
- FHWA Synthesis of Approaches for Addressing Resilience in Project Development for information on engineering-informed assessments.
- FHWA Gulf Coast Study Vulnerability Assessment Tools for various tools to collect data and assess exposure and sensitivity.

Vulnerability assessments can be conducted at a variety of scales, from assessing the vulnerability of a single project or asset to identifying vulnerable points throughout the transportation network. Even if your agency has limited or imperfect data, you can tailor the scale of the vulnerability assessment to your needs and capabilities.

For detailed step-by-step information on how you can conduct a vulnerability assessment, refer to FHWA's Vulnerability Assessment and Adaptation Framework (FHWA, 2017f). Three approaches for conducting vulnerability assessments are described in Sections 4.3.1, 4.3.2, and 4.3.3. Section 4.3.4 highlights the value of also considering the consequences of asset damage, disruption, or failure because of natural hazards.

Example Vulnerability Assessments

FHWA has funded numerous vulnerability assessments, which can also be great resources for understanding how to apply the various approaches of the vulnerability assessment framework to a transportation network:

- FHWA 2010-2011 Climate Change Resilience Pilots for agency examples (FHWA, 2011).
- FHWA 2013-2015 Climate Change Resilience Pilots for agency examples (FHWA, 2016a).
- USDOT Gulf Coast Study for agency examples and other tools and resources for conducting vulnerability assessments (FHWA, 2014).
- Post-Hurricane Sandy Study of NY, NJ, and CT for a vulnerability assessment of the transportation assets within the greater NY-NJ-CT metropolitan region (FHWA, 2017c).

4.3.1 Stakeholder and public input

The stakeholder and public input approach relies primarily on institutional knowledge and partnerships to assess vulnerability. Your agency can gather institutional knowledge from transportation practitioners, engineers, scientists, government officials, and the public to better understand local experiences and observations that may not be formally documented by your agency. Establishing or utilizing existing partnerships and collaborations can also help your agency identify resources not found in the initial desk review. Working with others to understand what information is readily available in your region not only distributes the burden of conducting studies and assessing data across organizations, but also expands the knowledge base to be more interdisciplinary and possibly more holistic.

To collect stakeholder and public input for your vulnerability assessment, consider:

- Providing a simple map where staff or the public can circle areas that frequently experience impacts from a given hazard (e.g., flooding).
- Reviewing maintenance records for repeat hazard-related damages.
- Holding a series of regional and mode-specific workshops similar to Washington State DOT (WSDOT), which assessed facility vulnerability to temperature, precipitation, sea level rise, wind, and fire (FHWA, 2017f). Staff and subject matter experts used a qualitative scoring system to assess asset exposure and sensitivity (see Figure 4-5) based on maps of the historical and projected trends of each hazard. WSDOT then prepared a series of maps showing the vulnerability ratings for major assets, which can be used for future planning and programming both by WSDOT and other local or regional stakeholders.

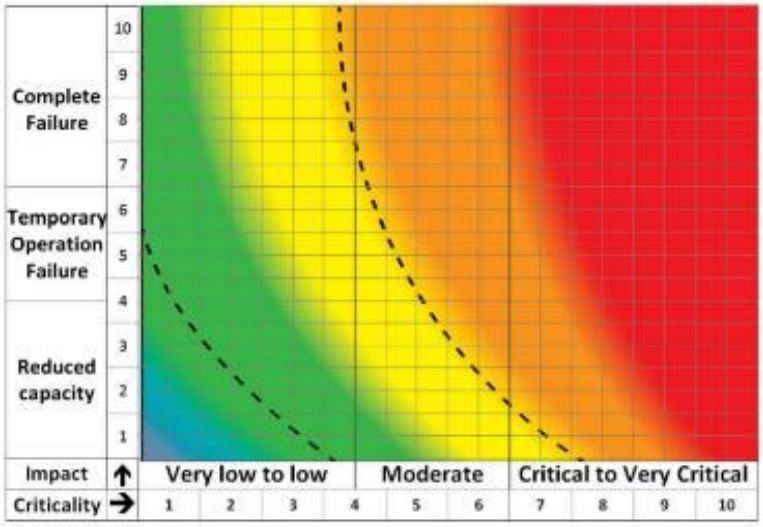


Figure 4-4. WSDOT qualitative workshop impact - asset criticality matrix (WSDOT, 2011).

- Developing surveys and other crowdsourcing methods. For example:
  - Tennessee DOT (TDOT) surveyed hundreds of transportation experts and stakeholders across the State to assess the potential impacts of natural hazards on different types of assets on a four-point scale (nominal, moderate, significant, and catastrophic). (FHWA, 2016a). The survey results were incorporated into TDOT's vulnerability assessment by developing "impact scores" for each transportation asset type and weather category combination.

  - Fayette Raleigh MPO (WV) reached out to local jurisdictional officials to supplement existing data with local knowledge of where problems had occurred in the past (FRMPO, 2016).

These sources could allow you to compile an inventory of facilities with established vulnerabilities. See Chapter 2 for more information on stakeholder engagement strategies.

4.3.2 Indicator-based desk review

The indicator-based desk review approach relies primarily on existing quantitative data to assess vulnerabilities. Even if you have limited or imperfect data, your agency can determine specific indicators to serve as a proxy measurement of exposure, sensitivity, or adaptive capacity. For example:

- Exposure: Percentage of network segments permanently inundated by 1, 2, or 3 feet of sea level rise by 2100.
- Sensitivity: Bridge scour rating.
- Adaptive capacity: Average annual daily traffic.

Your agency can collect quantitative data on assets and climate change beginning with data collected in Sections 4.1 or 4.2. Useful potential sources may include transportation planners at the DOT or MPO, transportation system managers, universities, or other local or regional agencies. Indicator data can then be converted to a single vulnerability score (e.g., 1-4) for each asset and hazard. USDOT developed the Vulnerability Assessment Scoring Tool (VAST) to assist with this process. After calculating the scores, it is important to vet the findings with subject matter experts, and adjust the scores, if needed.

4.3.3 Engineering-informed assessment

The engineering-informed assessment approach is tailored to a specific asset, going into much greater detail on how a specific asset would be affected by a hazard. This approach is generally more appropriate for informing asset design than for long-range planning. More information on this approach can be found in FHWA's Synthesis of Approaches for Addressing Resilience in Project Development (FHWA, 2017d) and FHWA's Vulnerability Assessment Framework (FHWA, 2017f).

4.3.4 Consider the consequences of asset damage, disruption, or failure because of natural hazards

To further refine the results of your vulnerability assessment, it is valuable to consider the risks, more specifically the consequences, of natural hazard impacts to the transportation system (e.g., impacts to operations, society, the economy, the environment). Assessing a diverse set of consequence categories provides a more holistic look at natural hazard impacts.

For example, in 2016, Northeast Ohio Areawide Coordinating Agency (NOACA) (OH) developed a risk assessment and risk register as part of their transportation asset management program to better understand the risk natural hazards pose to the transportation network (NOACA, 2016). NOACA engaged a steering committee of stakeholders (e.g., Ohio DOT, FHWA, and city and county engineers and

planners) and used surveys to gather input and rate the level of risk for each event identified in the assessment. The risk register for environmental and extreme weather risk events is shown in Table 4-1.

Table 4-1. NOACA's Risk Register for Environmental and Extreme Weather Risk Events (NOACA, 2016)

Event Description	Likelihood	Consequence					
		Public Safety	Asset Condition Impact	Regional Scope	Mobility	Finance	Event Score
Pavement and bridge deck is damaged by major floods, caused by excess rainfall	2	5	4	2	4	2	6.8
Ice flows break up and damage bridge infrastructure	2	2	2	1	1	1	2.8
Bridges and ancillary infrastructure are structurally damaged by extreme weather	1	4	4	2	4	2	3.2
Pavement and bridge deck is damaged by extreme temperature	3	1	3	2	3	2	6.6
Bridges are structurally damaged by major floods, caused by excess rainfall	2	1	3	3	3	1	4.4
Wind events damage infrastructure (including ancillary assets)	3	2	2	2	2	2	6.0
Extreme snowfall causes major disruptions in mobility	5	3	1	5	5	2	16.0

NOACA's risk register was completed at the regional level and assigned ratings of 1 to 5 for likelihood, public safety, asset condition impact, regional scope, mobility, and financial impact. NOACA used the following calculation to determine risk scores for each event: Risk = Likelihood x Average Consequence (public safety, asset condition impact, regional scope, mobility, financial impact). In this case, the likelihood of impact is closely associated with the exposure of the asset to the natural hazard.

Vulnerability assessments and risk considerations can not only help your agency better understand problems and needs in regards to natural hazards and changing environmental conditions, but the results can also be used to help justify resilience investments and prioritize assets based on the extent of their natural hazard vulnerabilities and risks.

4.3.5 Available Web-Based Trainings

The following web-based trainings related to topics covered above are available free of charge on the National Highway Institute (NHI) website.

- FHWA-NHI-142081 Understanding Past, Current and Future Climate Conditions
- FHWA-NHI-142082 Introduction to Temperature and Precipitation Projections
- FHWA-NHI-142083 Systems Level Vulnerability Assessments
- FHWA-NHI-142084 Adaptation Analysis for Project Decision Making

Share Special Study Results with Implementing Agencies

Sharing the results from any of the previous integration actions with potential implementing agencies is an important final step for defining problems and needs. Local and county transportation departments often own, operate, and maintain most roadways and therefore could be knowledgeable of the risks and vulnerabilities to natural hazards and climate change to better manage those roadways. These departments may not have the resources to conduct these types of studies on their own and therefore might rely on resources from your agency or other regional entities.

By sharing these results and processes, implementers can develop and submit projects that address resilience needs. Without full knowledge of local or regional risks and vulnerabilities, these entities are unlikely to submit resilience-related projects during the call for projects.

4.4 Recap of approaches to considering resilience while defining problems and needs

This chapter presented three core approaches to considering resilience while defining transportation problems and needs (see Table 4-2). These approaches range from reviewing existing resources on known natural hazard vulnerabilities, to analyzing the exposure of assets to various current and future natural hazards, to a more rigorous natural hazard vulnerability assessment. The chapter also contains information on the value of considering the consequences of natural hazard events as well as sharing the findings of this work with other stakeholders who are responsible for submitting transportation projects to the DOT or MPO.

Why Consider Resilience When Defining Problems and Needs?

By including resilience in your agency's definitions of the transportation problems and needs, resilience considerations can influence the rest of the planning process.

Table 4-2. Defining Problems and Needs Recap

Integration Action	Key Action?	Potential Approaches
Identify known risks and vulnerabilities because of natural hazards and climate change through existing studies	✓	▪ Review existing reports (e.g., vulnerability assessments, hazard mitigation plans, emergency funding reimbursement requests).
Conduct a natural hazard exposure screen		▪ Compare the location of key assets to natural hazard data to understand which assets may be exposed.

Conduct a natural hazard vulnerability assessment		▪ Use stakeholder or public input to complete a qualitative system-level vulnerability analysis. ▪ Conduct an indicator-based desk assessment to develop a quantitative understanding of vulnerability across your system. ▪ Conduct an engineering-informed assessment to develop a robust understanding of the vulnerability of a specific asset. ▪ Consider the consequences of natural hazard impacts to further refine your analysis.

Chapter 5
Evaluating Solutions

Chapter 5 Evaluating Solutions

After identifying problems and needs, the next step is to find and select strategies that will address these problems and needs while working to accomplish your goals and objectives. Evaluation criteria can help you ensure that existing and proposed strategies are likely to meet your goals and address your needs. Once you have gathered a list of potential strategies, the next step is to prioritize them and identify which you will nominate for inclusion in the long-range plan.

Importance and benefits of integrating resilience: This step allows your agency to use information on hazards and vulnerabilities to develop resilience strategies. Prioritizing the solutions that your agency will eventually include in the TIP, STIP, long-range plan, or other plans can be a natural continuation of the resilience work described in the preceding chapters. There is also an interrelationship to the prioritization of resilience projects among planning initiatives. The prioritization of projects that is conducted in developing Resilience Improvement Plans should inform the prioritization of projects in long-range plans, which will ultimately inform the projects that are programmed in the TIP and STIP (see Foreword). Without developing and evaluating solutions to known vulnerabilities, the information that has been gathered thus far may have a difficult time being translated into action. Developing resilience-specific strategies and evaluation criteria can help ensure that these solutions advance.

The following steps for gathering and evaluating solutions provide opportunities for resilience:

- **Establish evaluation criteria.** To understand how strong a role resilience should have in evaluation of proposals, include resilience in the discussions you have with the public and your stakeholders as you set your agency's priorities. This information will help you develop evaluation criteria that will help project sponsors develop relevant projects and help you to review proposals objectively.
- **Gather relevant strategies identified in existing studies or plans.** By gathering relevant resilience strategies from existing documents, you do not have to spend time or effort reinventing the wheel. Knowledge transfer in this way can also provide you with a better understanding of the efforts occurring at the local scale within your agency's jurisdiction and highlight opportunities for collaboration. You can also look to others outside of your area at the local, State, and national scales for ideas.
- **Release call for projects.** Request new ideas when issuing calls for projects. Encourage proposals that address resilience concerns and that will score well on resilience-related evaluation criteria.
- **Evaluate and prioritize among solutions.** Just as your agency likely needs to prioritize among problems and needs, it is also beneficial to prioritize among potential solutions. Without unlimited time and resources, it will likely not be feasible to implement all the strategies you find. Integrating resilience into this step can help ensure that the projects that do make it into your plan include resilience concerns.

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Evaluating Solutions

Standard Sub-steps	Resilience Integration Actions
Establish evaluation criteria	Include resilience as a topic in priority-setting discussions
	Integrate resilience priorities into evaluation criteria
Gather relevant strategies identified in existing studies or plans	Gather information on relevant resilience strategies from sources within your jurisdiction
	Gather information on relevant resilience strategies from sources relevant to your context
Release call for projects	Request resilience ideas in calls for projects
Evaluate and prioritize among solutions	Apply pre-established evaluation criteria that include resilience considerations
	Prioritize resilience solutions based on urgency/importance and implementation feasibility

Figure 5-1. Key steps and resilience integration actions for evaluating solutions.

Figure 5-1 illustrates the key steps for evaluating solutions and possible resilience integration actions. The following sections provide detailed information about each resilience integration opportunity, including resources and tools to help your agency

5.1 Add resilience considerations to evaluation criteria

You can add resilience considerations to the evaluation criteria your agency uses to inform its solution- and project-selection processes and to ensure that the selected projects will further the goals and priorities of your constituents and agency. Evaluation criteria help decisionmakers understand the relative importance of various factors—to understand which tradeoffs can be made while still accomplishing multiple agency goals. Updating and publicizing the evaluation criteria prior to reviewing potential solutions can help project sponsors understand what characteristics they should include in their proposals.

This chapter describes general approaches for creating evaluation criteria, but later chapters provide some options for applying these approaches to evaluating scenarios for the long-range plan (Chapter 6) and to evaluating and prioritizing projects for the STIP/TIP (Chapter 8). The evaluation criteria used here can inform those and vice versa; agencies often use each update cycle to reiterate and refine the criteria to meet current priorities.

Key Resources for Developing Evaluation Criteria

- FHWA's PlanWorks tool contains a Decision Guide that includes key decisions relating to developing evaluation criteria. Each key decision offers a range of helpful questions to consider when developing criteria.
- Integrating Climate Change in Transportation and Land Use Scenario Planning: An Example from Central New Mexico provides lessons learned on using a scenario approach to prepare for the potential impacts of natural hazards.
- A Framework for Considering Climate Change in Transportation and Land Use Scenario Planning: Lessons Learned from an Interagency Pilot Project on Cape Cod provides information on the project's steps and offers observations and recommendations to help others.

5.1.1 Include resilience as a topic in priority-setting discussions

To develop an understanding of what priority resilience will have in your evaluation criteria, include resilience in your priority-setting activities and discussions. This is a key integration action that all agencies can undertake.

Although your agency established goals and objectives at the beginning of the planning cycle, there will have to be tradeoffs amongst them when it comes to selecting solutions to implement. Input from constituents and stakeholders is a valuable source of information on what factors to include in your evaluation criteria and how to weight those factors.

Since public participation is required for the Statewide and metropolitan transportation planning processes,[9] many agencies use their public participation activities as an opportunity to get feedback on priorities by asking participants to rank various options. The Miami-Dade Transportation Planning Organization (FL) did this in a series of community workshops and meetings while developing their 2040 LRTP. At these meetings, the agency gave community participants a sum of "play" money and asked them to allocate the money across eight goal area ballot boxes. The agency used the total sum of money in each ballot box to determine the goal weights (Miami-Dade TPO, 2019). In this way, the community was directly involved in the planning process and could voice their priorities in a quantifiable way.

At these discussions of priority, ensure that resilience is part of the conversation. This could be facilitated by presenting or otherwise sharing information on the findings of the natural hazard related problems and needs (see Chapter 4). For a discussion on including resilience priorities in policy-based transportation plans, see Section 6.1.1.

[9] 23 CFR 450.210(a), 450.316(a).

5.1.2 Integrate resilience priorities into evaluation criteria

The most direct way to develop resilience-related evaluation criteria is to tie them back to your resilience goals and objectives (Chapter 3). Not only is this an efficient strategy, as it gives ready-made direction to your criteria, but it also ensures that the strategies selected will work towards accomplishing your goals and objectives. Even if your agency has not established resilience goals or objectives on which to base evaluation criteria, you can still develop resilience evaluation criteria by considering what would help your agency build resilience. These evaluation criteria are often developed into a points system that assigns varying weights to the criteria, depending on their varying level of priority to the agency and its constituents, as demonstrated by the example in the textbox below.

Example of Integrating Priorities into Evaluation Criteria

Boston Region MPO used scoring criteria in 2017 to translate its goals and objectives into a prioritized project list. In total, the MPO's scoring criteria include 134 possible points, and high scoring projects are typically in the 60- to 70-point range (Boston Region MPO, 2017) Under system preservation scoring criteria, a project can receive six points if it improves the ability to respond to extreme conditions (that is, improves resilience) (Boston Region MPO, 2017). Specifically, these points are awarded if a project:

- "Addresses flooding problems and/or sea level rise issues and enables facility to function in such a condition" (+2 points).
- "Brings facility up to current seismic design standards" (+1 point).
- "Addresses critical transportation infrastructure" (+1 point).
- "Protects freight network elements" (+1 point).
- "Implements hazard mitigation or climate adaptation plans" (+1 point).

One resilience-related element to add to evaluation criteria could be to ask whether proposed projects are in a high-risk hazard area, as identified during a vulnerability assessment or other study described in in Chapter 4. Projects in high-risk hazard areas might need additional scrutiny to ensure that, if approved, they are designed and implemented to be resilient. Conversely, projects in low-risk hazard areas can be more valuable if they also serve as an alternate route to an important existing asset that is at high risk.

When developing evaluation criteria, confirm that the information needed to support the evaluation criteria is available. For example, if your agency does not have maps to assess whether projects are in a high-risk hazard area, you might determine a) how difficult it would be to create such information, b) how important that evaluation would be to your agency (if it is a criterion worth the effort of collecting the data), and c) if there are similar evaluation methods that do not require the missing data, but would still offer a meaningful assessment.

5.2 Gather relevant resilience strategies identified in existing studies or plans

Gathering relevant strategies identified in existing studies or plans is a key resilience integration action. The most efficient strategy is to begin with the materials most relevant to your context, then expanding your scope if further information is needed:

- Start with the low-hanging fruit: assess the results of existing internal studies.
- Once you have looked through the internal sources to find pre-identified strategies, then you might look to studies conducted outside of your agency but still concerned with your geographic region, such as another local or State agency's risk assessment.
- After exhausting these resources, you might broaden your scope to surveying sources that are relevant to your context, but completed outside your agency's jurisdiction. To be useful, these studies ought to be dealing with similar risks and vulnerabilities as those faced by your agency.

In gathering resilience strategies, you will likely find that they fall into one of five categories (FHWA, 2020):

1. **Maintain and manage**: This involves frequent, relatively low-cost activities to maintain assets and infrastructure in a good state of repair. These strategies are performed with shorter timeframes in mind (e.g., responding to minor damages or preparing for near-term conditions). This can also involve operational strategies that help the department plan better and be more responsive to hazards.
2. **Redundancy**: This involves ensuring alternate routes and backup infrastructure/systems so that a disruption to the system or loss of infrastructure will not wholly remove the ability to provide a certain service.
3. **Protect**: This involves installing physical protection measures to shield assets and infrastructure from expected hazards. These strategies can employ both natural and hard infrastructure.
4. **Accommodate**: This involves changing plans, standards, operations, or other aspects of transportation planning and design in order to meet changing conditions with a continued level of performance.
5. **Relocate**: This involves moving assets and infrastructure out of vulnerable locations to decrease exposure to hazards.

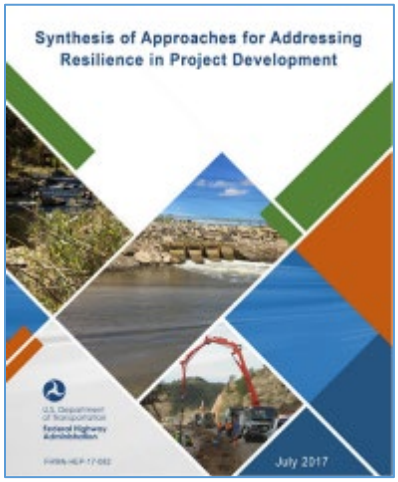


Figure 5-2. Synthesis of Approaches for Addressing Resilience in Project Development (FHWA, 2017d).

Table 5-1 below provides examples of resilience strategies under each of these categories. For more information on strategies and examples, please see the FHWA's *Synthesis of Approaches for Addressing Resilience in Project Development* (Figure 5-2) (FHWA, 2017d). This report provides strategies for each core engineering discipline, including coastal, riverine, geotechnical, and mechanical/electrical. While this handbook is focused on providing information on how to develop strategies, the synthesis report provides more detailed information on the strategies themselves.

Table 5-1. Examples of the Five Types of Resilience Strategies

Strategy Type	Possible Strategies	Example from State DOT Transportation Planning Document
Maintain and manage	Regularly fix minor damage (e.g., potholes); salt roads during icy conditions.	▪ Maintaining assets in a good condition to better withstand extreme weather (District DOT, 2014). ▪ Conducting "rehabilitation and repair of culverts… based on biannual inspections to maintain/improve hydraulic capacity and structural integrity" (District DOT, 2018). ▪ "Monitor storm water quantity and quality from MaineDOT porous pavement project(s)" (MaineDOT, 2017).
Redundancy	Have redundant paths for critical infrastructure (e.g., major highways, critical bridges).	▪ "Construct alternate routes or bypass roads" (FHWA, No Date). ▪ "Develop alternate routes and transportation system redundancy to maintain mobility during emergencies or natural disasters" (Oklahoma Transportation, 2020). ▪ "Accept loss of roadway and identify alternate route" (Rhode Island DOT, 2012).
Protect	Install wetlands and marshes in floodplains and along coasts; harden or elevate infrastructure.	▪ "Reinforce critical lifeline facilities… prioritize roads that provide connectivity in rural areas of the state" (FHWA, No Date). ▪ Plant trees to protect roads from snow (MaineDOT, 2017) ▪ Build a storage facility for passenger rail cars to protect them against storm damage. Install pumps, flood walls, and berms at maintenance facilities and rail stations (New Jersey DOT, 2015). ▪ Use of vegetated buffer or 'grassy strips' to protect roads from flooding and snow (Rhode Island DOT, 2012).
Accommodate	Install culverts and storm drains with a greater water flow capacity; permeable pavement; cool pavement; build to a more rigorous standard; avoid new development in vulnerable areas.	▪ Green infrastructure options for attenuating stormwater include: rain gardens, street trees, landscape areas, permeable pavement, and removing unnecessary paving (District DOT, 2014). ▪ Raising light rail substations and improving drainage. Install additional stormwater inlets and larger drainage pipes (New Jersey DOT, 2015). ▪ "Raising roadway profile to correct drainage and flooding issues. Includes earthwork and culvert replacement. Construction of stormwater management basin" (Ohio DOT, 2017). ▪ Integrate extreme weather conditions into design and engineering standards for transportation infrastructure and into all land use planning. "Avoid placing people and infrastructure in vulnerable locations" (Vermont DOT, 2009).
Relocate	Move roads, parking lots, and other infrastructure	▪ "Relocate roads away from shoreline…Clearly identify shoreline areas affected by climate change and…relocate at-risk transportation facilities" (FHWA, No Date).

	further from a coastline or floodplain.	▪ "Purchase property… to construct new storage track locations to store rolling stock above the advisory flood elevation." Relocate the primary maintenance facility if necessary (New Jersey DOT, 2015). ▪ Realign roadway on higher ground to accommodate sea level rise (Rhode Island DOT, 2012).

The tables that follow provide an example of how you might organize your findings as you gather strategies from your various sources. Table 5-2 provides example questions you might ask to identify strategies that address specific vulnerabilities. Table 5-3 provides examples of feasibility issues to keep in mind. Asking yourselves about these types of issues can help you gather strategies that are relevant to your needs. These tables can also help you clearly identify gaps throughout the process to understand when you may benefit from consulting additional resources or when you have sufficient information.

Asset(s)	Hazard	What makes it vulnerable?	How can you address this vulnerability?	Specific adaptation action
***Example*: Highway**	Sea-level rise	The highway is close to the shore and is inundated during storms.	Protect, Elevate, Relocate	Installing marsh habitat and riprap to absorb water and protect the highway.

Table 5-2. Example Questions for Identifying Strategies Addressing Specific Vulnerabilities

Asset(s)	Adaptation Action	Relative Costs	Feasibility	Consistency with other priorities
***Example*: Local roads**	Increase frequency of repair activities for potholes.	Medium	High	Improve mobility for underserved populations. Extend the service life of the pavement.

Table 5-3. Example Questions for Identifying Strategies Concerned with Feasibility

Even if you do not use a framework such as these tables, it will probably be a useful exercise to ask: what about this system or asset makes it vulnerable to these hazards? Is there a way to physically modify the structure to reduce its vulnerability? If not, is it possible to relocate this system or asset to a less vulnerable area or to create a more resilient detour route?

The sections below describe how you might go about this process of identifying strategies, starting with the easiest and most applicable sources.

5.2.1 Gather information on relevant resilience strategies from sources within your jurisdiction

Gathering information on relevant resilience strategies from sources within your jurisdiction is a key resilience integration action. There might already be sources such as vulnerability assessments, Transportation Asset Management Plans, FHWA case studies, or other research and reports that have looked at hazards within your jurisdiction and identified measures for addressing these hazards. These sources are an excellent starting point for gathering strategies, as it saves your team time and effort.

Learning from internal experience

Your own agency might already have studies that have come up with resilience strategies. This may have occurred during other steps in the planning process – particularly with defining problems and needs. The findings from the studies and screens conducted in Chapter 4 can provide insight into which areas within your jurisdiction are vulnerable, to what degree, and to which hazards. For example, Rockingham Planning Commission's (NH) 2015 *Tides to Storms* vulnerability assessment resulted in recommended resilience actions as well as maps with information on the extent and depth of projected sea-level rise and storm surge and the location of transportation infrastructure (Rockingham Planning Commission, 2015b).

Possible Questions to Ask Staff

The answers to these questions can provide insight into tested strategies within your jurisdiction.

- How have you resolved past issues?
- Could those solutions be proactively applied in other locations to decrease vulnerability?
- Do you have ideas for strategies that could decrease the impact of hazards?
- What parts of the infrastructure have failed in the past? What made them vulnerable?
- What parts did not fail, and what made them resilient?

Internal sources can include risk screens, vulnerability assessments, corridor studies, and other studies that in addition to identifying problems and needs, also identified potential adaptation strategies. Information on possible strategies does not only have to come from studies. There may be staff members within your agency who have dealt with disruptions and damages to the system. The experience of these personnel is a valuable source of insight on what does and does not work when it comes to protecting against and rebounding from hazards.

Examples of Sources

Sources that have already identified possible strategies for your jurisdiction will be the most direct and efficient way of collecting strategies. You might look to the following sources for this information:

Internal

- MPO or DOT risk or vulnerability assessments.
- Corridor studies.
- Transportation Asset Management Plan.

External

- Other State/local agency risk or vulnerability assessments.
- Local hazard mitigation plans.
- Local emergency management plans.
- Local college/university studies.
- FHWA case studies (Adaptation Case Studies and TEACR Studies).

Learning from external, overlapping studies

Your agency is likely not the only organization in your area developing plans to address natural hazards. Once you have looked through relevant internal plans to find the strategies that have already been identified by your agency, you might look to the plans and initiatives by other local agencies and organizations. Doing so is not only a source for inspiration, but can also boost coordination on resilience efforts in your region and can possibly lessen the burden for your own agency.

Coordinate to Avoid Maladaptation

Washington DOT (WSDOT) actively engaged the U.S. Army Corps of Engineers when they learned the Corps was undertaking a major flood study to determine how and where to invest in levees and other flood risk reduction projects (WSDOT, 2015). Transportation assets were likely to be affected by the outcomes of the study, but they were not the focus of the study. WSDOT engaged to help search for compatible long-term solutions that would create a more resilient transportation system. The key finding from the study was that without coordination, WSDOT and the Corps could have separately invested in adaptation plans that were in conflict with each other (i.e., maladaptation). This finding emphasizes the need to coordinate with overlapping studies within your planning area.

5.2.2 Gather information on resilience strategies from sources relevant to your context

Once you have exhausted the resources that overlap your agency's jurisdiction, you may identify remaining vulnerabilities that do not have identified strategies to address them. To fill these gaps, you might look to others who have already conducted studies, identified, and even implemented strategies. Start by looking to neighboring areas or other locations around the country that are dealing with similar risks. For example, the Washington, Oregon, and California DOTs worked together through a climate peer-exchange organized by FHWA (FHWA, 2012b). Your agency can also look to areas that are currently experiencing the conditions that are projected for your region in the future. For example, if your area is expected to experience temperature increases, you may look to see how transportation agencies in currently hot climates are dealing with high temperatures.

5.3 Request resilience ideas in calls for projects

Whenever your agency reaches out for new ideas for projects or services, encourage respondents to include ideas that will improve resilience, and remind potential applicants of your agency's commitment to improving resilience. Three potential options for integrating resilience considerations into your agency's calls for projects include:

- Encourage applicants to address known natural hazard vulnerabilities in your region or State through projects. Your agency might direct people to an existing report or provide a list of known natural hazard vulnerabilities for their consideration.
- Encourage projects that increase resilience through the inclusion of one or more of the five resilience strategy categories (see Section 5.2):
  - Maintain and manage
  - Redundancy
  - Protect
  - Accommodate
  - Relocate
- In addition to stand-alone resilience projects, encourage adding consideration of resilience to proposed projects. Adding resilience considerations to projects that are priorities for other reasons can be an efficient and effective way to increase resilience without taking away from other priorities. The added cost of a resilience component is likely smaller than a stand-alone resilience project, and smaller than retrofitting a project that is not designed with resilience in mind.

5.4 Evaluate and prioritize among resilience solutions

Sorting through the many proposed solutions and projects can be a daunting task. Setting up a system of evaluation and prioritization can help you to be more efficient and transparent. Such a process would start by applying the pre-established evaluation criteria (see Section 5.1) to enable you to focus on a smaller subset of candidates. Then you could prioritize among those based on a project's relative urgency, importance, cost, effort, and time needed for implementation.

Throughout all of this, your agency staff and leadership will also want to apply your working knowledge of what is feasible and palatable to your constituents. Formal processes necessarily simplify the factors that influence a decision-making process, and you will want to apply your local understanding to capture factors that might not be well represented in the formal process.

5.4.1 Apply pre-established evaluation criteria that include resilience considerations

To make the selection process more efficient and transparent, you can use pre-established evaluation criteria to assess how well the various proposals will address agency goals and priorities. See Section 5.1 for ideas on how to integrate resilience into such criteria. The application of these evaluation criteria and expert judgment will likely lead to three groupings of projects: those that score very highly and are obvious candidates for funding; those that do not score well and that might be removed from consideration; and those that fall in the middle range of scores. You can then focus your prioritization efforts on the highest-ranked candidates. If any of those turn out to be low priority items, then you can move on to the middle-ranks until you fill out your list of solutions to advance.

5.4.2 Prioritize resilience solutions based on urgency/importance and implementation feasibility

Prioritization approaches balance a variety of factors including two general categories of consideration: (1) Urgency/Importance and (2) Feasibility of Implementation, including considerations of cost, time, and level of effort required. This section describes some approaches to balancing these interests as you prioritize among solutions.

Table 5-4 below provides examples of how strategies vary by effort and urgency and how an agency might score these factors. Source: Adapted from Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance (FHWA, 2015a)

Table 5-5 then shows how that score can translate into an overall prioritization. Often, agencies assign higher priority to high-urgency projects. As illustrated in these tables, however, low-effort projects are sometimes also assigned high priority, as they might be cost-effective solutions that the agency can act upon without significant sacrifices or trade-offs with other objectives.

Table 5-4. Prioritizing Strategies Based on Timing and Importance/Urgency

Adaptation Strategies	Time Period for Implementation	Importance/ Urgency	Prioritization
Strategy takes 0-5 years to implement, but is not needed for another 30 years.	Short	Low	Low
Strategy takes 0-5 years to implement, but should be	Short	High	Medium

undertaken now to be effective.			
Strategy takes 30 years to implement, and should be undertaken now to be effective.	Long	High	High
Strategy should be undertaken soon because it will influence future decisions (e.g., long-term plans).	Ongoing	Medium	Medium

Source: Adapted from Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance (FHWA, 2015a)

Table 5-5. An Example Matrix for Prioritizing Projects Based on Urgency and Effort

	Low Effort	**Medium Effort**	**High Effort**
High Urgency	High	High	Medium
Medium Urgency	High	Medium	Low
Low Urgency	Medium	Low	Low

Your agency's method of prioritization using these factors will be influenced by your thresholds for what constitutes low, medium, and high urgency and effort. The questions and examples below can help your agency determine what these thresholds are and how you might consider how urgency and effort contribute to priority.

Urgency and Importance

Urgency: The question of urgency focuses on the likelihood and timing of the hazard increasing the risk of an event, and therefore how soon adaptation strategies need to be implemented to avoid damages. The questions below and the findings from Chapter 4 can help you determine urgency:

- What is the likelihood of the hazard in the short-, medium-, and long-term?
- If the hazard is projected to increase in frequency or intensity over time, when do you expect the hazard to create an impact on the transportation system?
- Is the hazard expected to impact the system before the next asset rehabilitation or reconstruction, or after the end of their useful life?
- How vulnerable is the asset or system in question? What would be the consequences of impact?

If your answers to these questions indicate that the hazard will occur far in the future, and the asset in question will likely be replaced before that occurrence of an event, then the urgency is likely low and you can wait to integrate resilience into the rehabilitation or replacement of the asset. If, however, the asset in question will still be useful when the hazard is projected to occur (e.g., a bridge built to last 100 years), then it is likely a higher priority to proactively increase resilience now.

On the other hand, if a hazard is already impacting the system or an event is likely to occur within your next planning cycle, then this would likely translate into higher urgency – prioritizing resilience now. In some circumstances, it may be recommended to implement a resilience strategy following a "trigger" event or threshold (e.g., when annual delays because of flooding exceed a specified number of hours, or putting in place flood-mitigation measures after a wildfire since burned areas can increase floods and debris flows).

Figure 5-3. "Trigger" events, such as exceeding a designated number of hours of delay because of flooding, may be used to spur implementation of resilience actions (Caltrans, 2018b).

Importance: The question of importance focuses on how great of an impact would be felt if the resilience strategies were not put in place now – if assets retained their current level of vulnerability. This focuses on high-risk, high-value assets, such as high-volume structures in poor condition, roads that are communities' only evacuation routes, slopes prone to failure, or assets subject to regulatory compliance (e.g., drainage structures in ecologically sensitive areas).

- What would be the consequences if certain vulnerable assets or systems were to be disrupted, damaged, or destroyed by events because of unaddressed hazards?
  - How necessary is the asset or system?
  - How dependent are the users of the transportation system upon the asset/system in question? Does the asset serve public transportation-dependent communities?
  - How much cost would be incurred in the event of a natural hazard impact?
  - How quickly could the asset be put back in service?
- Is there redundancy to the asset/system in question?

FHWA's *Incorporating Risk Management into Transportation Asset Management Plans* provides information on high-risk, high-value assets (FHWA, 2017b). Generally, highly important assets and systems that would cause major disruptions to normal functioning of the transportation system and loss of access to communities or would incur great costs to bring back to function would be given higher priority.

Redundancy can slightly reduce this prioritization, as redundancy is a resilience strategy in and of itself and affords your agency a backup plan in the case of an incident (assuming that the redundant route/asset is not vulnerable to the same hazards). For example, if you are expecting a major evacuation route to be vulnerable to flooding, it may be well worth your effort to prioritize strategies protecting that route, even if there is a low (but increasing) probability of flooding. For routes that are less busy (a

measure of importance) or less vulnerable, however, immediate action might not be needed. Table 5-6 as follows provides examples of how importance and urgency can interact as you prioritize.

Table 5-6. Examples of How to Determine Priority Based on the Interaction Between Urgency and Importance

	Low Importance	High Importance
Low Urgency	Low Urgency; Low Importance *Example: Sea-level rise is expected to inundate a minor road by the year 2099.* *Prioritization: Low priority to install a seawall.*	Low Urgency; High Importance *Example: Increased precipitation may increase scour and damage an important bridge.* *Prioritization: Medium priority to implement measures to better attenuate stormwater.*
High Urgency	High Urgency; Low Importance *Example: Wildfires regularly damage and block access to a bus stop that serves a small population, none of whom are dependent on transit.* *Prioritization: Medium priority to move the bus stop.*	High Urgency; High Importance *Example: Flooding regularly occurs at the central train station and is expected to worsen.* *Prioritization: High priority to install flood protection measures and create redundancies in the event of station closure.*

Feasibility: Cost, Effort, and Timing

Feasibility of implementation consists of an array of overlapping considerations related to cost, effort, and timing. Cost considerations generally ask whether the solution is expensive or affordable. Effort, which can influence cost and timing, is an indicator of how complicated or challenging the solution would be to implement. Timing considerations look at how long it would take to implement the solution to determine whether it fits within the current plan or program. Feasibility is tied to the question of urgency/importance in that highly urgent or important solutions (such as those that score highly on your evaluation criteria) might be worth a higher cost or effort.

Questions to consider when assessing feasibility include:

- How costly is the resilience strategy?
- How much time would it take to implement the strategy?
- How difficult is it to obtain the support and resources to implement the strategy?

DelDOT created a prioritization system in which each resilience strategy is assigned a score of 1-3 across four categories: Enabler (of another strategy), Impact, Cost, and Ease. Based on the outcome of the

prioritization, DelDOT developed three tiers of priority, which eventually contributed to their development of an implementation timeline (Delaware DOT, 2017):

- Tier 1 contained the most pressing and influential actions. All Tier 1 recommendations were suggested to commence immediately (2017).
- Tier 2 contained actions that were important for achieving their goals and objectives but that had less impact relative to the Tier 1 actions.
- Tier 3 contained the lower priority actions: those with less impact, those enabling fewer other recommendations, and/or that are more expensive and/or more complex to implement.

Table 5-7. Example of DelDOT's Prioritization Scheme (Delaware DOT, 2017)

Recommendation		Implementation Category				Total	Tier
		Enabler	Impact	Cost	Ease		
Continue development of geospatial data sets that can help identify vulnerable areas and help estimate the impact of reasonably anticipated events.		3	3	1	2	9	1
Integrate resiliency into project development, traffic, bridge, and highway design manuals.		3	3	2	1	9	1
Conduct comprehensive assessment of State roadway risks and assets.		3	3	1	1	8	2
Develop revised maintenance schedule in response to air quality.		1	1	2	2	6	3

Table adapted from *Strategic Implementation Plan for Climate Change, Sustainability and Resilience for Transportation* (Delaware DOT, 2017).

5.5 Recap of approaches to considering resilience while evaluating solutions

This chapter presented approaches to considering resilience while evaluating solutions (see Table 5-8). By using evaluation criteria and prioritization approaches, you can sort through the existing strategies and newly proposed strategies to identify resilience improvements to pursue.

Why Consider Resilience When Evaluating Solutions?

By including resilience in your agency's selection and prioritization of solutions, you can better ensure that strategies aimed at building resilience are included in your agency's final plans.

Table 5-8. Evaluating Solutions Recap

Integration Action	Key Action?	Potential Approaches
Add resilience considerations to your evaluation criteria	✓	▪ Include resilience as a topic in priority-setting discussions. ▪ Integrate resilience priorities into evaluation criteria.
Gather relevant resilience strategies identified in existing studies or plans	✓	▪ Gather information on relevant resilience strategies from sources within your jurisdiction. ▪ Gather information on resilience strategies from sources relevant to your context.
Request resilience ideas in calls for projects		▪ Encourage proposers to address resilience or to propose projects that will score well on resilience criteria.
Evaluate and prioritize among resilience solutions		▪ Evaluate based on pre-established criteria. ▪ Prioritize based on urgency/importance. ▪ Prioritize based on timing/effort/cost.

Chapter 6
Developing Transportation Plans

Chapter 6 Developing Transportation Plans

This chapter focuses on how to incorporate resilience into the long-range plans of MPOs (Metropolitan Transportation Plans) and State DOTs (Long-Range Statewide Transportation Plans) based on the information identified and developed in earlier steps of this handbook. The integration actions, while focused on the aforementioned types of long-range plans, are also applicable to other transportation plans, such as corridor plans and Transportation Asset Management Plans (TAMPs).

Importance and benefits of integrating resilience: The Long-Range Statewide Transportation Plan (LRSTP) and Metropolitan Transportation Plan (MTP), developed by State DOTs and MPOs respectively, typically have 20-year planning horizons, giving planners time to predict future needs of transportation system users and to begin to act to meet those needs. The drafting of these documents provides an opportunity to anticipate future threats from climate change, and begin making policy and investment decisions to mitigate potential risks from those threats.

The following typical steps provide opportunities for resilience:

- **Determine policy and investment priorities –** Some investment and policy choices might be mandated by law or policy, others will be based on your agency's vision for the future. This step is important for identifying how to build the resilience of the transportation system within the constraints of limited budgets and many competing priorities. Including resilience considerations when identifying policy and investment priorities will help ensure that risks from extreme weather and climate change are given appropriate weight alongside other risks and priorities.
- **Develop the plan's financial assumptions –** Agencies can include resilience as an element of their financial plan by identifying funding sources reasonably available for resilience improvements or by incorporating incremental funding to ensure the resilience of proposed projects. Agencies may benefit from consulting their State TAMP's sections focused on life-cycle planning and risk management, consulting sections in their State TAMPs focused on the financial plan and investment strategies for information on potential costs associated with addressing resilience and revenue sources, and working with State DOT staff that are assigned the responsibility of developing the TAMP.
- **Develop baseline and alternative scenarios –** In this step, your agency can request project ideas that include resilience, evaluate those recommendations, and package them into portfolios of investments. Current and future environmental conditions could also be a consideration when requesting projects, evaluating them, and developing scenarios.
- **Evaluate scenario impacts to develop the preferred scenario and adopt into long-range plan –** Once your agency identifies which scenarios to analyze, you can evaluate them and discuss trade-offs to determine which to adopt as the long-range plan's preferred scenario. By including resilience considerations in these discussions, you can improve the resilience of the transportation system.

Figure 6-1 illustrates the key sub-steps and possible resilience integration actions for transportation plans. The following sections provide detailed information about each resilience opportunity, including resources and tools to help your agency integrate resilience into your transportation planning processes.

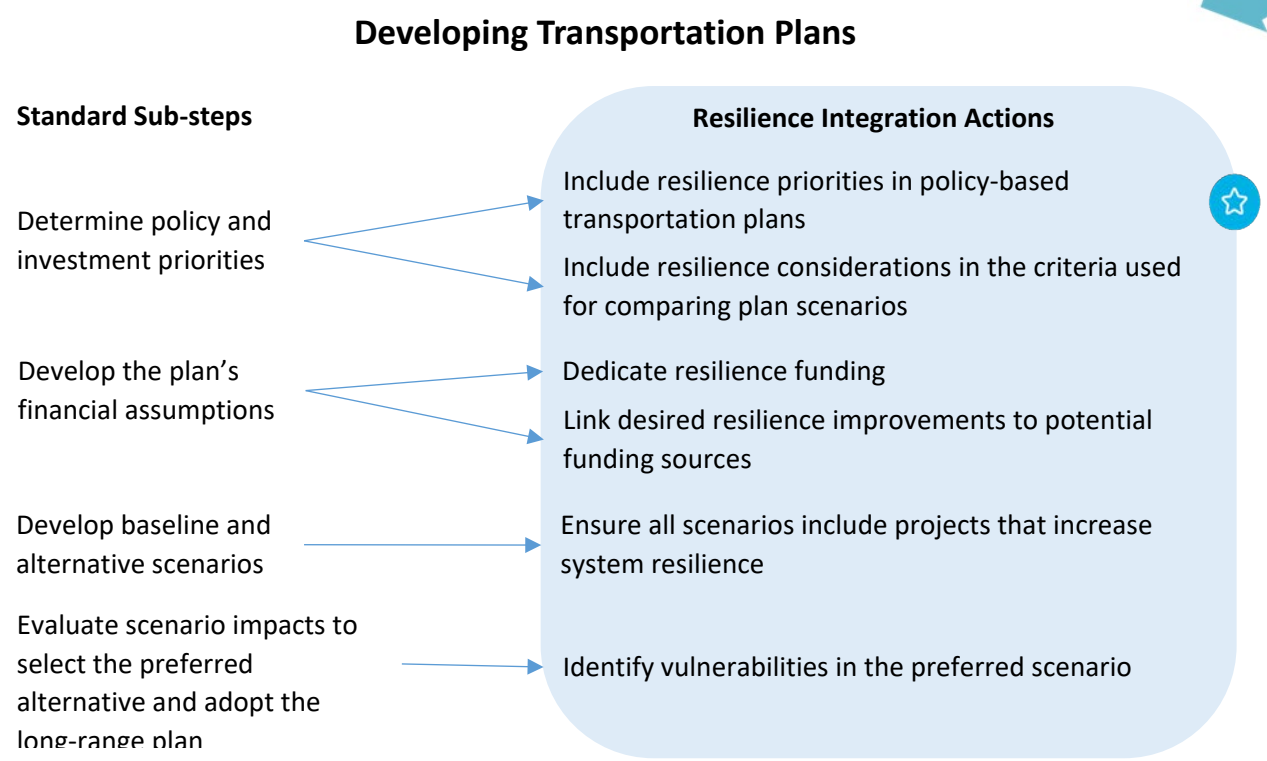


Figure 6-1. Key steps and resilience integration actions for developing transportation plans.

6.1 Include resilience when establishing priorities and evaluation criteria

When developing a long-range plan, you can integrate resilience throughout the plan by ensuring that resilience is included when you establish the strategic direction and priorities for the plan. The preceding chapters on setting goals and objectives (Chapter 3), defining problems and needs (Chapter 4), and evaluating solutions (Chapter 5) provide options for incorporating resilience as a priority through the phases of long-range plan development. Here, the handbook provides some approaches you can apply specifically to your long-range plan.

6.1.1 Include resilience priorities in policy-based transportation plans

Many State DOTs and land management agencies do not develop transportation plans focused on project-level concerns. Rather, they develop more broadly applicable policy-based transportation plans to outline focus areas for investments without explicitly stating what those investments will be.

If your agency is creating a policy-based transportation plan, you can engage internal and external stakeholders to determine how important of a factor resilience should be in developing agency policy. Chapter 2 provides suggestions on how to engage these groups to share information and how to communicate and collaborate. In addition to engaging stakeholders, you can consult existing plans, reports, and resource documents. Consult your State TAMP's risk management analysis, which may include identification of climate change risks and risk mitigation plans relevant to your agency's plan.

As one example of weighting agency goals, Hawaii DOT (HDOT) used stakeholder engagement to resolve the question of how resilience fits in among other goals. To reflect constituent priorities, HDOT created Stakeholder Advisory Committees (SAC) and Community Advisory Committees (CAC) to assign weights to each Federally-required planning factor and each State goal (FHWA, No Date). Each SAC was focused on an area like Environment, and each CAC was comprised of members from local communities. The results from the CAC and SAC weight assignment exercises influenced broader regional goal weights (Figure 6-2).

Figure 6-2. Hawaii DOT's method for weighting goals (FHWA, No Date).

System Preservation (at the time, the planning factor most related to resilience) was weighted the highest (31 percent) of the planning factors, and Environmental Sustainability was weighted at 4 percent. From among the 22 State goals, the second highest priority goal (weighted at 7.6 percent) was to "promote long-term resiliency relative to all hazards mitigation, namely global climate change, with considerations to reducing contributions to climate change from transportation facilities, and reducing the future impacts of climate change on the transportation system". (FHWA, No Date).

6.1.2 Include resilience considerations in the criteria used for comparing plan scenarios

If your planning process includes a comparison of scenarios or portfolios of potential projects (see Section 6.3), you can include resilience considerations in developing the criteria that you will use for evaluating scenarios. Your agency can return to their goals and objectives to identify evaluation measures that will help select a scenario which seems most appropriate for meeting your goals. For general information on creating resilience-related evaluation criteria, see Chapter 5; or read on for options specific to long-range plans. Consider identifying evaluation measures based on which severe weather events you anticipate impacting your transportation system, such as those you might have identified when defining problems and needs (Chapter 4). For example, a team of Federal, State, and local agency representatives collaborated on a pilot project in Cape Cod, Massachusetts to assess scenarios according to several resilience evaluation metrics, including vehicle miles traveled and percent of new population in areas vulnerable to sea level rise, erosion, and other severe weather-related events (FHWA, 2012a).

Key Resources for Establishing Priorities and Evaluation Criteria

- FHWA's INVEST contains system-level planning notable practices to help agencies evaluate their programs.
- Integrating Climate Change in Transportation and Land Use Scenario Planning: An Example from Central New Mexico provides lessons learned on using a scenario approach to prepare for the potential impacts of natural hazards.
- A Framework for Considering Climate Change in Transportation and Land Use Scenario Planning: Lessons Learned from an Interagency Pilot Project on Cape Cod provides information on the project's steps and offers observations and recommendations to help others.

You can also use your public outreach activities to identify your constituents' priorities and use those to guide your criteria. Constituents of the Mid-Region Council of Governments (Mid-Region COG) in New Mexico identified water sustainability and environment as key challenges for their region. To incorporate these concerns into their scenario planning process, the agency used the following criteria as part of their evaluation and comparison of scenarios:

- Greenhouse gas emissions;
- Water consumption; and
- Development in areas with a high risk to flooding and forest fire.

The comparison allowed Mid-Region COG to make decisions about their transportation system and the projects they would invest in based on potential climate futures (FHWA, 2015b).

6.1.3 Include resilience in Planning and Environment Linkages activities

The transportation planning process and the development of transportation plans also provides an opportunity to integrate resilience through Planning and Environment Linkages (PEL) which is a collaborative transportation decision-making approach that:

- considers environmental, community, and economic goals early in the transportation planning process, and
- uses the information, analysis and products developed during planning to inform the environmental review process.

Ultimately, the goal of PEL is early collaboration to facilitate better planning to inform National Environmental Policy Act (NEPA) reviews to accelerate project delivery. In the context of resilience, PEL enables a connection between resilience considerations that arise during the planning process to be carried through project development in an integrated fashion.

For more information, see FHWA's Planning and Environment Linkages webpage.

Figure 6-3. Benefits of PEL (FHWA, No Date)

6.2 Identify funding for improving resilience

Agencies have access to a wide range of funding programs that can be used to incorporate resilience into project implementation and will want to consider all possible sources, from creating dedicated sources to fund resilience to advising project sponsors how to fund resilience efforts using traditional sources.

6.2.1 Utilize resilience funding

In addition to using well-established federal aid funding programs such as the Surface Transportation Block Grant Program and the National Highway Performance Program, the Bipartisan Infrastructure Law (BIL) includes several federal and discretionary funding programs that can be specifically used to implement resilience, notably the Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) Program.[10] The BIL established the PROTECT Program and authorized $7.3 billion in formula funding to help make surface transportation more resilient to natural hazards, including climate change, sea level rise, flooding, extreme weather events, and other natural disasters through support of planning activities, resilience improvements, community resilience and evacuation routes, and at-risk costal infrastructure.[11] Guidance for this formula program describes the

[10] 23 U.S.C. 176.

[11] PROTECT Formula Program Fact Sheet

program purpose, governing authorities, funding, eligibility, resilience improvement plans, program evaluation and more in order to assist States in the implementation of PROTECT.[12]BIL also established the PROTECT Discretionary Grant Program. More information on this competitive grant program can be found here.

Some agencies are also creating resilience-dedicated funding for local agencies or setting aside technical assistance funds for resilience studies that can be accessed when needed. These new funding sources can be used to fund important resilience strategies that might not rise to the top as priorities when distributing traditional transportation funding. Some examples of States who have implemented new resilience funding legislation include:

- California passed a law creating an Adaptation Grant Program, designed to reduce damage to California's transportation system from extreme weather events by providing local and regional planners with funds to conduct vulnerability assessments, plan for evacuations because of extreme weather events, and evaluate adaptation strategies (Caltrans, 2018a).
- Massachusetts passed legislation authorizing $100 million in funding for "the design, construction, reconstruction, rehabilitation, retrofitting, repair or removal of coastal infrastructure and resiliency measures" (Commonwealth of Massachusetts, 2018).

If your State has a funding source, project sponsors may wish to include resilience strategies in projects submitted for traditional funding. You can make significant progress on funding resilience efforts if these dedicated resilience funds are used as a supplementary option to fund resilience rather than the primary or only source.

6.2.2 Link desired resilience improvements to potential funding sources

Consider assisting project sponsors by providing some advice about how to fund resilience strategies using traditional funding sources. It may help to categorize items as planning activities or as capital projects. Transportation agencies have access to funding or reimbursement through multiple Federal-aid programs for planning efforts and project development. These existing programs are applicable to resilience studies or improvements that might be listed in the long-range plan:

- Planning funding programs are eligible for conducting studies that can inform an agency about transportation system vulnerabilities.
- Project funding programs can be used to implement the findings of those studies, either by constructing new infrastructure or by adding protective features to existing assets.

[12] FHWA PROTECT Formula Grant Program (dot.gov)

6.3 Use scenario planning to increase system resilience

Scenario planning is an analytical tool that can provide a framework for developing a shared vision for the future by analyzing various forces (e.g., transportation, economic, environmental, land use, etc.) that affect growth. Scenario planning, which can be done at the statewide level or for metropolitan regions, tests various future alternatives that meet State and community needs. It is not meant to be a predictive model, but rather a method for understanding how the different drivers could impact future conditions.

PlanWorks

FHWA's PlanWorks helps transportation planners improve the development of transportation plans and projects. PlanWorks contains a section called Approve Plan Scenarios which offers questions to consider in creating baseline and alternative scenarios that cover a range of agency priorities.

Transportation planners using this technique often establish baseline and alternative scenarios, then compare scenarios across a wide range of metrics to develop a final scenario that best meets agency goals and objectives. In the baseline scenario, you would analyze your likelihood of achieving your goals if you undertook no new projects other than those that have already been adopted for implementation. In the alternative or build scenarios, you would compile one or more portfolios of projects and programmatic investments. Then you compare the forecasted outcomes of the build scenarios to the baseline scenario and to each other to determine which approach is most likely to help you reach your goals. These scenario planning processes often result in the adoption of a hybrid scenario into the long-range plan that uses the best-performing portions of each of the modeled scenarios.

To incorporate resilience when developing alternative scenarios, your agency could include a set of projects in one or more scenarios that will increase the overall resilience of the system. This could be addressed through a programmatic investment in resilience (see Hillsborough example below) or through targeted individual projects that address critically vulnerable locations. Scenarios without resilience investments are likely to require additional life-cycle maintenance funding (to respond to damage from extreme weather events) or additional capital costs (to replace structures destroyed by extreme weather events). Projecting these future costs (or the cost savings of acting) can help make the business case for resilience improvements, which can factor into the selection of the preferred scenario.

Resilience Strategy: Managed Retreat

Managed retreat requires foresight, a long implementation timeline, and a systems-level perspective on land use and transportation. This strategy focuses on moving assets and people away from known hazards rather than building additional protective structures to mitigate threats. Particularly for infrastructure threatened by erosion, flooding, or sea level rise, your agency might consider relocating assets or shifting investments to areas less at risk. The topic of managed retreat or disinvestment may be easier to discuss at the scale and timeframe of a long-range plan, rather than at the individual project level. Areas that may require managed retreat could be discussed early and in close collaboration with other agencies and the public.

If your agency uses evaluation criteria to evaluate solutions (see Chapter 5), consider using the results of those evaluations in developing scenarios that include projects that score high on resilience criteria. The overall level of investment and types of projects will likely vary from alternative to alternative. For

example, projects can range from smaller projects, such as the addition of mitigation infrastructure (e.g. floodwalls), to larger projects (e.g., elevated bridges).

One example of a programmatic approach to addressing resilience is Hillsborough County MPO (FL) The Hillsborough County MPO pilot project on identifying critically-at-risk infrastructure and geographic areas provides examples of integrating resilience into scenarios that would inform a long-range plan. Among other analyses, they developed three 20-year order-of-magnitude risk management investment scenarios after completing a vulnerability assessment to estimate the costs of different sea level rise/storm surge risk management strategies (Hillsborough County MPO, 2014):

- Base/low – Represents current levels of local and state funding spent on stormwater and drainage improvements in the county.
- Medium – Represents increased stormwater and drainage funding, covering present measures as well as improvements to low-lying Interstates during routine scheduled maintenance or reconstruction (e.g., upgrading to higher capacity pipes and inlets, raising the roadway, or installing wave attenuation devices).
- High – Encompasses all costs of the base/low and medium scenarios as well as the full deployment of mitigation strategies for arterial roadways and Interstates.

The cost of various risk management investments under the medium and high investment scenarios are shown in Figure 6-3 and the results informed the agency's decisions about what to include in the long-range plan.

	Unit	Unit Cost	Base/Low	Medium	High
Raise profile/strengthen base*	Lane mile	$268,883		$20,854,540	$68,807,075
Wave attenuation (WADs)	1 Unit	$750		$3,887,400	$17,628,600
Shoreline protection (riprap)	Linear ft	$350		$5,442,360	$24,680,040
Drainage improvements*	Cent mile	$14,737		$816,566	$816,566
TOTAL				$31,000,866	$111,932,281
Total plus contingency	20%			$37,201,039	$134,318,738

**Counts marginal cost only all cost are approximate*

Figure 6-4. Hillsborough County MPO cost estimates for various risk management investments using the medium and high investment scenarios. See Appendix B of the Hillsborough County MPO Vulnerability Assessment and Adaptation Pilot Project for more details (Hillsborough County MPO, 2014).

6.4 Identify vulnerabilities in the preferred scenario

Use your pre-established evaluation criteria to inform your selection of a preferred scenario to adopt. Once you have adopted the preferred scenario, you can use those same evaluation criteria or conduct additional assessments to identify the vulnerabilities of the preferred scenario.

Document these vulnerabilities and provide them to project sponsors so resilience is considered during the scoping and design of the project. For example, coastal communities that will be impacted by sea-level rise might choose to look at the amount of vehicle miles traveled that is forecasted to occur on roadways that will be under water in the forecast year. Early identification of vulnerabilities can help project developers to design and implement adaptive solutions.

6.5 Recap of Approaches for considering resilience while developing a transportation plan

This chapter presented four core approaches to considering resilience while developing transportation plans (see Table 6-1). These approaches include strategies for policy-based and project-based plans, and encourage engaging stakeholders to ensure the plan accurately addresses the needs of the local community.

Why Consider Resilience When Developing a Transportation Plan?

By including resilience considerations in your transportation plan, you lay the groundwork for implementing policies and projects that will reduce your transportation system's overall vulnerability to natural hazards.

Table 6-1. Developing Transportation Plans Recap

Integration Action	Key Action?	Potential Approaches
Include resilience when establishing priorities and evaluation criteria	✓	▪ Consider public engagement activities which can accurately assess constituent priorities. ▪ Engage internal stakeholders to determine the relative importance of multiple goals. ▪ Create a policy to support local agencies to develop their resilience options. ▪ Use these priority-setting discussions and policy documents to develop criteria for evaluating plan scenarios.
Identify funding for improving resilience		▪ Utilize any specific resilience funding sources in your State or agency. ▪ Link desired resilience improvements to existing transportation funding sources.
Use scenario planning to increase system resilience		▪ Vary the level of investment in projects which increase system resilience when conducting scenario planning exercises. ▪ Identify target areas for investment where resilience projects would have the most substantial impact.
Identify vulnerabilities in the preferred scenario		▪ Document the preferred scenario's potential future vulnerabilities to natural hazards, and pass that information along to project sponsors so they may consider it during project design and scoping.

Chapter 7
Other Studies and Work Plans

Chapter 7 Other Studies and Work Plans

Your agency may produce other plans or conduct intermediate studies and scoping prior to developing your transportation improvement programs (TIPs). These intermediate studies can help your agency prepare for the TIP by developing a short-term work plan or longer-term strategic or investment plan to follow, studying a specific corridor, or integrating your asset management plan into the STIP/TIP. Your agency can use these intermediate studies to establish a better understanding of the problems and needs, cost, scope, and readiness for any projects that might later be proposed. In addition, your agency can use these intermediate studies and plans to take a closer look at specific issues such as resilience and ensure consistency across various plans.

Resilience Improvement Plans are also important studies that are not specifically discussed in this chapter. Information specific to the development of Resilience Improvement Plans can be found in the forward of this document and in the program guidance for the PROTECT Formula Program.[13] In a mature transportation planning process where resilience is fully integrated, Resilience Improvement Plans will likely impact the development of the long range transportation plan which will in-turn inform the development of a STIP/TIP.

Importance and benefits of integrating resilience: This step provides an opportunity for your agency to refine and reiterate the information collected on risks and vulnerabilities to current and future environmental conditions through additional studies and work plans that may be developed between the transportation plan and the TIP or in parallel with the planning cycle. These studies and work plans allow your agency to take a more detailed look at resilience challenges and opportunities by, for example, studying a specific corridor or researching a particular topic in more depth. These studies and work plans can help your agency understand at a more localized scale where your agency may need to invest in resilience and what resilience strategies are most appropriate to implement.

There may also be opportunities to add a resilience component to other studies and work plans and ensure consistency in addressing resilience across multiple plans. For example, if your strategic plan already addresses resilience, your other plans could draw on and compliment the resilience component of the strategic plan. In addition, particularly for rural areas not covered by regional transportation plans, these intermediate studies and work plans might be the first occasion your agency (especially State DOTs) has to consider resilience in the planning process for these non-metropolitan areas.

Table 7-1 provides a sample list of common types of plans that provide opportunities to consider resilience. This chapter takes a deeper dive into integrating resilience into short-term work plans, longer-term strategic plans or capital investment plans, corridor planning studies or other sub-area studies, and asset management plans.

[13] FHWA PROTECT Formula Grant Program (dot.gov)

Table 7-1. Common Types of Plans that Provide Opportunities for Resilience.

Plan Type	Why consider integrating resilience into this plan?	Example of how to integrate resilience
Asset management plans	These plans are an important management tool for operating, managing, monitoring, and evaluating your assets. Asset management systems also consolidate valuable data on assets that your agency can use in resilience planning.	See Section 7.4.
Bicycle and pedestrian plans	Bicycle and pedestrian planning offers opportunities for reducing impervious surface and controlling stormwater runoff, which can reduce the severity of water-related hazards. After extreme events, bicycle and pedestrian modes might be the most reliable means of conveyance, and bicycle and pedestrian infrastructure is generally easier and less expensive to replace.	Bicycle and pedestrian facilities are particularly well-suited to the use of permeable materials, and plans can prioritize their use where appropriate.
Corridor planning studies or other sub-area studies	These studies identify and increase understanding of the range of specific needs (e.g., traffic congestion relief) for a particular corridor or area, which can then be addressed in later planning steps or in the next planning cycle. To address resilience concerns, your agency can choose to conduct a study on the impacts of a specific vulnerability (e.g., flooding) on a corridor or add resilience considerations to an existing corridor study.	See Section 7.3.
Environmental justice-related studies	Environmental justice activities should identify, analyze, and address disproportionate and adverse human health and environmental effects (including risks) and hazards of Federal activities, including those related to climate change and cumulative impacts of environmental and other burdens on communities with environmental justice concerns. Environmental justice communities may be more vulnerable to natural hazards, such as having fewer options for evacuating or for accessing	Assess whether minority populations and low-income populations are equitably benefiting from resilience efforts. Determine whether these populations face heightened exposure risk, and identify steps to reduce that risk to levels experienced by other populations.

	emergency relief services. Because of these issues, extreme weather events could potentially have a more severe impact on environmental justice communities.	
Freight plans	Freight plans improve the coordination of transportation services for the movement of goods. Natural hazards and extreme events create a variety of threats to freight movement, including port and pipeline closures, flooding, releases of hazardous materials, saltwater intrusion, and loss of power to essential equipment. Disruptions to freight movement can create significant economic losses. Resilience planning can help improve industry coordination and develop adaptation strategies to improve resilience of freight movement.	Identify alternative routes and modes for maintaining freight movement if primary facilities are damaged in an extreme weather event. Identify freight infrastructure that is of high value and at high risk; identify adaptation strategies applicable to those assets.
Longer-term strategic plans or Capital Improvement Plans	Some State DOTs use these plans to track State funding of specific construction projects in the pipeline, but with a longer time-horizon than the TIP. For example, your agency may have a 10-year capital improvement plan that contains more specifics about each project than the LRTP. These plans provide an opportunity to detail the implementation of resilience strategies as part of existing or new projects. Other agencies might use these strategic plans to guide and influence other plans; adding resilience to the overall agency strategy can then permeate into other agency plans.	See Section 7.2.
Short-term work plans	These plans include Unified Planning Work Programs (UPWP) and State Planning and Research (SPR) work programs, which typically detail actionable next steps following the adoption of the long-range plan, or identify information that can support prioritization criteria or performance measures, or specific studies or funding. These studies offer an opportunity for resilience planning	See Section 7.1.

	and may help to identify problems and needs (Chapter 4) and potential solutions (Chapter 5).	
Transportation Systems Management and Operations Plans	Transportation Systems Management and Operations (TSMO) Plans outline the strategic, programmatic, and tactical objectives for TSMO and the steps needed to achieve them by highlighting existing capabilities and potential vulnerabilities. TSMO is an integrated set of strategies to optimize the performance of existing infrastructure through the implementation of multimodal and intermodal, cross-jurisdictional systems, services, and projects designed to preserve capacity and improve safety, mobility, and reliability of the transportation system while rapidly recovering from disruptions.	Consider TSMO solutions that reduce congestion, which can also improve GHG emissions. Consider vulnerabilities of identified TSMO strategies to natural hazards using the vulnerability assessment and resilience framework outlined in Chapter 4.

Maintaining consistency between various planning documents is key to building a resilient transportation network. Coordinate with internal and external stakeholders and other agencies to ensure planning documents are consistent in how they approach resilience and to ensure there are not duplicative efforts. Each plan can likely benefit from the resilience strategies or data from other plans.

Key questions to consider when integrating resilience into any of these plans or studies are listed in the textbox below. These questions are modified from a Planning and Environmental Linkages (PEL) questionnaire (FHWA, 2016c).

Key Questions to Consider for Other Studies and Work Plans

- Are you including natural hazards and resilience in the scope of the study?
- Are you including resilience in the purpose and need statement?
- Do your planning assumptions include climate change?
- Has the asset been directly affected by natural hazards in the past?
- Are you considering alternatives that would be more resilient?
- Are you involving key stakeholders (e.g. asset managers, scientists, engineers, etc.)?
- Are you coordinating with others who may be implementing natural hazard or resilience-related projects in the area?
- Does this study sufficiently address resilience issues or will you need additional follow on studies?

Figure 7-1 illustrates the key sub-steps and possible resilience integration actions for other studies and work plans. The following sections provide detailed information about each sub-step and associated

resilience opportunities, including resources and tools to help your agency implement resilience into your transportation planning processes.

Other Studies and Work Plans

Standard Sub-steps	Resilience Integration Actions
Develop short-term work plans	Integrate resilience into short-term work plans
Develop longer term strategic plans or capital investment plans	Integrate resilience into longer term strategic plans or capital investment plans
Conduct corridor planning studies or other sub-area studies	Integrate resilience into corridor planning studies or other sub-area studies
Develop asset management plans	Integrate resilience into asset management plans

Figure 7-1. Key sub-steps and resilience integration actions for other studies and work plans.

7.1 Integrate resilience into short-term work plans

Some agencies develop interim work plans between the long-range plan and TIP/STIP as an intermediate step in the planning process. These short-term work plans provide an opportunity for your agency to identify actionable next steps for increasing the resilience of your transportation system. Examples of short-term plans include:

- MPOs are required to have a UPWP, which outlines their planned priorities and activities (e.g., vulnerability assessments, corridor studies) for the next fiscal year annually or biennially.
- DOTs often have a State Planning and Research (SPR) work program or a program that similarly outlines a short-term research strategy for supporting an agency's goals and objectives.
- Any other 1-year internal management plans or other short-term work plans.

Your agency can integrate resilience into short-term work plans by including research and planning projects to address needs that were identified over the course of the long-range planning process. The following questions can help identify relevant research needs:

- What resilience-related ideas or strategies were too complex or resource-intensive for your agency to address in this planning cycle?
- Were there any research or knowledge gaps that prevented your agency from moving forward with any resilience strategies?

- What resilience-related ideas or strategies would your agency like to prioritize to address in the next planning cycle?
- What actions can your agency take now to begin preparing for the next planning cycle?
- Did any existing plans identify research needs related to resilience?

Based on the responses to these questions, consider designing projects to help your agency better understand risks and move towards implementing and mainstreaming resilience strategies. These actions may include research studies, planning and structural investments, operational strategies, or funding programs. The appropriate next steps for your agency will vary, but may include:

- Forming partnerships and increasing collaboration between different stakeholders, agency departments, and transportation system owners in particularly vulnerable locations.
- Organizing an interdepartmental team to discuss design procedures to account for changing future flood patterns or other risks that may change in the future. Your team may include engineers, planners, and asset managers.
- Conducting targeted research studies to address any knowledge gaps. These studies can be included in your agency's research program.
- Conducting corridor studies to further evaluate the vulnerabilities of a specific corridor. These studies allow your agency to focus on the vulnerabilities and conditions of a specific area and gather institutional knowledge from all involved stakeholders (e.g., business owners, residents).
- Pursuing additional funding opportunities, such as grants to ensure your agency has the funds necessary to implement resilience strategies as well as fund resilience projects put forth by municipalities.

7.2 Integrate resilience into longer-term strategic plans or capital improvement plans

Agencies may also have a variety of longer-term strategic plans or capital improvement plans. Strategic plans detail the vision and policy direction of the agency while capital improvement plans detail specific projects in the pipeline. Transportation projects are listed based upon delivery schedules, regional and statewide goals and targets for infrastructure performance and condition, and expected funding availability. Many agencies document the State budget process that determines amounts available for highway and bridge projects. For example, your agency may have a capital improvement plan that is more specific than the LRTP, but a longer time-horizon than the STIP.

Minnesota DOT (MnDOT), for example, used a 10-year Capital Highway Improvement Plan, updated annually to reflect the next ten years of planned investments (MnDOT, 2018). Meanwhile, MnDOT's LRTP has a 20-year time horizon, while its STIP reflects the next 4 years of projects. See Chapter 6 and Chapter 8 for information on integrating resilience into the LRTP and STIP/TIP respectively.

Similar to short-term work plans, longer-term strategic or capital improvement plans provide an opportunity to expand on the details of certain projects or policies, including any resilience

considerations. Key questions to consider when integrating resilience into longer-term strategic or capital improvement plans include:

- What is the time horizon of your agency's resilience strategies? What are the intermediate next steps and what is the timeframe for implementation?
- Are there certain projects in the pipeline that could benefit from the addition of a resilience strategy? What are the steps to implementing that strategy in combination with the pipeline project?
- Are there certain resilience-related projects that could be added to the pipeline? What would the specifics of the project be and how would it be implemented?

North Jersey Transportation Planning Authority (NJTPA) integrated resilience considerations into its Regional Capital Investment Strategy, which outlines investment principles and guidelines to inform project selection and policy direction for the 2045 LRTP (NJTPA, 2017b). The strategy identifies increasing regional resiliency as one of NJTPA's investment principles, stating that "investments should be made to mitigate risks associated with climate change, extreme weather, homeland security, and other threats. Investments should consider criticality of infrastructure, vulnerability, and level of risk." A few of NJTPA's investment guidelines for increasing regional resiliency include (NJTPA, 2017b):

- Prioritize transportation investments that offer additional benefits for resiliency, for system preservation projects as well as upgrades and expansions.
- Incorporate vulnerability and risk assessments into project development.
- Scrutinize investments that are in places highly vulnerable to potential flooding/sea level rise.
- Invest in alternate fuel infrastructure in support of energy independence.

7.3 Integrate resilience into corridor planning studies or other sub-area studies

Corridor planning studies provide an opportunity to engage with your local stakeholders and take an in-depth look at resilience challenges for a specific area or asset.

Resilience concerns may be added to routine corridor studies as an additional factor, or they may be the driving reason for the study. As flooding becomes more routine and ever more prevalent, there will likely be an increased need to focus corridor studies on these concerns. An example of a corridor study with a flood resilience focus is highlighted in the textbox below.

Example of Integrating Resilience into Corridor Studies

The **Metropolitan Transportation Commission (CA) (Kimley Horn and AECOM, 2018)** prepared a corridor plan for State Route 37, which includes an assessment of sea level rise in addition to congestion. The roadway currently experiences periodic closures because of flooding and may experience permanent flooding towards the end of the century. The corridor study resulted in a phased adaptation approach with short-term (protect), medium-term (protect/accommodate), and long-term (accommodate) approaches. This phased approach aligns with the adaptive management concept outlined in Section 10.3 of this document.

The opportunities to integrate resilience into these studies are similar to the integration actions described in the previous chapters:

- **Scope:** Incorporate resilience into your corridor plan's scope. This process includes engaging with resilience-related resource agencies such as State or local hazard mitigation planning experts to solicit their input throughout the planning or study process. Additionally, because of the small scale of corridor studies, your agency has the benefit of being able to engage with all or most stakeholders who live, work, or regularly interact with the corridor under review to help determine the scope of the study. See Section 2.3 for more information on engaging external stakeholders.
- **Public outreach and engagement:** Increase local buy-in and understanding of the importance of resilience investments through public outreach and engagement. Specialized studies provide a unique opportunity for your agency to engage with those who are within the geography of the study or project and directly impacted by the specific vulnerability being studied. Public engagement is critical for increasing support for resilience investments as well as gathering local knowledge and immediate feedback on the scope and details of the project. See Section 2.4 for more information on engaging the public.
- **Problem statement:** Include resilience in the study's problem statement by identifying any known natural hazard risks. This step can build on the problems and needs identified in Chapter 4 but may require a more thorough analysis of specific problems and needs related to transportation, community, and environment at the corridor-level. Questions to consider include (FHWA, 2015c):
  - Does the problem statement reflect the full range of objectives, outcomes, deficiencies, problems, issues, opportunities, and desired performance characteristics in the corridor?
  - Are there potential solutions beyond traditional transportation investment and policies, such as land use management or resilience strategies?
- **Goals and objectives:** Establish goals and objectives for the study, including improving resilience. See Sections 3.2 and 3.3 for more information on developing resilience goals and objectives. The goals and objectives for your corridor study may be more specific and tailored than those identified in your long-range plan. Your agency can also gather input from stakeholders on the goals and objectives of the study through public meetings, surveys, or other communication methods. The following questions are important to keep in mind during this process (FHWA, 2015c):
  - Are the goals consistent with other plans and programs?
  - Do the goals enable development of measurable objectives and performance metrics?
  - Are the goals appropriate and broad enough to allow consideration of all the problems and opportunities?
  - Are the goals broad enough to incorporate all stakeholder interests?
- **Environmental considerations:** Include resilience in the study's high-level consideration of potential environmental impacts by screening for potential natural hazard risks. See Section 4.2 for more information on conducting a natural hazard exposure screen. Types of data may include (FHWA, 2015c):
  - GIS data and layers for the corridor, including natural hazard layers, if available.

  - Analysis to reconcile or validate existing data, including data on natural hazards and climate change.
  - Detailed analysis of fiscal and physical operational needs of the corridor.
  - Field survey data, such as observed natural hazard impacts from a recent event.

- **Evaluation criteria:** Include resilience considerations in the evaluation criteria that your agency will use to compare potential solutions. Evaluation criteria can be designed to help differentiate between potential solutions and support the study's goals and objectives. It is important to engage stakeholders in the development of evaluation criteria to ensure the top solutions meet their needs. See Chapter 5 for more information on developing evaluation criteria.
- **Potential solutions:** Determine a range of potential solutions, including those that improve resilience. This process is critical for identifying projects for the STIP/TIP or intermediate work plans. Corridor studies can provide more accurate information on the costs and implementation of projects as these projects are not fully scoped when first listed in the LRTP. It is important to engage with stakeholders and be transparent about the solutions evaluation process to ensure the recommended solutions address their needs. See Chapter 5 for more information on evaluating solutions.
- **Prioritize solutions:** Identify readiness actions and sequencing needs to help prioritize solutions for implementation. A second set of evaluation criteria, measures, and methods is developed for prioritizing the implementation of the prioritized solutions. See Section 5.4 for more information on prioritizing solutions. Key questions to consider include (FHWA, 2015c):
  - What factors will play a role in project sequencing?
  - How will factors be weighted or considered in the implementation plan?
  - How will the technical analysis (e.g., natural hazard risks and vulnerabilities) impact the criteria in comparison to cost, public support, or project feasibility?

More commonly, your agency is likely conducting corridor studies on issues other than natural hazard resilience, such as pedestrian safety. However, these corridor studies still provide opportunities to integrate resilience, particularly in the range of possible solutions. For example, if the solution to pedestrian safety is to put a buffer between the street and sidewalk, your agency could choose to implement an impervious buffer that improves pedestrian safety but exacerbates stormwater runoff, or implement a type of buffer that will not only improve pedestrian safety, but also improve stormwater management among other benefits. These buffers might include:

- Grass for water absorption.
- Permeable pavements to avoid excess stormwater runoff but maintain a traversable surface.
- Raingardens to manage stormwater and provide a pollinator habitat.

7.4 Integrate resilience into asset management plans

Integrating resilience into asset management plans is a key resilience integration action. State DOTs are required to develop a risk-based asset management plan (TAMP) for the National Highway System (NHS) to improve or preserve the condition of the assets and the performance of the system.[14] TAMP requirements were amended by the BIL (§ 11105) to require that States take into consideration extreme weather and resilience within their lifecycle cost and risk management analysis. (23 U.S.C. 119(e)(4)(D)). The risks that can affect the condition of NHS pavements and bridges and the performance of the NHS include risks associated with current and future environmental conditions, such as extreme weather events, climate change, seismic activity, and risks related to recurring damage and costs as identified through the evaluation of facilities repeatedly damaged by emergency events carried out under 23 CFR part 667.[15]

FHWA's *Incorporating Risk Management into Transportation Asset Management Plans* provides some general information on integrating risks into the TAMP (FHWA, 2017b). Further, State DOTs are required under 23 CFR 515.9(h) to integrate their asset management plan into the transportation planning processes that lead to the STIP. FHWA's *Addressing Resilience to Climate Change & Extreme Weather in Transportation Asset Management* is designed to help transportation practitioners incorporate natural hazard resilience into asset management (FHWA, 2023).

The TAMP likely contains useful asset data and information that can help to inform multiple stages of the planning cycle, as well as other studies and work plans, ensuring consistent application of asset data such as (FHWA, 2021):

- Asset management objectives, performance measures, and targets.
- Asset conditions.
- Performance gaps.
- Life cycle planning.
- Risk management analysis
- Financial plan.
- Asset management strategies and investment strategies.

Your agency may also be able to use asset data from the TAMP to assess any trends or responses to natural hazards and climate change. For example, your agency may find that an asset or asset group is deteriorating faster than expected, perhaps because of repeated extreme events like heat waves or flooding. Therefore, your TAMP may consider environmental projections over the lifespan of the asset(s) and how changes in environmental conditions may affect deterioration and management options. This analysis may help to influence other plans and decision making. For example, it may reveal a need to

[14] 23 U.S.C. 119(e)

[15] 23 CFR 515.7(c)(1))

accelerate certain projects in the pipeline of your LRTP. The steps of the planning cycle, such as defining problems and needs, and the TAMP can work in parallel to inform each other and identify and address resilience challenges.

The Northeast Ohio Areawide Coordinating Agency (NOACA) (OH), for example, has woven resilience throughout many of its planning documents, including its TAMP, LRTP, strategic plan, and water quality plan. Each of these plans help to inform the others and build on the same definition of resilience. The TAMP (NOACA, 2017c) and LRTP (NOACA, 2017a) are particularly intertwined. For example, NOACA developed a risk assessment and risk register as part of its TAMP to better understand the likelihood and consequences of natural hazard risks to the transportation network. The results helped to inform the LRTP, particularly for understanding problems and needs.

Coordinating with Land Use Planning

The best transportation planning cannot create a resilient community unless land use planning also focuses on resilience. Land use planning and transportation planning directly affect one another. As a result, it is important to coordinate and integrate transportation network resilience efforts into the land use planning process. Otherwise, land use decisions may not support a resilient transportation network. A number of resources are available to help your agency coordinate land use and transportation planning efforts, including:

- *FHWA Planning Processes: Land Use and Transportation*: Provides an overview as well as various tools and resources for coordinating land use and transportation planning efforts (FHWA, 2017a).
- *PlanWorks Land Use Application*: Identifies opportunities and provides discussion questions centered on integrating land use considerations into various stages of the LRTP (FHWA, 2015c).
- *Integrating Climate Change in Transportation and Land Use Scenario Planning – An Example from Central New Mexico*: Case study example of integrating natural hazard and changing future environmental condition considerations into both transportation and land use planning (FHWA, 2015b).
- *A Framework for Considering Climate Change in Transportation and Land Use Scenario Planning – Lessons Learned from an Interagency Pilot Project on Cape Cod*: Case study example of integrating natural hazard and changing future environmental condition considerations into both transportation and land use planning (FHWA, 2012a).
-

7.5 Recap of approaches to considering resilience in other studies and work plans

This chapter presented four core groupings of other studies and work plans that offer opportunities for considering resilience (see Table 7-2). See the textbox for the list of other studies and work plans discussed in this chapter. Potential approaches range from including projects/investments in short or longer term plans that target better understanding natural hazard and extreme weather risks or the implementation of resilience strategies, to coordinating with and utilizing asset data from your TAMP. Consistency and coordination between different planning documents, agencies, and stakeholders is key to establishing a resilient transportation network.

What Other Studies and Work Plans Offer Opportunities for Resilience Considerations?

- Bike/ Pedestrian and Active Transportation Plans
- Environmental Justice and Equity-related Studies
- Freight Plans
- UPWP
- State Planning and Research Work Program
- Capital Improvement Plan
- Long-Term Strategic Plan
- Corridor Planning Studies
- Asset Management Plan
- Land Use and Comprehensive Plans
- Programmatic Mitigation Plans
- Safety Plans

Table 7-2. Other Studies and Work Plans Recap

Integration Action	Key Action?	Potential Approaches
Integrate resilience into short-term work plans		▪ Design and include projects (e.g., research studies, planning and structural investments, operational strategies, funding programs) in short-term work plans (e.g., UPWP or SPR) to help your agency better understand risks and move towards implementing resilience strategies.
Integrate resilience into longer term strategic plans or capital improvement plans		▪ Utilize longer term capital improvement plans to expand on the details of certain projects, including any resilience considerations.
Integrate resilience into corridor planning studies or other sub-area studies		▪ Incorporate resilience into the scope. ▪ Increase local buy-in and understanding of the importance of resilience investments through public outreach and engagement. ▪ Include resilience in the problem statement by identifying any known natural hazard risks. ▪ Establish goals and objectives, including improving resilience.

		▪ Include resilience in the study's high-level consideration of potential environmental impacts by screening for potential natural hazard risks. ▪ Include resilience considerations in the evaluation criteria for comparing potential solutions. ▪ Determine a range of potential solutions, including those that improve resilience. ▪ Identify readiness actions and sequencing needs to help prioritize solutions for implementation.
Integrate resilience into asset management plans	✓	▪ Utilize asset data to assess any trends or responses to natural hazards and climate change. ▪ Analyze environmental projections over the lifespan of the asset or group of assets and how changes in environmental conditions may affect deterioration and management options.

Chapter 8
Developing the STIP and TIP

Chapter 8 Developing the Statewide Transportation Improvement Program (STIP) and Transportation Improvement Program (TIP)

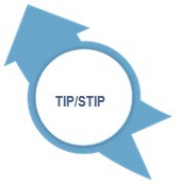
Whereas the long-range transportation plan typically has a 20-year planning horizon, the Statewide Transportation Improvement Program (STIP) and an MPO's Transportation Improvement Program (TIP) describe the portfolio of projects that an agency plans to fund over the next four years. The portfolio of projects in the STIP or TIP is consistent with the recommendations of the long-range plan, and guided by the projected available funding sources. Given the shorter horizon, there is more certainty in projected sources of funding and the set of projects for implementation is more concrete. To develop a STIP or TIP, your agency will identify available funds for transportation projects and select projects to fund for the applicable timeframe.

Importance and benefits of integrating resilience: A transportation system can become more resilient if there is funding available and if resilience is considered in project design. For any project to be funded with funds administered by FHWA or FTA (resilience projects or otherwise), the project must be in the STIP/TIP.[16]

The following typical STIP/TIP development sub-steps provide opportunities for resilience:

- **Identify revenue and funding sources –** At this point in the transportation planning process, your agency will identify any restrictions or requirements on use of funds to determine which revenue sources can be used for which projects. It is valuable to identify which funding programs can be used for adaptation-specific projects (most funding sources are likely eligible). Projects that are primarily motivated by other needs, but which contain resilience elements, can likely be funded from a single funding source.
- **Develop a method for identifying project costs and benefits –** It is important that a project cost methodology is consistent so that project costs are developed uniformly, to allow for meaningful comparison between projects. Including resilience components as part of estimating project costs and benefits reflects the value of resilience improvements in areas like operations and maintenance. Resilient infrastructure may have reduced life-cycle costs, because of a decreased risk from extreme weather events.
- **Develop criteria for allocating revenue –** After identifying available revenue and determining project costs, your agency will make decisions on which projects can be funded. Developing criteria to select projects for funding reduces bias from the selection process and helps to ensure that the final list of projects for implementation address a wide range of agency goals, including system resilience.
- **Develop a 4-year project list –** At this point in the planning process, your agency will develop a 4-year list of projects from the long rang plan or corridor plans for funding. Each project or project phase included in the TIP/STIP must be consistent with the metropolitan transportation

[16] 23 CFR 450.222, 450.332(d).

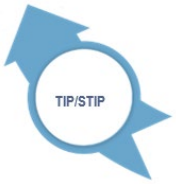


plan or long-range statewide transportation plan.[17] Part 667 of 23 CFR also requires periodic evaluation of facilities repeatedly requiring repair and reconstruction due to emergency events. The transportation system can be made more resilient if your agency pursues projects that incorporate countermeasures to known vulnerabilities, so it is important to know how certain projects would improve the overall system's ability to respond to and withstand severe weather events.

- **Prioritize projects for implementation –** Once your agency has a list of potential projects to be funded, you will prioritize those projects to determine the sequence in which to make investments. Considerations include the associated costs of projects, ability to deliver projects, and the fiscal constraints of your agency. The projects on the prioritized list are the projects that will be constructed in the near-term. Including projects in the STIP or TIP with countermeasures to known vulnerabilities helps to increase the resilience of the transportation system.
- **Adopt the STIP/TIP –** After developing a prioritized list, your agency will confirm that available funding will allow it to pursue the projects on that list, and that the project list meets requirements from Federal and State authorities. If there is not sufficient funding for all items on the priority list, your agency can support resilience by giving priority to projects ranked highest on the list. The projects included in the draft STIP or TIP are released for public comment. Edits are made following public comment, and the agency adopts the TIP or STIP, implementing the projects listed within it.

Figure 8-1 illustrates the standard sub-steps and possible resilience integration actions for developing TIPs and STIPs. The following sections provide detailed information about each sub-step and associated resilience opportunities, including resources and tools to help your agency.

[17] 23 CFR 450.330.



Developing the STIP and TIP

Standard Sub-steps	Resilience Integration Actions
Identify revenue and funding sources	Identify funds available for resilience improvements
Develop the method for identifying project costs	
Develop criteria for allocating revenue	
Develop a project list from the adopted transportation plan	Screen projects to identify facilities repeatedly requiring repair and reconstruction due to emergency events
Prioritize projects for implementation	Prioritize projects using one or more resilience evaluation criteria
Adopt STIP/TIP	

Figure 8-1. Key steps and resilience integration actions for developing the Statewide Transportation Improvement Program (STIP) and Transportation Improvement Program (TIP).

8.1 Identify funds available for resilience improvements

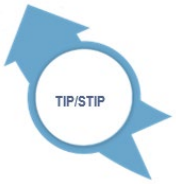
MPOs are required to identify and project reasonably available funding sources for the long-range planning process,[18] however the difference in planning horizons for the long-range plan (see Section 6.2) and the TIP[19] means funding sources and cost estimates may have changed. Additionally, new funding sources may be available, or corridor studies conducted after the long-range plan may have identified new or additional sources of funds. Therefore, it may be necessary to revisit what funding sources are available as well as cost estimates when drafting a TIP. State DOTs are not required to identify funding sources in their long-range plan, but are required to identify funding sources for their 4-year STIP.[20]

Although most funding sources can generally be used for resilience-focused projects, funding restrictions could limit the type of eligible resilience projects. Your agency can work with other agencies such as those responsible for State hazard mitigation to identify potential funding for projects. When selecting projects, it is important to bring these relevant stakeholders to the table to identify areas where other agencies might have similar projects or goals to avoid duplicating efforts. Potential stakeholders include other State or local agencies like offices of hazard mitigation, or Federal agencies like the U.S. Army Corps of Engineers.

[18] 23 CFR 450.324(f)(11).

[19] 23 CFR 450.326(a)

[20] 23 CFR 450.216(m), 450.218(i)(3).



When identifying which funding sources can be used for resilience improvements, the following questions can help facilitate discussion among necessary stakeholders:

- What grants or funds have been awarded to our agency? Are any specifically for resilience improvements?
- What requirements or restrictions exist on potential revenue sources that would prevent implementing specific resilience improvements?
- Do any corridor planning studies identify additional potential revenue or funding sources?
- Have potential funding sources for advance mitigation efforts been identified as part of ecological planning efforts?

8.2 Screen projects to identify facilities repeatedly requiring repair and reconstruction and to identify future vulnerabilities

Screen projects to identify those that are vulnerable to present and future conditions. Each State DOT is required to conduct statewide evaluations to determine if there are reasonable alternatives to address the root cause of damage to roads, highways, and bridges that have required repair and reconstruction activities on two or more occasions due to emergency events.[21] The evaluations for each identified location should identify and consider alternatives that will mitigate, or partially or fully resolve, the root cause of the recurring damage, estimate the costs for each solution, and the likely duration of the solution. The evaluation must consider the risk of recurring damage and cost of future repairs under current and future environmental conditions.[22]

Before including a project in your STIP or TIP, your agency is encouraged to consider the results of 23 CFR part 667 evaluations. If a project has been evaluated for repeated damage under 23 CFR Part 667, consider including one of the identified reasonable alternatives to address the root cause of the damage. It may also be useful to review agency records for past damage events, including data collected and analyzed for the State's TAMP. For other projects, consider screening for the risk of future changes in environmental conditions that would pose a threat to the project or project area. The next chapter of this handbook contains information on natural hazard risk screenings (Section 9.2), which may be useful for this process.

The Boston Region MPO (MA) uses an All-Hazards Planning Application tool that maps the transportation network and TIP projects in relation to natural hazard zones to determine if proposed projects are at risk of flooding, hurricane storm surges, earthquake liquefaction, or sea level rise (see Figure 8-2).

[21] 23 CFR 667.1

[22] 23 CFR 667.3

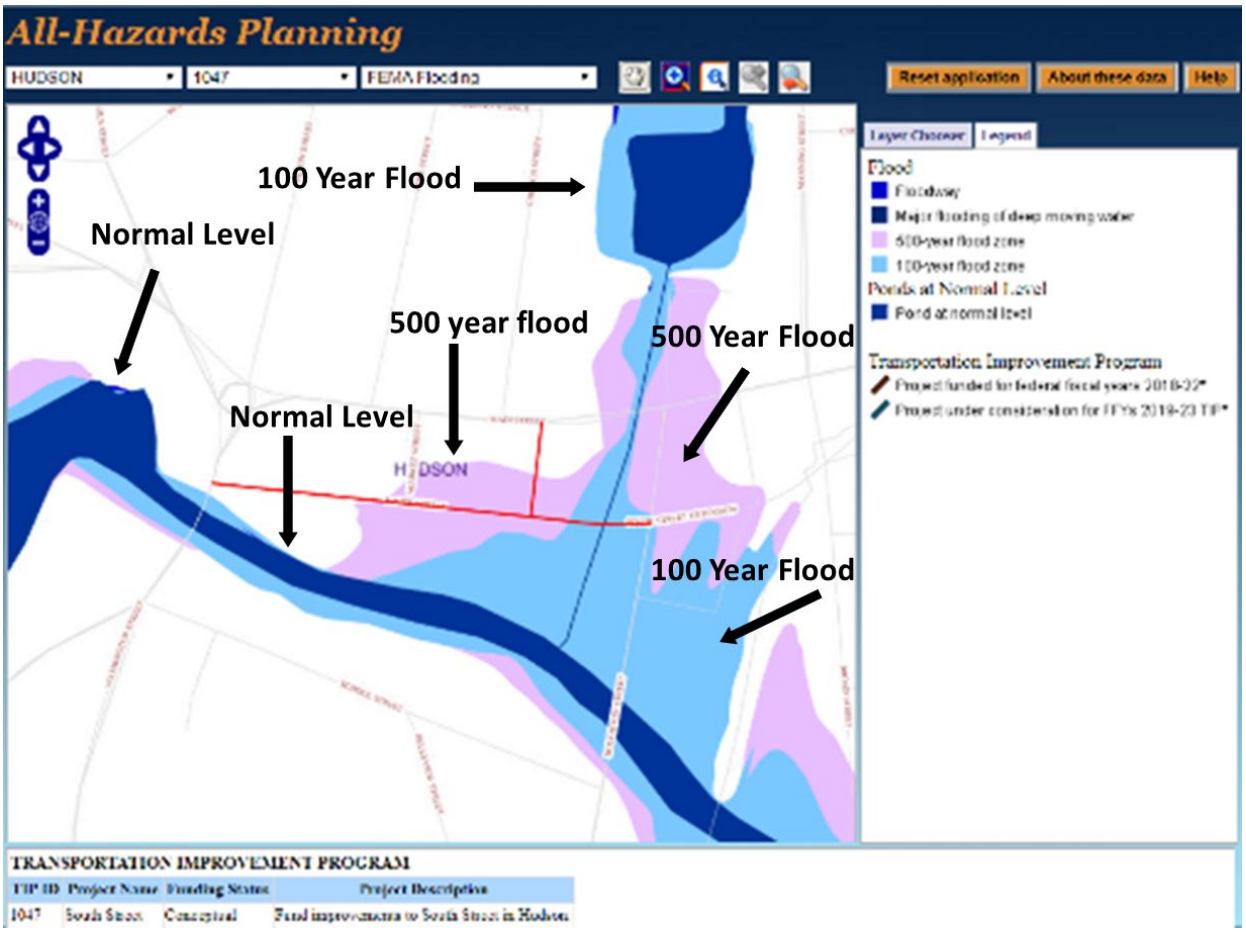
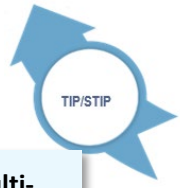


Figure 8-2. All-Hazards Planning tool, showing a project from Boston Region MPO's most recent TIP overlaid on FEMA Floodplain layers (Boston Region MPO, No date)

8.3 Prioritize projects using one or more resilience evaluation criteria

Once your agency establishes revenue projections and determines how much individual projects are expected to cost, you can determine the number and types of projects which will receive funding in your STIP or TIP. Your agency can prioritize projects to ensure funding is distributed among various policy priorities and to meet goals and objectives by developing a method to allocate funding that will address the multiple competing needs within your transportation system. To integrate resilience at this point, consider including resilience criteria into the methodology for allocating funding and prioritizing projects. See Chapter 5 for general ideas on integrating resilience into evaluation criteria; this section presents some options that you can apply to the TIP.

This integration action provides strategies for including resilience as a criterion for project prioritization, but there is no “one-size fits all” strategy for all transportation agencies. Your agency can use these strategies to guide incorporation of resilience into project prioritization, but will ultimately need to consider your needs and goals to determine a strategy that works best for your agency.



8.3.1 Strategy 1: Multi-criteria analysis

Key Resources for Conducting a Multi-Criteria Analysis (MCA)

- The FHWA *Vulnerability Assessment and Adaptation Framework* describes the MCA evaluation and provides examples from other transportation agencies.
- Chapter 6 of the FHWA *Synthesis of Approaches for Addressing Resilience in Project Development* provides a range of economic analysis techniques and lessons learned.

Multi-criteria analysis (MCA) is a method of qualitatively evaluating projects across a wide range of metrics. MCA offers a means to evaluate features of projects that might not normally be considered in an evaluation, such as resilience benefits. Since resilience considerations can be integrated into MCAs, this is one approach for selecting and prioritizing projects for inclusion in the STIP or TIP.

The FHWA *Vulnerability Assessment and Adaptation Framework* describes the MCA method for evaluating adaptation options (FHWA, 2017f). To conduct an MCA, identify and describe evaluation criteria that will influence project selection. If desired, the criterion can be weighted if certain criteria are deemed more important to the agency. Projects that score high across these criteria would be worth consideration for funding. Table 8-1 contains sample criteria for an MCA; however, the table is not comprehensive of all possible resilience evaluation criteria. Consult with stakeholders to determine which criteria will be most meaningful to your agency's region.

Including resilience as a criterion can help increase the overall resilience of the transportation system. Section 6.1.2 described a method of creating an evaluation system that would focus on projects that achieved agency resilience goals. Performance measures can both identify and measure resilience strategies and issues. They can support system performance during evaluations and can help decision makers to understand the consequences of investment decisions across transportation assets or modes. As part of your agency's criteria scoring system for allocating funding, include an element or elements which reflect high scoring projects on these resilience evaluations. This will allow projects which incorporate resilience to score higher and therefore be more likely to be included in the sequence of projects in the STIP or TIP.

Table 8-1. Sample Evaluation Criteria, Weights, and Descriptions for a Multi-Criteria Analysis

Evaluation Criteria	Score	Description
Project readiness/Technical feasibility	1-5	1 – Project is still in the design phase. 5 – Project is ready for implementation and agency has the resources to implement.
Risk of no action*	1-5	1 – Low risk of perceived threats if project is not adopted. 5 – High risk of perceived threats if project is not adopted.
Up-front capital cost	1-5	1 – High up-front capital cost. 5 – Low up-front capital cost.
Life-cycle costs*	1-5	1 – High anticipated life-cycle costs. 5 – Low anticipated life-cycle costs.
Relation to agency goals, system PMs and targets	1-5	1 – Project has little or no relationship to agency goals, PM and targets. 5 – Project works meaningfully towards one or more agency goals, PM and targets.

Effectiveness at reducing vulnerability*	1-5	1 – Project has little to no impact on vulnerability of asset/system. 5 – Project erases vulnerability of asset/system to perceived threat.
Public acceptance	1-5	1 – Public disapproves of project; project is not feasible in current political environment. 5 – Public approves of project; project is feasible in current political environment.
Permitting constraints	1-5	1 – Permitting of project would likely lead to delays. 5 – Project has few or no permitting constraints.
Flexibility of design*	1-5	1 – No flexibility in project design. 5 – Project design allows for future adaptation options to provide a higher level of protection from perceived threats.
Environmental justice impacts	1-5	1 – Project has potential for displacement of traditionally underserved populations. 5 – Project provides benefits to traditionally underserved populations.

*These metrics are likely to have a higher impact on increasing system resilience. If desired, these could be weighted higher than other metrics.

The benefit of these broad evaluation criteria is they offer a method to rate and rank a variety of project types and categories. Establishing criteria that can be applicable to multiple project types ensures a consistent method of selecting and sequencing projects in the STIP.

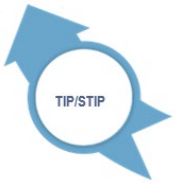
8.3.2 Strategy 2: Calculate life-cycle costs

Key Resources to Calculate Life-cycle Costs

- Chapter 5 of the FHWA *Vulnerability Assessment and Adaptation Framework* provides instruction on how to conduct economic analyses documenting long-term benefits of a project.
- Chapter 6 of the FHWA *Synthesis of Approaches for Addressing Resilience in Project Development* provides a range of economic analysis techniques and lessons learned.

Life-cycle cost analysis is a process for evaluating the total economic worth of a usable project segment by analyzing initial costs and discounted future costs, such as maintenance, user, reconstruction, rehabilitation, restoring, and resurfacing costs, over the life of the project segment. Investments in resilient infrastructure are intended to pay off down the road in the form of decreased maintenance costs, decreased social and economic impacts of roadway closures, and avoided replacement costs to assets damaged or lost in extreme weather events. These values are not likely reflected in the upfront capital cost of a project, but they are nonetheless important since they determine the life-cycle cost of the asset. When looking at life-cycle costs through project development in the process of developing your STIP/TIP, there is potential crossover with activities undertaken as a part of asset management planning; however, it is important to keep in mind that planning and asset management processes consider life cycle costs differently. "Life cycle cost" and "life cycle planning" in asset management focus on the costs of managing multiple assets, either an asset class (e.g., pavements) or asset sub-group (e.g., concrete pavements), over their whole life (see 23 CFR 515.5).

Life-cycle cost analyses are a form of cost-benefit analysis which compare the relative impacts of alternative designs on future revenue streams and allocation. One alternative may have a larger up-



front cost and still be the most fiscally sound choice, if the additional principal results in a better return on investment (in the form of decreased maintenance or replacement costs). It is important to distinguish between costs and benefits prior to conducting an analysis to fully account for the required initial investment and to understand potential outcomes resulting from that investment. TAMP life cycle plans and investment strategies may contain useful information to support plan development. Table 8-2 breaks down costs and benefits as they relate to resilient transportation projects.

Table 8-2. Costs and Benefits of Adaptation Measures (FHWA, 2017d)

Cost of Adaptation Measures (Costs Incurred Relative to No-Adaptation Option)	Benefits of Adaptation (Costs Avoided Relative to No-Adaptation Option)
Costs to Agency: ▪ Increased upfront engineering, land acquisition, and construction costs. ▪ Increased routine operation and general management costs. ▪ Increased reconstruction/rehabilitation costs. ***Costs to Users:*** ▪ Increased travel delay, safety, and vehicle operating costs during initial construction, maintenance activities, and reconstruction/rehabilitation.	***Direct Benefits to Agency:*** ▪ Reduction in physical damages, repair costs. ▪ Reduction in operations and management. ***Direct Benefits to Primary Users:*** ▪ Reduction in travel time costs from detours. ▪ Reduction in vehicle operating costs from detours. ▪ Reduction in disruptions to freight movement. ***Indirect Benefits to Non-Primary Users:*** ▪ Impacts of lost access to businesses and government fees/taxes on revenues. ▪ Impacts to nearby properties (e.g., flooding caused by an undersized culvert).

The FHWA *Vulnerability Assessment and Adaptation Framework* describes how to conduct a life-cycle cost analysis, by looking at direct costs like operating and maintenance expenses, future necessary repairs, and infrastructure replacement or retrofit costs that are reasonably expected to occur over the life of an asset. When combined with the initial construction cost, planners can make more informed decisions about which projects are better investments.

8.4 Recap of approaches to considering resilience in developing the STIP and TIP

This chapter presented three core approaches to considering resilience while developing STIPs and TIPs (see Table 8-3). These approaches include steps to identify resilience-specific funds, screen projects to identify facilities repeatedly requiring repair and reconstruction, and prioritize projects based on their relative influence on system resilience.

Why Consider Resilience When Developing the STIP and TIP?

The STIP or TIP is where projects are financed and selected for an order of implementation. Considering resilience at this stage can result in more projects being developed to withstand natural hazards.

Table 8-3. Recap of STIP and TIP Resilience Considerations

Integration Action	Key Action?	Potential Approaches
Identify funds available for resilience improvements		▪ Work with stakeholders to identify streams of revenue available to finance resilience projects.
Screen projects to identify facilities repeatedly requiring repair and reconstruction and to identify future vulnerabilities	✓	▪ Screen projects to identify facilities repeatedly requiring repair and reconstruction because of emergency events (as consistent with the requirements of 23 CFR part 667) and those facilities at risk of damage from future events.
Prioritize projects using one or more resilience evaluation criteria		▪ Conduct a multi-criteria analysis with resilience metrics to assess project benefits that are not normally quantifiable. ▪ Calculate the life-cycle costs of a project to inform long term investment; consult TAMP life cycle planning and investment strategy information.

Chapter 9
Project Development

Chapter 9 Project Development

As a planner, there are some approaches you can take to strengthen the connection between planning and implementation, including considerations for project initiation processes, engaging in public outreach, and possibly recommending incorporation of resilience into project purpose and need. Corridor studies can also be considered an early part of the project development process. For examples of integrating resilience into corridor plans, see Section 7.3.

Planners can assist in the National Environmental Policy Act (NEPA) environmental review process by documenting their earlier work as planning versions of the project's purpose and need, preliminary alternatives, evaluation of alternatives, screening of potential environmental risks and hazards, and potential mitigation. PEL can bridge the gap between transportation planning and environmental review by using the information, analyses, and products developed during planning as part of or to inform environmental studies conducted in accordance with NEPA.

Importance and benefits of integrating resilience: Incorporating resilience at this step is crucial not only because it is the time when resilience strategies can be practically developed and be made ready for implementation, but also because those who have the largest role at this stage may not be the same people who have been involved in the preceding resilience integration actions. Therefore, while this step carries a lot of promise for realizing resilience strategies, it is not a given that this will happen.

The following sub-steps provide opportunities for resilience:

- **Initiate project planning**: By working directly with the staff at your agency responsible for project implementation, you can ensure that the work you have conducted so far can come to fruition and transfer the knowledge you have gained, and help build your agency's capacity to plan for resilience.
- **Environmental review**: Providing relevant information that your department has already collected via resilience planning efforts can give your department an opportunity to integrate resilience into project design and selection.

Figure 9-1 illustrates the key sub-steps and possible resilience integration actions for project development. The following sections provide more information about each sub-step and associated resilience opportunities, including resources and tools to help your agency implement resilience into your transportation planning processes.

Project Development

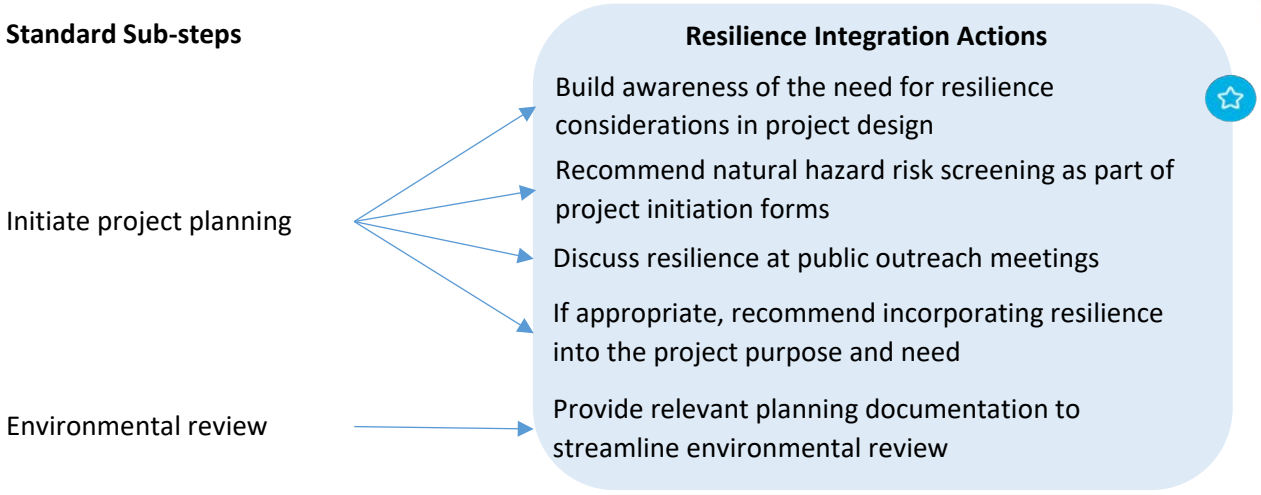


Figure 9-1. Key steps and resilience integration actions for project development.

9.1 Build awareness of the need for resilience considerations in project design

Building awareness of the need for resilience considerations in project design is a key resilience integration action. Most transportation planners have a less direct role in the implementation of infrastructure projects, so it is important that you clearly articulate to the project development team the problems/needs identified during the planning phase. Like the stakeholder engagement strategies described in Chapter 2, you can engage these other disciplines in resilience efforts through communication and outreach to gain support and build partnerships.

Figure 9-2. Winter Storm Riley floods Ocean Boulevard and Foss Beach in Rye, NH. Information on vulnerabilities such as this can be useful in building awareness of the need for resilience (New Hampshire Coastal Adaptation Workgroup, 2019).

When you do engage with the project development team, there are essentially two types of information being transferred:

1. Information and materials gathered through the planning process, including vulnerable areas, main hazards, and projects prioritized for resilience purposes.
2. Resources designed to guide resilience in project development and implementation.

There are several key FHWA resources that you can point project developers to that can provide information on incorporating resilience into their processes:

- *Synthesis of Approaches for Addressing Resilience in Project Development* (FHWA, 2017d). This document provides critical information to a range of disciplines for integrating climate resilience into transportation project development, such as:
  - Where, why, and how to integrate climate resilience into project development.
  - Sources of information, methodology, and lessons learned for using climate information, completing resilience-informed engineering assessments and design, conducting economic analyses, and evaluating additional considerations.
  - Monitoring and revisiting as needed.
- *Nature-Based Solutions for Coastal Highway Resilience: An Implementation Guide* (FHWA, 2019). The Implementation Guide is designed to help transportation practitioners understand how and where nature-based solutions can be used to improve the resilience of coastal roads and bridges.
- *Geohazards, Extreme Weather Events and Climate Change Resilience Manual* (FHWA, 2023). This manual supports transportation agencies in adopting a proactive Geohazards and Climate Change Resilience approach.
- *HEC-17 – Highways in the River Environment: Extreme Events, Risk, and Resilience: 2nd Edition* (FHWA, 2016b). This manual provides technical information and methods for dealing with the transportation and river nexus, particularly in relation to extreme events, risk, and resilience.
- *HEC-25 – Highways in the Coastal Environment – 3rd edition* (FHWA, 2020). This manual presents tools for the planning, design, and operation of highways in the coastal environment. It focuses on roads near the coast that are influenced by coastal tides and waves constantly, or occasionally during storms. FHWA estimates that there are more than 60,000 miles of these "coastal highways" in the United States. A primary goal is the integration of coastal engineering principles and practices in the planning and design of these roads and bridges to make them more resilient.

Additional in-person trainings are available via the National Highway Institute:

- ***Addressing Resilience in Highway Project Development & Preliminary Design*** FHWA-NHI-142085
- ***Building highways in the coastal Environment*** FHWA-NHI-135082

Another way to engage different departments is through the development of design guidelines, which inform project development. For example, the Miami-Dade Transportation Planning Organization (TPO) (FL) worked with stakeholders to develop a uniform set of standard guidelines and objectives that projects must meet (e.g., account for sea level rise in the year 2025). Published in the Miami-Dade County Comprehensive Development Master Plan, these project guidelines can be referenced by project engineers when developing their projects to ensure that the projects will meet the requirements. Under this solution, the TPO provided predictable requirements to project engineers and ensured resilience guidelines were applied uniformly to all projects.

Talking Points for Discussing Resilience

- How resilience fits into goals and objectives.
- Findings of vulnerability assessments and/or other studies relating to natural hazards.
- Examples of resilience strategies in place at other, relevant agencies.
- How resilience factors into project evaluation.
- How the transportation system will look with and without resilience strategies.

9.2 Recommend natural hazard risk screening as part of project initiation

Natural hazard risk screens are widely in practice across a variety of fields, including transportation. The purpose of risk screens is to take a quick, low-effort look at how known or projected hazards may overlap with planned projects – that is, if your projects and assets are likely to be at risk to current and future natural hazards. By advocating for the use of such tools early on as part of project initiation forms, risks are flagged early, indicating which projects may need resilience strategies.

Ideas for Engaging Project Developers in Risk Considerations

As a planner, there are various ways you can provide information gathered in the planning process on risk and vulnerability to project developers:

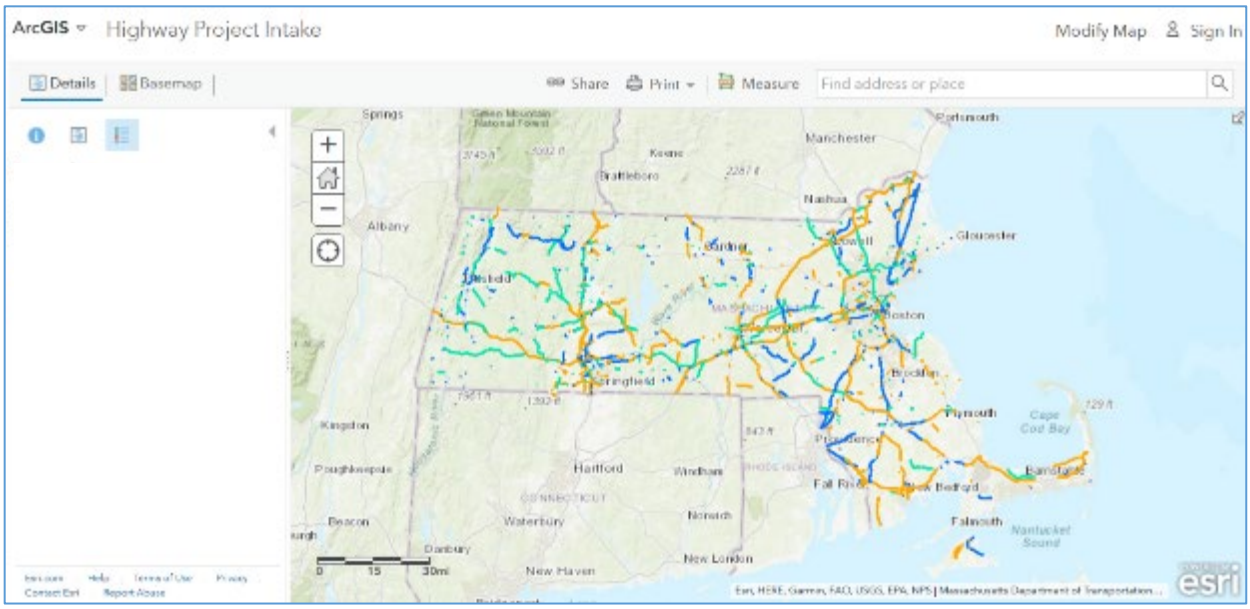
- Questions or checklists to answer as part of the project initiation process.
- Providing information on areas of vulnerability to compare with project locations.
- Flagging potential vulnerability issues as a part of applying for funding.

Risk screens can range in complexity from a simple set of questions for project developers or project sponsors to complete, to a data-filled tool fully integrated into the planning and design process. Repeatedly damaged facilities should already have been identified as part of the 23 CFR part 667 evaluations. Massachusetts DOT (MassDOT) has developed a more complex tool: the online Project Intake Tool (MaPIT), a web application that screens roadway projects against all relevant in-house GIS resources (Figure 9-3) (MassDOT, 2018). MassDOT took this risk screen a step further by having the app automatically pre-populate a Project Need Form and a Project Initiation Form. This project notification process ensures that the project designers are aware of relevant risks.

Figure 9-3. Screenshot of MaPIT, the MassDOT Project Intake Tool (MassDOT, 2018)

Risk screens can also take a simpler form, such as a set of questions or a checklist designed to engage designers and engineers in thinking about how natural hazard risk intersects with the project at hand. To help with answering these questions, you can present the material your team has developed in the earlier stages, particularly vulnerability information developed in Chapter 4. Possible questions to ask project sponsors include:

- Does your proposed project fall within any of the identified hazard areas?
- Which hazards could the project be affected by?
- How sensitive is your project to that hazard? What would the impact be if your project experienced the hazard?
- If it is sensitive, is there an alternative design or protective measure that would reduce its vulnerability?
- Can this project be modified over time to accommodate changes in conditions? If so, what actions could be taken now to facilitate future modifications?
- Was this project identified as repeatedly damaged in the 23 CFR part 667 evaluations?



The City of San Francisco (CA) requires a sea-level rise checklist to be filled out for projects costing at least $5 million and located within the City's sea-level rise vulnerability zone. The checklist includes questions related to the project lifespan; past, current, and future flooding risk; project sensitivity to flooding and sea-level rise impacts; project adaptive capacity; and possible level of damage, disruption, and costs in the event of a flooding or sea-level rise hazard (City of San Francisco, 2020).

Similarly, the California DOT (Caltrans) developed screening criteria for the Project Development Team to examine whether a project located on the coast is in an area exposed to future sea-level rise, if the project will be affected by sea-level rise, and if the design life of the project extends beyond 2030. Caltrans requires this screening as a component of the project initiation document, and project engineers must include a discussion of whether the project warrants consideration of sea-level rise, and

if so, how they will do so (Caltrans, 2011). These questions help the project designers incorporate vulnerability considerations into their project initiation process.

You can also simply provide previous findings to staff involved in project design and implementation. Washington State DOT (WSDOT) has internal maps that are available to their engineers and maintenance staff. WSDOT has also provided guidance to staff such as those undertaking corridor planning studies, statewide policy plans, asset management plans, and other planning efforts on how to use the information from the maps and obtain additional information to integrate resilience considerations into plans (WSDOT, 2022).

9.3 Discuss resilience at public outreach meetings

It is common for transportation planners to accompany design teams at outreach meetings to discuss proposed projects with the local community. At these meetings, you can provide a regional perspective on the project. Participating in public outreach meetings can also be a broader opportunity to introduce the public to the risks they face and show how local agencies are addressing them. This approach can dovetail nicely with Section 2.4.

9.4 If appropriate, recommend incorporating resilience into the project purpose and need

This section discusses a project's purpose and need in the context of the NEPA process, but a project's purpose and need may be developed during the development of a transportation plan or earlier in the planning process (see chapter 6). PEL allows practitioners to develop a statement of purpose and need for a project during planning that can be used in the environmental review process, as long as it meets NEPA requirements. The project purpose and need drives how the project is developed. If resilience is incorporated into the purpose and need, then it will remain a core project element throughout design and construction, and it will not be removed from the project during value engineering. Any resilience concerns identified during the planning process can be documented and communicated to the project developers during project scoping to spark a conversation about the appropriateness of integrating resilience considerations into the purpose and need statement.

9.5 Provide relevant planning documentation to streamline environmental review

Targeted transportation planning activities can benefit subsequent phases of the transportation project development process—environmental, design, or construction phases—and produce beneficial outcomes. Your agency can reduce time and resources spent on environmental reviews by coordinating and integrating the resiliency information developed in the planning process with those involved in the environmental review and preliminary design process.

Transportation Project Development Process

Environmental review helps agencies understand how their proposed projects may affect the surrounding area in terms of impacts to the environment. Environmental review is part of the National Environmental Policy Act (NEPA) process, which is required for projects using Federal funds or requiring a Federal agency decision,[23] as well as some state-level environmental policy requirements. For example, WSDOT requires staff to integrate climate considerations into their environmental review under the NEPA and State Environmental Policy Act (SEPA). (WSDOT, 2022). WSDOT has developed guidance to point these staff towards relevant information such as the State vulnerability assessment and provide sample language to help staff fulfill the requirement to document their findings (WSDOT, 2022)

One coordination approach to consider is the Planning and Environment Linkages (PEL) process. By incorporating PEL as part of the normal transportation planning and environmental review processes, transportation planners and environmental practitioners can increase the potential for project success by using planning information in the environmental review and permitting processes. Specifically, incorporating PEL principles into planning-related work can accelerate the environmental review process under NEPA and provide benefits addressing resilience and equity efforts. It is important to note that there are certain conditions that must be met for planning products to be used in the environmental review process. For more information, see FHWA's PEL Questions and Answers.

[23] 42 U.S.C. 4321 et seq.

9.6 Recap of approaches to considering resilience during the project development process

This chapter presented five core approaches to considering resilience during project development (see Table 9-1). The approaches range from simply building awareness for the need for resilience considerations in project design to ensuring that resilience is included in project development via risk screens. This chapter also provided information on discussing resilience at public outreach meetings and providing relevant information to streamline environmental review.

Why Consider Resilience During Project Development?

By including resilience in project development, you can help ensure that the work your team has put in so far continues into the design and construction of projects.

Table 9-1. Project Development Recap

Integration Action	Key Action?	Potential Approaches
Build awareness of the need for resilience considerations in project design	✓	▪ Provide resources to project developers. ▪ Develop design/project guidelines that include resilience.
Recommend natural hazard risk screening as part of project initiation		▪ Provide previous risk findings, such as the 23 CFR part 667 evaluations. ▪ Recommend simple risk screens. ▪ Integrate risk screen tools into the project design process.
Discuss resilience at public outreach meetings		▪ Discuss proposed resilience-related projects. ▪ Inform the community of natural hazard risks and how you are addressing them.
If appropriate, recommend incorporating resilience into the project purpose and need		▪ Include resilience in the project purpose and need to ensure it is a core project element to be carried through design and construction. This should be done as early in the planning process as practicable (see chapter 6)
Provide relevant planning documentation to streamline environmental review		▪ Follow the Planning and Environmental Linkages approach (PEL). ▪ Contribute resilience information during key steps of the environmental review process

Chapter 10
Monitoring and Reporting

Chapter 10 Monitoring and Reporting

With the move to performance-based planning, your agency is likely already undertaking monitoring and reporting or is actively moving towards that approach. Monitoring and reporting is useful for any planning effort – doing so can help you check progress on achieving your performance measures, goals, and objectives against timelines for project implementation and asset management. It also increases transparency between your agency and its stakeholders and the community, and provides supporting/funding organizations with documentation such as progress reports.

Throughout the resilience integration actions described so far in this handbook, planners have likely already gathered information that could help with identifying risks, including which natural hazard risks your agency faces, the relative likelihood and potential impact of these risks, and possible strategies for managing these risks. For example, if a State DOT has identified resilience as a top-priority risk, the TAMP's risk mitigation monitoring plan may be a good option for collaboration between planners who are considering resilience and asset managers who are required to consider and monitor risk.

Importance and benefits of integrating resilience: As with any goal, objective, or performance measure your agency establishes, assessing progress and examining the results will inform and improve your agency's actions in the future. This is particularly relevant for resilience, as this field deals with climate change and regularly updated science and future projections. Tracking hazards and infrastructure condition over time will help your agency better understand the challenges it is facing and their impact on the transportation system. Assessing the effects of your resilience efforts to improve future planning cycles and activities will not only improve your own practice, but help to advance the field of transportation resilience.

The following steps provide opportunities for integrating resilience into monitoring and reporting:

- **Monitor existing conditions and compare to the established goals, objectives, performance measures, or targets:** It is important to continue monitoring to ensure that progress is being made towards goals, objectives, performances measures, or targets and to identify areas for improvement.
- **Report on performance and progress to policymakers, stakeholders, and the public:** It is important to keep policymakers, stakeholders, and the public informed of your agency's progress. Oftentimes, this sort of reporting is a requirement of external funding sources. Reporting ensures transparency and accountability and can help maintain support for your agency's actions. Creating public documentation also increases knowledge sharing among agencies and can be an important way of building the resilience field and body of knowledge.
- **Identify improvements for the next cycle:** This step ensures that your agency is continually working towards accomplishing its goals and objectives and is doing so in an effective, efficient manner. Throughout the process described in this handbook, your agency will have collected a wealth of knowledge. This knowledge can be used to make sure that your investments in the transportation system are sound and will create desired outcomes.

Figure 10-1 illustrates the key sub-steps and possible resilience integration actions for monitoring and reporting. The following sections provide detailed information about each sub-step and associated

resilience opportunities, including resources and tools to help your agency implement resilience into your transportation planning processes.

Monitoring and Reporting

Standard Sub-steps	Resilience Integration Actions
Monitor existing conditions and compare to the established goals, objectives, performance measures, and/or targets	Track resilience over time
Report on performance and progress to policymakers, stakeholders, and the public	Report on performance of resilience measures and progress to policymakers, stakeholders, and the public
Identify improvements for the next cycle	Use adaptive management to make adjustments to increase resilience Integrate monitoring and reporting results into agency practices

Figure 10-1. Key steps and resilience integration actions for monitoring and reporting.

10.1 Track resilience over time

Tracking resilience over time is a key resilience integration action. Measuring the effectiveness of the implemented strategies and then revisiting and revising plans and policies as needed, in an iterative fashion, will ensure progression toward a robust and efficient program. Tracking resilience can also help inform whether additional resilience measures need to be taken or if conditions are changing in an unexpected way.

This step can be qualitative or quantitative. Qualitative approaches include measurements that are compared against criteria for progress towards goals, objectives, performance measures, or targets. Quantitative approaches to monitoring can be useful, as they provide objective and precise measurements than can be clearly tracked and compared over time. However, quantitative data are not always available, and might not capture all nuances and points of interest to your agency and the public.

The main elements to this step are collecting information and using that data to assess progress toward resilience. The rest of this section provides further details on methods and tips for decision making.

10.1.1 Develop a monitoring and reporting plan

A challenge of monitoring and reporting is to find the balance between frequent information updates and using resources effectively and efficiently (FHWA, 2013a). A monitoring and reporting plan can help resolve this challenge by clearly articulating what is being tracked, what data need to be collected, who will collect it and how they will do so, how often data collection will occur, how the data will be used, and how it will be reported. This plan can be as informal or formal as suits your agency needs. It may be a standalone plan that focuses solely on resilience, or you may integrate monitoring and reporting of resilience into relevant existing practices. No matter your approach, having a plan in place can give your monitoring and reporting efforts clear direction and make them more streamlined and transparent.

Possible Elements for Inclusion in a Resilience Monitoring and Reporting Plan

- How to define baseline conditions.
- Tools and methods for collecting data on current conditions.
- Timeline for comparing collected data to baseline.
- Methods for measuring performance measures and targets.
- Timeline for reporting.
- Audience for reporting.

Table 10-1 below provides an example template for identifying what to monitor, when to compile data, who is responsible for collecting the data, and how data will be collected.

Table 10-1. Hypothetical Example Table of Elements for an Agency to Monitor

What to monitor	When to monitor (schedule)	Who is responsible	How to monitor
Cost of emergency repair and maintenance because of natural hazards	Annually	Maintenance	Develop work codes for each natural hazard and use those to tag expenditures.
Flooding impacts	Annually	Operations Maintenance	Develop operational codes for flooding-related road closure hours and use them to track incidents. Use GIS-based app that crowdsources flooding information from users to track number of chronically inundated assets.
Number of projects that elevate the roadway grade above the 100-year flood plain	Annually	Engineers	Have a log for engineers to enter each project that raises the roadway grade. Compile at the end of each year.

Percentage of TIP/STIP projects with improved stormwater management and treatment	Every four years (TIP/STIP cycle)	Stormwater management team Engineers Asset managers	Keep a log of how many TIP/STIP projects meet the measurement. Could include as part of asset management plan or as a field to fill out in project initiation documents.
Percentage of facilities that accommodate two feet sea level rise	Now and every 5 years	Engineers	Track and record which projects accommodate sea level rise.
Damage to facilities in the event of a wildfire	Post-event	Disaster response team	Track and record the physical and monetary damage following each wildfire.

10.1.2 What to track

Which elements of resilience your agency chooses to track will likely depend on your performance measures, goals, and objectives (as established in Chapter 3). These are the measures of resilience that your agency has already deemed important, so tracking progress on these fronts is likely a good focus for your monitoring efforts.

Developing metrics for tracking over time, establishing a baseline, and comparing current conditions against the baseline allows you to measure the results of your resilience actions, and to simply have a record of conditions over time. There are several types of information that you could track, including:

Figure 10-2. DelDOT worked with the Delaware Environmental Observing System and the Delaware Geological Survey to develop a weather and flood monitoring system for transportation (Delaware Geological Survey, 2017).

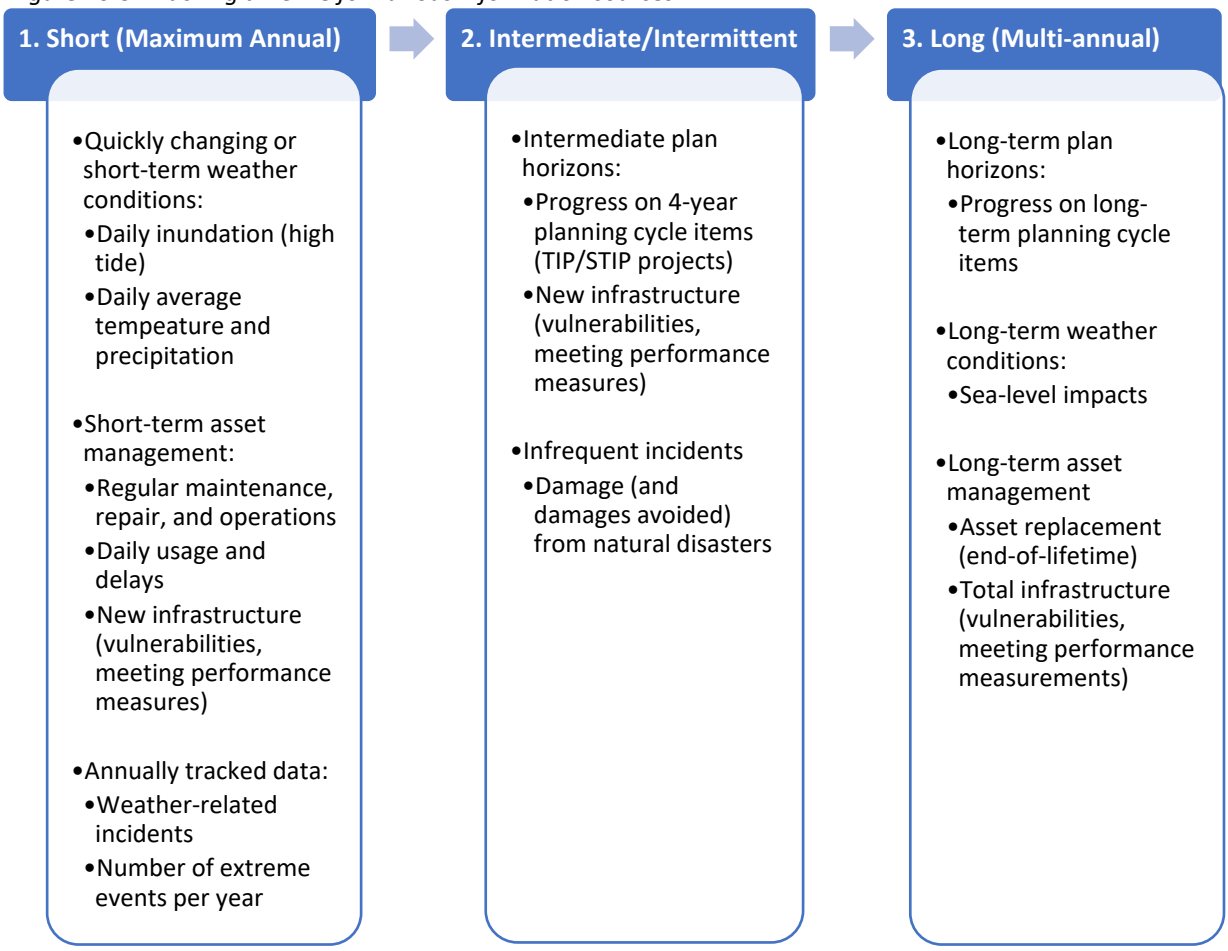
- *Conditions relative to impacts:* An agency can measure resilience by tracking the magnitude of impacts over time, with the assumption that resilience strategies will reduce the magnitude of impacts. For example, an agency might track the number of weather-related road closures, or weather-related repair and maintenance costs.
- *Conditions relative to vulnerability:* If you completed studies such as vulnerability assessments (see Chapter 4), then these are excellent baselines. The information gathered in these studies provides you with valuable data on current vulnerability. Your resilience measures are likely aimed at reducing this vulnerability. Agencies can periodically update the vulnerability assessments to measure the effect of resilience actions by recording the decrease in vulnerability.
- *Conditions relative to performance measures/targets:* In this case, an agency would directly measure progress towards resilience-related performance measures or targets. For example, a

performance measure may be the number of highway miles within the floodplain, and a target may be providing updates to 100% of stormwater infrastructure within a sensitive area.

10.1.3 When to track

How often these data are collected depends on what is being tracked as well as feasibility. On the shorter time scale, frequent monitoring can help your agency identify emerging areas of risk, such as how hazards like flooding might be increasing in extent over time, or hotspots, such as areas that are regularly exposed to hazards. On the longer time scale, data gathered over the course of years can help your agency identify long-term trends and influence future plans. This information can also demonstrate the lasting effects of decisions and resilience actions. Longer timelines are likely more appropriate for metrics that are slow to change, and vice-versa. Some metrics may be triggered by an event, such as a 100-year flood or wildfire, and would be tracked on an as-needed basis. The timeline below illustrates how various metrics call for different monitoring schedules (Figure 10-3).

. Figure 10-3. Tracking timeline for various information sources



10.1.4 Who is responsible

In many cases, planners will not be the people who collect information on assets. Therefore, identifying and teaming up with these people will help streamline the process and tap into information that is already being collected. A good place to start are other groups internal to your agency such as asset managers and operations/maintenance staff. They may already be following notable practices on resilience tracking, such as those in the 2015 FHWA guide *Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance* (FHWA, 2015a), which provides insight on how operations and asset management can track resilience-related impacts.

In general, reaching out to other departments who likely already have the information your team needs will decrease the burden of resilience tracking. For example, there might even be an inter- or intra-agency working group on performance management that could serve as a forum for information exchange.

10.1.5 How to track

There are several approaches to tracking information:

- *Compiling data from internal sources:* If other groups are identified as the responsible parties for collecting information, the "how" for planners will largely involve connecting with these stakeholders and compiling/processing information.
- *Institutional knowledge:* Even if there is no formally documented information on asset conditions and hazard impacts, operations and maintenance staff are likely aware of the conditions/hazards encountered regularly. For example, staff at your agency may know which areas have begun flooding in the last year that did not previously – or where flooding issues have been resolved.
- *Crowdsourcing data:* Even the general public can be a source for information, such as commuters who can identify which areas of the road network have potholes, or how regularly their routes require detours because of hazards. Some agencies have integrated the ability to report these conditions into 311 websites and apps. Others have developed partnerships with private companies to crowdsource data.
- *Updated external data sets:* If you have already conducted a vulnerability assessment or other study that used external local, State, or Federal datasets on hazards or asset data, then you can check for the availability of updated datasets.

Key Resources for Tracking Resilience over Time

- Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance (FHWA, 2015a) section III.F Monitor and Revisit offers steps and notable practices for tracking information.

10.1.6 Assessing progress based on monitoring

The data you gather from tracking resilience will be used to assess progress. This assessment allows you to determine whether the chosen strategies are effective, and if there are improvements or course corrections to be made. By checking in on a regular basis, you can make sure that your agency is steadily making progress towards achieving your goals and targets. This data can also help guide future decision making by providing information on the relative success of various strategies.

Assessing Progress

Once you have collected information on conditions and compared to goals and other metrics of success, you are able to ask:

- Are we on the right track?
- How can we improve?
- What is working well, and what is missing?

You can assess progress at both the system level and the project or program level. The broader system-level scale can help you determine the extent to which your resilience measures have contributed toward accomplishing your goals and objectives. The more targeted project- or program-level scale can help you assess the effectiveness of specific strategies (FHWA, 2013a).

To aid in this assessment, you might bring together experts and stakeholders to help you evaluate why your agency has experienced the level of success/effectiveness it has. For example:

- The Northeast Ohio Areawide Coordinating Agency (OH) established a steering committee of local stakeholders, the Ohio Department of Transportation, FHWA, and local safety forces (NOACA, 2017a). The steering committee was responsible for developing performance measures and targets for monitoring and reporting progress on resilience strategies.
- The North Jersey Transportation Planning Authority is part of Together North Jersey, a coalition of almost 100 stakeholders that has laid out a vision for the region that includes resilience as one of four key priorities. The Resilience Task Force of Together North Jersey met quarterly to discuss progress on implementing resilience-specific strategies from the regional plan developed by the coalition (Together North Jersey, 2017).

10.2 Report on performance of resilience measures and progress to policymakers, stakeholders, and the public

This step bolsters accountability and upholds communication between your agency and policymakers, stakeholders, and the public. This step can be accomplished in a variety of ways, from informal presentations, press releases, and other short-term communications, to more formal reports that are released on a regular schedule and contain comprehensive updates. See Table 10-2 for potential informal and formal reporting methods.

Table 10-2. Examples of Both Informal and Formal Styles of Reporting

Informal	Formal
Fact sheets/infographics	Regular progress reports to the public, and other stakeholders, with agreed-upon measures of progress
Website	Memoranda
Internal presentations (e.g., at monthly staff meetings)	Presenting to outside audiences (e.g., at a town hall, to State legislature, to stakeholders)

Considering your audience is a key component to developing your report and message, as the audience will influence elements of your report such as tone, level of technical detail, visual presentation, and length. Possible audience members include: the general public, internal stakeholders, external stakeholders, stakeholder agencies and organizations, and similar agencies in other jurisdictions.

Understanding Your Audience

- As a rule of thumb: those involved in the resilience planning process (funders, governments, agencies and organizations, and other stakeholders) will likely want more information and formal reporting.
- Those who experience the impacts of your planning (the general public and certain stakeholders) will likely want to receive the most pertinent facts in a quickly digestible format.

A streamlined approach to reporting is to integrate resilience programs into current agency methods and documents used for reporting progress, if available. You can also develop a standalone resilience progress report. This approach could focus more heavily on specific details and next steps relating to resilience. For example, DelDOT helped the Delaware Department of Natural Resources and Environmental Control compile a comprehensive *Progress Report* to report on progress toward achieving strategies laid out in Climate Framework for Delaware (DNREC, 2016).

The timeline for reporting the results of your monitoring is influenced by the nature of the information you are reporting and the needs of your report's audience:

- Some information may change from year to year (e.g., maintenance activities, easily installed protection or accommodation measures), and therefore would be well-suited to an annual report.
- Other information may be expected to change over a longer timeframe (e.g., if you are relocating assets or building more intense protection measures), so might only require an update every several years.
- In terms of your audience, funding sources will likely request frequent progress reports, while the general public could be overwhelmed by a yearly full report.

Tailor your reporting strategy to best meet these needs. You can release separate reports to accommodate these different influences.

10.3 Use adaptive management to make adjustments to increase resilience

Adaptive management uses system monitoring to identify needed adjustments to the system based on trends and changes. With an adaptive management approach, you are selecting strategies that can be adjusted over time as needed, taking an incremental approach to resilience and reducing costs. This strategy is particularly useful in the resilience context given the uncertainty in natural hazard predictions and the potential high cost of building resilience to the worst-case scenario.

A good starting place for adaptive management is section 10.1. Gathering regular inputs on conditions is vital to successful adaptive management, as such data allows you to track changes and continually check if the assumptions used for previous decisions are holding up, or if you need to course-correct to accommodate new conditions. This is particularly relevant for resilience to climate hazards, as these are expected to change over time.

The Case for Adaptive Management

- Current investments do not negate the possibility for future adjustments.
- Uses "no regrets" options, which can meet needs under a range of possible conditions (Rodehorst, et al., 2018).
- Reduces cost and increases flexibility implementing strategies based on the most relevant concerns rather than building for all possible future scenarios.
- Provides for decision points to revisit assumptions and conditions.
- Allows for abandoning courses of action when reviews show that they were maladaptive (FHWA, 2017c).

There are several ways you can use the information you gather to implement adaptive management:

- **Know if the chosen strategies are adequate, or if vulnerability remains.** As you and your stakeholders monitor the system, you can assess whether there is a need for further resilience measures. If there is, adaptive management allows you to enhance or adjust current measures to meet the new need.
- **Know when you have reached tipping points for action.** If conditions reach this point, then you can act to implement new strategies or change those already in place. This is an efficient strategy, as it allows you to operate in a "business-as-usual" fashion until the tipping point is reached. It also makes your vulnerabilities and priorities clear by identifying key thresholds.

For example, your agency may have a current approach to dealing with high tide that is projected to be effective until sea level rise hits a certain threshold. When that threshold is reached, your agency can implement a resilience strategy designed for the new conditions. If higher thresholds are met, further actions can be taken that build on previous measures and respond to the changing conditions.

10.4 Integrate monitoring and reporting results into agency practices

The information from monitoring and reporting can feed back into planning, asset management, operations, and maintenance. The data can be used to make refinements and improvements to many steps in the planning cycle, including understanding of vulnerability, selection and prioritization of strategies, and how those strategies are monitored and assessed. Figure 10-6 below shows such opportunities for improving different components
of the cycle.

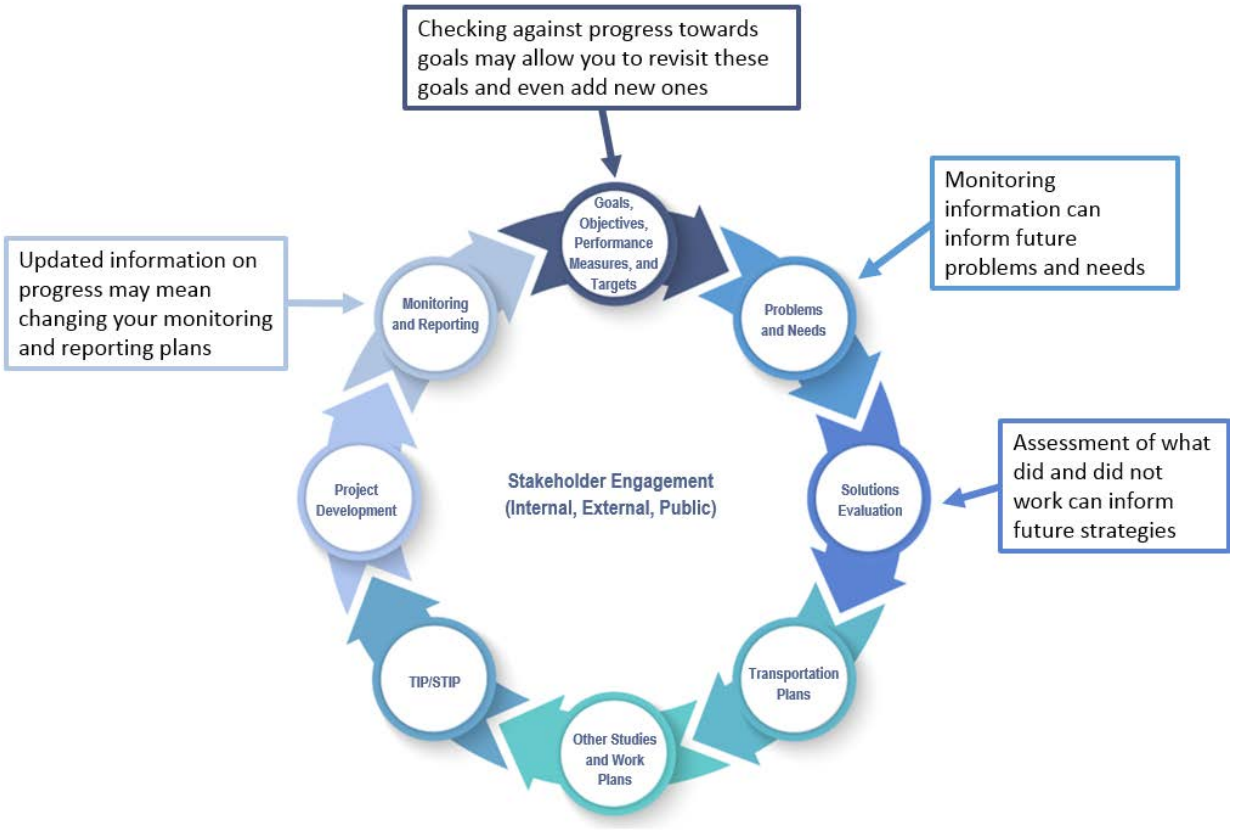


Figure 10-4. Opportunities for improvements to the next cycle based on results and lessons learned from monitoring and reporting efforts.

10.5 Recap of approaches to considering resilience while monitoring and reporting

This chapter presented four core approaches to considering resilience when monitoring and reporting (see Table 10-3). The approaches range from simply tracking resilience over time to reporting on performance. The chapter also provides information on carrying resilience considerations into future iterations of the planning cycle by using adaptive management to adjust and integrate monitoring and reporting results into agency practices.

Why Consider Resilience While Monitoring and Reporting?

Monitoring and reporting allows your agency to observe and measure the effects of your resilience efforts and to improve over time while sharing information with stakeholders.

Table 10-3. Monitoring and Reporting Recap

Integration Action	Key Action?	Potential Approaches
Track resilience over time	✓	▪ Develop a monitoring and reporting plan.
Report on performance of resilience measures and progress to policymakers, stakeholders, and the public		▪ Pursue informal avenues of reporting. ▪ Pursue formal avenues of reporting.
Use adaptive management to make adjustments to increase resilience		▪ Start with no-regrets actions. ▪ Use data gathered to understand when to make adjustments.
Integrate monitoring and reporting results into agency practices		▪ Revisit goals and potentially add new ones. ▪ Inform future problems and needs with data gathered via monitoring. ▪ Inform future strategies with information on what did and did not work. ▪ Update monitoring and reporting plan as necessary.

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Appendix A: Glossary

Adaptation – Adjustment in natural or human systems in anticipation of or response to a changing environment in a way that effectively uses beneficial opportunities or reduces negative effects.

Baseline – The observed level of performance for a specified performance period from which implementation begins, improvement is judged, or comparison is made.

Champion – Someone within the department or agency with some knowledge of and interest in resilience work. A designated leader may be important to the success of the initiatives, as they can serve as a voice for the effort, a central resource for all work related to resilience, and can make sure that the efforts remain on track.

Climate Change – Climate change refers to any significant change in the measures of climate lasting for an extended period of time. Climate change includes major variations in temperature, precipitation, or wind patterns, among other environmental conditions, that occur over several decades or longer. Changes in climate may manifest as a rise in sea level, as well as increase the frequency and magnitude of extreme weather events now and in the future.[24]

Emergency Event – A natural disaster or catastrophic failure (as defined in 23 CFR 667.3) resulting in an emergency declared by the Governor of the State or an emergency or disaster declared by the President of the United States (23 CFR 667.3).[25]

Extreme Weather Events – Extreme weather events can include significant anomalies in temperature, precipitation and winds and can manifest as heavy precipitation and flooding, heatwaves, drought, wildfires and windstorms (including tornadoes and tropical storms). Consequences of extreme weather events can include safety concerns, damage, destruction, and/or economic loss. Climate change can also cause or influence extreme weather events.[26]

Fiscal constraint – Financially constrained or Fiscal constraint means that the metropolitan transportation plan, TIP, and STIP includes sufficient financial information for demonstrating that projects in the metropolitan transportation plan, TIP, and STIP can be implemented using committed, available, or reasonably available revenue sources, with reasonable assurance that the federally supported transportation system is being adequately operated and maintained. For the TIP and the STIP, financial constraint/fiscal constraint applies to each program year. Additionally, projects in air quality nonattainment and maintenance areas can be included in the first 2 years of the TIP and STIP only if funds are "available" or "committed."[27]

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[24] FHWA. (2014c). *Order 5520.*

[25] FHWA has further guidance on 23 CFR Part 667 requirements, available here: FHWA 23 CFR part 667 (dot.gov).

[26] FHWA. (2014c). *Order 5520.*

[27] 23 CFR 450.104.

Goals – A broad, outcome-oriented statement that describes a desired end state and reflects both agency and community priorities (FHWA, 2013a).

Natural Hazard – A natural event with the potential to cause substantial damage, such as hurricanes, extreme precipitation, flash flooding, wildfire, droughts, sea level rise, loss of permafrost, and high heat.

Objectives – A specific, measurable statement that supports the achievement of a goal (FHWA, 2013a).

Performance Measures – Performance measures are based on a metric that is used to track progress toward goals, objectives, and achievement of established targets. They should be manageable, sustainable, and based on collaboration with stakeholders. Measures provide an effective basis for evaluating strategies for performance improvement (FHWA, 2013b).

Resilience – the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions.[28]

Risk – Threats to and opportunities for achieving strategies, goals and target (FHWA, 2013a).

Stakeholder – Person or group affected by, or who believe themselves to be affected by, a transportation plan, program or project. Person or group believing that they are affected by a transportation plan, program or project. Residents of affected geographical areas. (FHWA, 2013a).

Target – Level of performance that is desired to be achieved within a specific time frame (FHWA, 2013b).

Vulnerability – The degree to which a transportation system or asset is susceptible to, and unable to cope with, adverse effects of changing environmental conditions, variability, and extremes. Vulnerability is a function of exposure, sensitivity, and adaptive capacity.

Vulnerability Assessment – An approach for analyzing how natural hazards affect specific assets or systems by assessing exposure, sensitivity, and adaptive capacity. Exposure is the degree to which an asset or system experiences the direct effects of the hazard. Sensitivity refers to how an asset or system fares when exposed to the hazard. Adaptive capacity is the degree to which an asset or system is able to adjust to or cope with the hazard.

[28] FHWA. (2014c). *Order 5520.*

Appendix B: Acronym List

BIL – Bipartisan Infrastructure Law

CDOT – Colorado Department of Transportation

CFR – Code of Federal Regulations

DelDOT – Delaware Department of Transportation

DOT – Department of transportation

FAST Act – Fixing America's Surface Transportation Act[29]

FEMA – Federal Emergency Management Agency

FHWA – U.S. Federal Highway Administration

FLMA – Federal Land Management Agency

FRMPO – Fayette Raleigh Metropolitan Planning Organization (WV)

GIS – Geographic information systems

HUD – U.S. Department of Housing and Urban Development

IIJA – Infrastructure Investment and Jobs Act

LEDPA – Least Environmentally Damaging Practicable Alternative

LRTP – Long-Range Transportation Plan

MAP-21 – Moving Ahead for Progress in the 21st Century Act[30]

MaPIT – Massachusetts Project Intake Tool

MassDOT – Massachusetts Department of Transportation

MCA – Multi-criteria Analysis

Mid-Region COG – Mid-Region Council of Governments (NM)

MnDOT – Minnesota Department of Transportation

MOE – Measure of Effectiveness

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[29] Pub. L. No. 114-94.

[30] Pub. L. No. 112-141.

MPO –Metropolitan Planning Organization

MTP – Metropolitan Transportation Plan

NASA – National Aeronautics and Space Administration

NEPA – National Environmental Policy Act[31]

NGO – Non-governmental organization

NHS – National Highway System

NJTPA – North Jersey Transportation Planning Authority (NJ)

NOAA – National Oceanic and Atmospheric Administration

NOACA – Northeast Ohio Areawide Coordinating Agency (OH)

PEL – Planning and Environmental Linkages

PL – Metropolitan Planning Program

PPP – Public Participation Plan

RD&T – Research Development and Technology Program

RPC – Rockingham Planning Commission (NH)

RTPO- Regional Transportation Planning Organization

LRSTP –Long-Range Statewide Transportation Plan

SPR – State Planning and Research Program

STIP – Statewide Transportation Improvement Program

TAMP – Transportation Asset Management Plan

TIP – Transportation Improvement Program

TPO –Transportation Planning Organization

UPWP – Unified Planning Work Program

USACE – U.S. Army Corps of Engineers

U.S.C. – United States Code

[31] 42 U.S.C. 4321 et seq.

USGS – U.S. Geological Survey

USDOT – U.S. Department of Transportation

WSDOT – Washington State DOT