June 2022

State of the Practice Scan:

Freight Resilience Planning in the Face of Climate-Related Disruption

U.S. Department of Transportation
Federal Highway Administration

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Cover Image:

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
02-0602022	Final Report	n/a

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
State of the Practice Scan: Freight Resilience Planning in the Face of Climate-Related Disruption	693JJ321N300037
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)	5d. PROJECT NUMBER
Mason, DJ; McCoy, Kevin	51HW2LA621
	5e. TASK NUMBER VM723, VM724
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
Office of the Assistant Secretary of Transportation for Research and Technology, John A. Volpe National Transportation Systems Center 55 Broadway, Cambridge, MA 02142 Cambridge, MA 02142	DOT-VNTSC-FHWA-22-05

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
Federal Highway Administration Office of Planning U.S. Department of Transportation 1200 New Jersey Avenue, SE Washington, DC 20590	FHWA
	11. SPONSOR/MONITOR'S REPORT NUMBER(S) FHWA-HEP-22-022

12. DISTRIBUTION / AVAILABILITY STATEMENT
No restrictions

13. SUPPLEMENTARY NOTES
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14. ABSTRACT
The purpose of this research is to summarize the state of the practice for freight resiliency planning. Freight planning by public sector agencies is still a relatively new discipline. Given that climate change is causing more frequent and more severe extreme weather events and that these events are increasingly disrupting the movement of goods and services across the United States, this research provides a summary of current practices, methods, and gaps in freight resiliency planning to inform the development and improvement of freight resiliency planning to address climate change and extreme weather risks.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Mack Frost
N/A	N/A	N/A	None.	19	19b. TELEPHONE NUMBER (804) 775-3353

Standard Form 298 (Rev. 8-98)

List of Acronyms

BIL	Bipartisan Infrastructure Law of 2021 (also known as the Infrastructure Investment and Jobs Act)
CDOT	Colorado Department of Transportation
CFR	Code of Federal Regulations
CPI	Consumer Price Index
DOT	Department of Transportation
FAC	Freight Advisory Committee
FAST	Fixing America's Surface Transportation Act of 2015
FDOT	Florida Department of Transportation
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
GIS	Geographic Information Systems
IIJA	Infrastructure Investment and Jobs Act (also known as Bipartisan Infrastructure Law)
LRTP	Long Range Transportation Plan
MAP-21	Moving Ahead for Progress in the 21st Century Act
MPO	Metropolitan Planning Organization
NOAA	National Oceanic and Atmospheric Administration
OMB	Office of Management and Budget
PROTECT	Promoting Resilient Operations for Transformative, Efficient, and Cost-saving Transportation program
RIP	Resiliency Improvement Plan
SFP	State Freight Plan
SPC	Rhode Island Statewide Planning Council
STIP	Statewide Transportation Improvement Program
TAMP	Transportation Asset Management Plan
TIP	Transportation Improvement Program
TSMO	Transportation System Management and Operations
USC	United States Code
USDOT	United States Department of Transportation
VAF	Vulnerability Assessment and Adaptation Framework

Contents

1.0 Introduction

The U.S. depends on the safe, efficient, and timely movement of goods throughout the transportation network to maintain Americans' high quality of life, economic strength, and general welfare. Increasingly, the effects of climate change are negatively impacting freight operations across the transportation network. Stronger, more frequent storms and natural disasters cause major disruptions in freight operations and add significant costs to the maintenance of the infrastructure upon which these goods move.

The U.S. Department of Transportation's National Freight Strategic Plan (2020) defines *freight resiliency* as *"the ability of a system to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies… A resilient freight transportation system is responsive, able to provide reliable services when it encounters small disruptions and return to service quickly after large disruptions. Disruptions to the transportation system often require the coordinated activities of the public and private sectors to ensure freight transportation flows, both for emergency response and economic recovery. The availability of alternative routes and modes allows shippers to develop contingency plans enhancing their flexibility."*[1]

1.1 Purpose of this Report

The purpose of this research is to summarize the state of the practice for freight resiliency planning. Freight planning by public sector agencies is still a relatively new discipline. Given that climate change is causing more frequent and more severe extreme weather events,[2] and that these events are increasingly disrupting the movement of goods and services across the United States, this research provides a summary of current practices, methods, and gaps in freight resiliency planning to inform the development and improvement of freight resiliency planning to address climate change and extreme weather risks.

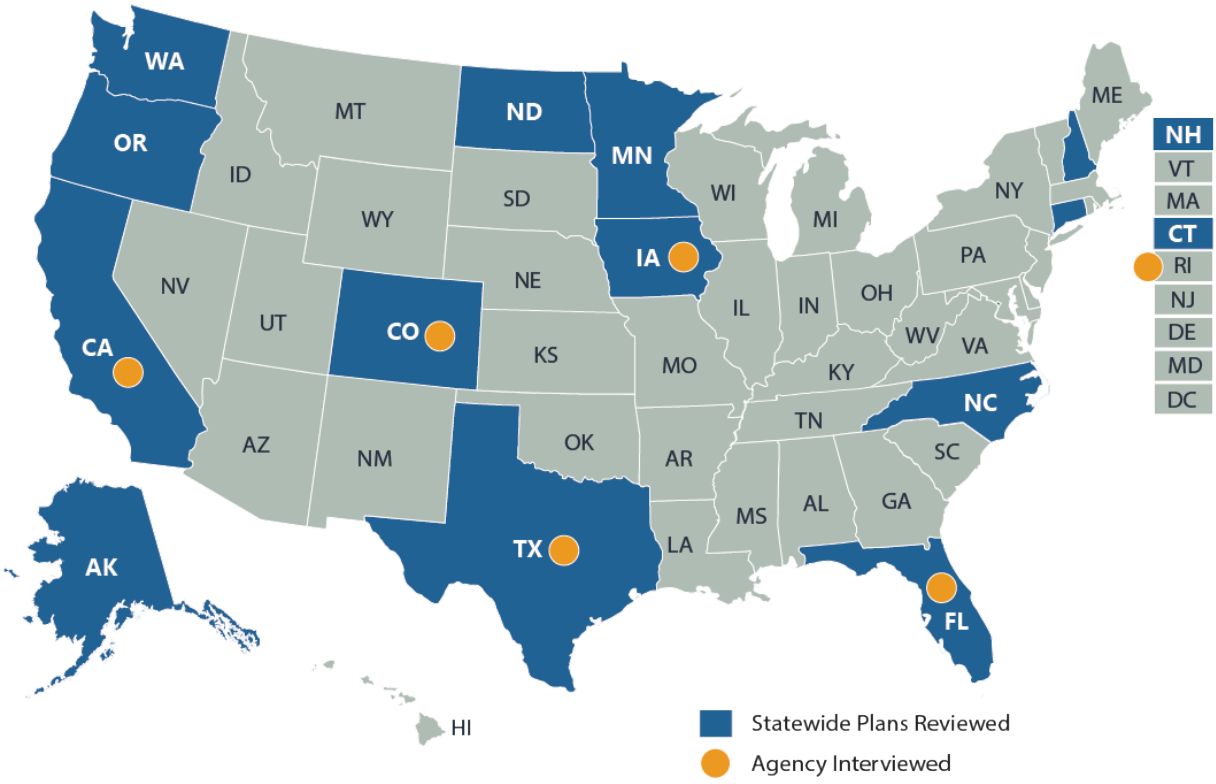
The report broadly characterizes the state of the practice in freight planning and operations in the public sector, particularly in the context of increasing climate change and natural disasters. The practices noted in this report provide examples of processes and approaches that State departments of transportation (DOTs) have implemented which other agencies could potentially adopt or adapt, as applicable to their circumstances. The report also includes potential recommendations to advance the state of practice in freight resiliency planning, based on discussions with freight planning practitioners.

The project team reviewed freight and transportation planning documents to form a baseline understanding of how transportation agencies are addressing resiliency in freight planning. First, the team reviewed State Freight Plans (SFPs), State Long Range Transportation Plans (LRTPs), Transportation Asset Management Plans (TAMPs), Hazard Mitigation Plans, Transportation System Management and Operations (TSMO) plans, Statewide Emergency Response Plans, and Emergency Routing documents. for 13 States, and then supplemented preliminary findings through discussions with six transportation agencies (five State DOTs and one MPO – Figure 1) to gain a greater understanding of the state of practice.

[1] U.S. Department of Transportation (September 4, 2020). "National Freight Strategic Plan (Full)." Accessed at https://www.transportation.gov/freight/NFSP/fullreport

[2] U.S. Environmental Protection Agency, (No Date). "Climate Change Indicators: Weather and Climate" Accessed at: https://www.epa.gov/climate-indicators/weather-climate

Figure 1: States and MPO freight resiliency-related efforts scanned for this report. Source: USDOT Volpe Center.



Relevant statewide planning documents from thirteen States (AK, CA, CO, CT, FL, IA, MN, NC, ND, NH, OR, TX, WA) and interviews with six public agencies (Caltrans, Colorado DOT, Florida DOT, Iowa DOT, Texas DOT, and the Rhode Island Statewide Planning Council (Rhode Island SPC)) informed the development of this report.

1.2 Recent Examples of Weather-Related Freight Disruption

Infrastructure and operations planning play critical roles in responding and adapting to natural disasters. The wide variety of impacts and the variability of climate change requires stakeholders to consider a range of responses. Table 1 on the following page illustrates several examples of recent climate-related natural disasters and their impacts on the freight transportation network:

Table 1: Recent examples of extreme weather disruptions to the U.S. freight transportation network.

Hurricane Maria	In September 2017, a Category 5 hurricane in Puerto Rico caused major damage across the island, damaging all major infrastructure. In the wake of the storm, food and critical supplies were rationed across the island as emergency relief supplies were stuck in containers at the Port of San Juan for several weeks, due in part to infrastructure damage caused by the storm.[3]
Texas Deep Freeze	In February 2021, Texas experienced historically low temperatures, causing the electrical grid to fail for several days across the State. Grocery stores across Texas experienced extreme food supply shortages, exacerbating already low supplies caused by the Covid-19 pandemic, and international freight crossing the U.S.-Mexico border saw delays of up to three days.[4]
Glenwood Canyon Wildfire and Subsequent Mudslides	In July 2021, heavy rains caused a mudslide wiping out a section of Interstate-70 in the Colorado mountains, blocking a 46-mile stretch of the highway for several weeks. A wildfire preceding the rains created a "wildfire burn scar" through the surrounding forest, enabling mudslide conditions. Commercial vehicles were required to take a 250-mile detour through a different mountain pass, delaying the delivery of fuel, food, and supplies to the Western Slope communities of Colorado affected by ongoing wildfires in the area.[5]
Delta Wildfires	In September 2018, a massive wildfire rapidly overtook a section of Interstate 5 in Northern California. Seventeen commercial vehicle drivers were forced to abandon their tractor-trailers to flee from the blaze and several of the rigs melted to the roadway surface. The Interstate was closed for several days after the fires were extinguished, further disrupting freight movement.[6]
2011 and 2019 Missouri River Flooding	In 2011 and 2019 Missouri River flooding was triggered by heavy snowfall in the Rocky Mountains followed by heavy spring rainfall. Flooding was caused by a combination of record snowfall followed by quick temperature rise and heavy late winter rainfall on frozen ground. In Nebraska, 3,000 miles of state highways were washed away or closed, cutting off access to communities. In Iowa, a section of I-29 was closed for a total of 100 days. Several bridges over the Missouri River were closed, disrupting movement of freight and people.

1.3 Costs of Extreme Weather Disruptions

Natural disasters come at a significant cost to both public and private sector freight stakeholders, and these costs have steadily grown more expensive over the last several decades. In 2021 alone, the U.S. experienced 20 separate billion-dollar weather and climate change-related disaster events. In total, these events were estimated to cost $145 billion dollars, the third most expensive year on record.[7] The

[3] CNN, (September 28, 2017). "Puerto Rico aid is trapped in thousands of shipping containers." Accessed at https://www.cnn.com/2017/09/27/us/puerto-rico-aid-problem/index.html

[4] Supply Chain Dive, (February 19, 2021). "Winter storm slams Texas food supply chains, logistics networks." Accessed at https://www.supplychaindive.com/news/winter-storm-texas-food-grocery-heb-supply-chains-logistics/595354/

[5] Associated Press, (August 7, 2021). "Colorado mudslides wreak havoc on major transportation route." Accessed at https://www.usnews.com/news/news/articles/2021-08-07/colorado-mudslides-wreak-havoc-on-major-transportation-route

[6] Overdrive, (September 15, 2018). "Wildfires prompt closure of I-5 in northern California, truckers forced to abandon their rigs." Accessed at https://www.overdriveonline.com/business/article/14895008/california-wildfires-prompt-closures-of-i-5

[7] National Centers for Environmental Information, (January 10, 2022). "Billion-dollar weather and climate disasters." Accessed at: https://www.ncdc.noaa.gov/billions/time-series

National Oceanic and Atmospheric Administration (NOAA) reports that the cumulative costs of these disasters between the years 2016 and 2021 exceeds $742 billion dollars, which is more than one-third of the total cost of the previous 42 years combined.[8] While these figures are not limited to freight related costs, it is a reasonable extrapolation that the movement of goods is similarly experiencing increasing disruption by extreme weather events, driven in-part by climate change.

1.4 Freight Planning Context

The movement of goods is largely a private sector endeavor, but State and local transportation agencies have a role in building, operating, and maintaining much of the transportation network upon which freight moves, including almost the entire highway network. However, freight planning is a relatively new practice for public sector transportation agencies. The 2012 *Moving Ahead for Progress in the 21st Century Act (MAP-21)* (Public Law 112-141) included the first federally defined requirements for statewide freight planning. It's successor federal surface transportation authorization law, the 2015 *Fixing America's Surface Transportation (FAST) Act* (Public Law 114-94), expanded on these provisions and created the first-ever Federal-aid program designated specifically for freight investment, the National Highway Freight Program. The FAST Act also included requirements for all States to develop statewide freight plans to describe how these federal freight funds would be invested.

Congress in 2021 passed the *Infrastructure Investment and Jobs Act (IIJA)* (Public Law 117-58, also known as the *Bipartisan Infrastructure Law (BIL)*), which amended Title 23 and Title 49 freight provisions from MAP-21 and the FAST Act. BIL further emphasizes the importance of building resiliency into all modes of transportation, and explicitly requires State Freight Plans develop strategies to improve the resiliency of the freight transportation system, including strategies to decrease the severity of impacts of extreme weather and natural disasters on freight mobility (49 USC 70202). It also creates a variety of new planning requirements, funding sources, and pilot programs to encourage States to enhance their infrastructural resiliency.

For instance, BIL creates the first-ever federal transportation resiliency highway trust fund program - the *Promoting Resilient Operations for Transformative, Efficient, and Cost-saving Transportation* (PROTECT), funding $1.46 billion in formula funding for State DOTs and $280 million in competitive grants annually, on average (23 USC 176). The program will support States' resiliency planning activities and provide funding for infrastructure projects mitigating the transportation system's vulnerability to climate change. Grant funding is divided into four set-asides for Planning Grants, Resilience Improvement grants, Community Resilience and Evacuation Routes grants, and At-risk Coastal Infrastructure grants.[9] States can unlock a higher federal share of funding for a PROTECT project if they or an applicable MPO develop a "Resiliency Improvement Plan" (RIP) and the project is prioritized in that plan or if they incorporate the RIP into their statewide or metropolitan improvement plans (23 U.S.C. §176; IIJA §11405) .

[8] Ibid.

[9] Congressional Research Service (February 7, 2022). "Federal Highway Programs: In Brief." Accessed at https://crsreports.congress.gov/product/pdf/R/R47022

1.5 Resiliency in Freight Planning

Resiliency can be integrated into State and local freight planning across many different planning processes, documents, and programs (Table 2). Resiliency itself is a wide-ranging concept, and often does not fit neatly within the purview of any one agency department or division. As a result, different States organize and communicate their freight resiliency planning and operations efforts in different combinations of the plans and programs (see also Section 2):

Table 2: Public Sector Planning Processes Related to Freight Resiliency. Source: USDOT Volpe Center.

Type of Plan and Law or Regulation	Freight Resiliency Function
State Freight Plans (SFPs) 49 U.S.C. 70202 *81 FR 71185*	SFPs describe the State's overall approach to investing in and maintaining its multimodal freight network. 49 U.S.C. 70202(b) requires these plans to, among other requirements, explicitly identify "strategies and goals to decrease…the severity of impacts of extreme weather and natural disasters of freight mobility." This requirement was added by the *Bipartisan Infrastructure Law of 2021* and therefore most States did not include a robust discussion or strategies in the SFPs they developed to meet the FAST Act's requirements.
State Long Range Transportation Plans (LRTPs) 23 CFR 450.216 and 23 CFR 450.324	LRTPs outline a comprehensive, multimodal, long-range vision and strategy for the development, maintenance, and operation of the transportation system of a State or metropolitan area, including the freight network. Resiliency is sometimes prominently featured in these plans as an overall goal for the State or regional transportation system.
Transportation Asset Management Plans (TAMPs) 23 CFR Part 515	TAMPs act as a focal point for information about the assets on the National Highway System and other public roads included at the option of the State DOT. These documents describe management strategies, long-term expenditure forecasts, and business management processes for transportation assets in a State. These plans describe management strategies for maintaining transportation infrastructure against threats, oftentimes including climate change and natural disasters. In these plans, the freight network is usually not called out separate from the general transportation network, except in instances where infrastructure class is freight-specific (e.g., truck parking facilities).
Hazard Mitigation Plans *44 CFR 201*	Hazard mitigation planning aims to reduce loss of life and property by anticipating and minimizing the impact of disasters. These plans incorporate freight by identifying major flows of hazardous materials throughout a State and the mitigating actions that will be taken to prevent serious crash or safety concerns, including mitigating storm-related events.

Type of Plan and Law or Regulation	Freight Resiliency Function
Transportation System Management and Operations (TSMO) Plans *No formal Federal requirement*	TSMO plans describe a State or region's plan to maximize the operational performance of the transportation system. TSMO provides flexible solutions to manage dynamic conditions, such as weather or emergency events. Operations plans in the event of a major disaster are a key feature of these plans. Routing of commercial vehicles during an emergency needs to consider factors such as bridge clearances, load posting, and other route restrictions.
Statewide Emergency Response Plans *No formal Federal requirement*	Describe the actions a State will undertake once an emergency declaration is made to quickly recover. These plans prominently feature actions a State will take, including identifying key emergency response stakeholders with whom it will coordinate, to ensure timely delivery of critical supplies during and after a disaster event.
Emergency Routing Section 5502(b) of the FAST Act	Following major disasters, emergency response and recovery activities are dependent on the expeditious movement of utility service vehicles and other trucks, emergency supplies, medicine, food, fuel, and infrastructure repair materials into the affected area. Responses to disasters rely on the timely receipt of equipment and supplies that may be travelling through multiple States. Special procedures are needed for expediting emergency permits for oversized and overweight (OS/OW) loads and routing trucks to the affected area.

2.0 State of the Practice Overview

This section examines the state of freight resiliency planning practice, based on the document review and interviews with selected agencies. Major findings are first summarized and then expanded upon in more detail with supporting examples. There are two major components in freight resiliency planning practice:

1. Planning infrastructure investments to mitigate the effects of extreme weather and natural disasters, and
2. Planning for emergency operations and responses needed to keep freight moving during extreme weather events or natural disasters.

Broadly, transportation agencies have identified freight resiliency as a key planning goal and are currently researching the most effective ways to operationalize resilience as a concept in freight planning and programming. However, many State DOTs are in the early phases of identifying their vulnerable freight infrastructure, coordinating relevant public and private stakeholders and planning processes, and crafting planning strategies.

2.1 Summary of Major Findings

- **Some State DOTs are working to develop collaborative data analysis, planning, and policy approaches to freight resiliency.** Agencies have a keen interest in researching and planning for resiliency in their freight networks and are developing innovative approaches to doing so. However, most agencies are in the early stages of building resiliency concepts into freight planning, and would benefit from additional tools, resources, and training.

- **State DOTs often think about resiliency primarily in the context of highway operations; building resiliency into the multimodal freight network through infrastructure investments is sometimes missing.** Transportation agencies have invested significant time and effort in coordinating stakeholders to respond to extreme weather and natural disaster events. While agencies recognize the critical importance of mitigating climate impacts on freight transportation infrastructure, these planning practices are less mature.

- **Long-range transportation planning efforts often focus on climate change mitigation (e.g., decarbonization strategies) in lieu of robust adaptation and resiliency strategies**. While some SFPs and LRTPs include strategies to reduce carbon emissions, few of them include robust adaptation strategies to improve the performance of infrastructure systems during and immediately after extreme weather events and natural disasters. However, many agencies interviewed have noted that they are working to include both climate mitigation and adaptation strategies in future SFP updates.

- **There is no single approach or office within State DOTs responsible for freight resiliency**. Some State DOTs integrate resiliency concepts as part of their SFPs. Others use operational approaches to collect data on travel time reliability and communicate optimized routing plans and communications to commercial vehicle drivers, allowing them to use existing or lowest risk routes most efficiently. Most agencies interviewed thought of resiliency as an important component of freight planning, but that planning for resiliency was not housed in their specific offices.

- **Transportation agencies are in the early stages of considering resiliency performance measures or factors for project prioritization.** State DOTs and MPOs often rely on models and performance metrics to evaluate and prioritize projects for funding. Methods and data for estimating the benefits of resiliency investments are lacking, particularly in comparison to mature processes for modeling infrastructure condition, safety, and roadway congestion and reliability. This gap in technical tools and data for quantifying resiliency impacts makes it difficult to describe and justify infrastructure investments intended primarily to increase resilience or system redundancy.

2.2 Freight Resiliency Planning Partnerships

As described in Section 1, many different offices and planning units within a State DOT or MPO may be involved in freight resiliency planning and operations. All agencies interviewed for this report stressed the importance of cross-department coordination and stakeholder collaboration as part of their freight resiliency efforts, particularly with the plans listed in Table 2. This section provides examples of freight resiliency planning partnerships identified as part of this research:

Interagency coordination and planning. Most often, public sector freight staff coordinate their resiliency efforts with the statewide or metropolitan long-range transportation planning and

programming functions. Some State DOTs and MPOs have completed transportation resiliency planning efforts focused on passenger vehicle travel or have addressed transportation resiliency in long-range transportation plans. Although freight stakeholders' needs differ from those of passenger vehicles in many ways, most transportation resiliency tools, reports, analyses and other planning efforts developed over the last several years at the statewide level provide valuable insights to freight resiliency planning as well. Most SFPs describe resiliency strategies and resources from their statewide long-range transportation plans, applying insights to freight more generally. Conversely, agency freight planning staff interviewed for this research commonly identified asset management program staff as an internal group they would like to collaborate with more and described current coordination as infrequent.

Freight Advisory Committees (FACs) and local stakeholder coordination. States and regions often partner with smaller units of government within their jurisdictions, relying on their closer relationships with local businesses and freight operators. For example, the Florida DOT (FDOT) hired a contractor to interview local governments and major freight generators in the State to determine operational and network vulnerabilities during hurricanes and other emergency events. Texas DOT (TxDOT) staff also conduct one-on-one interviews with members of its FAC to get more granular, honest feedback on its freight plans and programs to ensure the agency is addressing the most pressing issues in the State.

Emergency operations coordination. Most transportation agencies have identified a liaison in charge of coordinating with their Statewide Traffic Operations Center (or its equivalent) during both emergency events and in "blue sky" conditions. These liaisons work with operations staff to identify infrastructure needs across the transportation system, including the freight network, to ensure safe, efficient, reliable, and resilient goods movement. Operations staff provide valuable insights to planning staff that freight datasets likely would not capture, such as where designated staging grounds are located for various types of emergencies. In many States, Traffic Operations Center staff oversee planning efforts for emergency operations, including defining emergency supply routes. In major emergency events, Federal Emergency Management Agency (FEMA) regional staff directly hire and route commercial drivers to deliver critical goods and supplies to affected areas. FEMA staff coordinate directly with operations staff. Immediately before, during, and after a declared emergency, an increased number of oversized and overweight loads need expedited permits to travel to the affected area. This permitting and routing process is handled by State commercial motor vehicle enforcement agencies. Many States have online automated permitting systems that can auto-issue permits 24-hours per day, seven days per week, which can expedite the process for obtaining permits during an emergency. Activities during an emergency will typically be done through traffic management centers, emergency coordinators, and commercial motor vehicle enforcement agencies that issue oversized/overweight permits. Freight planning staff typically report that, aside from identifying a potential liaison or designee, their departments do not play primary roles during emergency events themselves.

Notably, all agencies contacted for this research described additional coordination and collaboration across stakeholder groups as a major opportunity area to improve freight resiliency planning and analysis.

2.3 Translating Freight Resiliency Insights into Infrastructure and Programming Decisions

Much like the overall concept of freight resiliency planning, agencies described a variety of approaches to developing projects to address freight resiliency and emphasizing resiliency through the project programming process. While almost all agencies contacted for this research did not identify an over-

arching resiliency programming framework or scoring methodology, each of them described ways in which resiliency was incorporated into project programming decisions. Some examples include:

TxDOT: The project prioritization process in Texas considers vital emergency freight routes as one of many scoring factors. Corridors that are identified as evacuation routes or important links in the freight network are assigned extra points in project prioritization.

FDOT: The FDOT 2020 State Freight Plan update added freight resiliency goals. This allows FDOT staff to develop policies that will help resiliency-focused projects better compete for Florida's National Highway Freight Program allocation. The development of these policies is part of FDOT's next phase of the resiliency focus for freight in Florida, with staff working to develop the specifics throughout 2022.

Rhode Island SPC: The MPO is currently working collaboratively with the Rhode Island DOT to modify how projects are ranked and scored considering resiliency and risk in the State's project prioritization process. The agencies are developing a risk-based planning approach to help score transportation assets in this updated process. While freight has not yet been explicitly included as part of this scoring process update, a separate process for making freight routes more competitive in the statewide transportation improvement program (STIP) prioritization process is also underway. Staff are optimistic that under the revised scoring process, projects that are located on important freight routes and incorporate resiliency concepts will compete well for funding.

2.4 Freight Resiliency Performance Management

Generally, most agencies described developing freight resiliency-focused performance measures to be a goal of their program. However, no agency reported successfully developing or tracking measures related to freight resilience to date, outside of the federally required truck travel time reliability index national performance measure in 23 CFR 490 Subpart F.

Agencies described several common reasons for this, including:

- Currently, the agency does not have a defined goal or desired end-state for its approach to freight resiliency, making it difficult to measure progress toward achieving that goal (i.e., defining performance measures at this stage is seen as a bit of "cart before the horse").
- A general lack of defined data and/or metrics to precisely measure projects toward goals.
- Agencies are not yet sure how to use these performance measures to create programmatic feedback loops that help to enhance or mature freight resiliency in their States or regions.

2.5 Freight Resiliency Planning Analysis Approaches and Examples

Transportation agencies could reasonably define several different goals to operationalize their freight resiliency efforts. For instance, one agency might seek to incorporate resiliency measures, metrics, and project decisions around a performance-based planning and programming approach, while another might strive to build strong emergency management and operations plans. While a range of approaches were revealed in this effort, most agencies interviewed described their freight resiliency efforts in discrete terms—characterized by standalone studies, pilots, projects, or research efforts the agency was undertaking—rather than a particular vision or end state to which the agency was working toward. Below are several examples of current practice:

2.5.1 Standalone Freight Resiliency Studies

Most agencies described their freight resiliency efforts as "new" or "under development." Explicit freight resiliency goals have not yet been defined in these organizations. Rather, these agencies are in an exploratory phase. To help develop a coordinated planning strategy for their States, several agencies are undertaking standalone freight resiliency planning efforts to define a vision, coordinate among the various stakeholders, identify data and gaps, and develop resiliency strategies.

TxDOT: The 2022 update to the Texas Statewide Freight Mobility plan will examine storm impacts on freight movements broadly, but TxDOT staff seek to conduct a bigger, more wide-ranging freight resiliency plan in 2022-23. This freight resiliency plan will draw on insights drawn from past extreme weather events to understand how freight was disrupted and to develop appropriate policies and emergency response strategies that position the freight network to perform better during similar future events. TxDOT found great value in examining truck probe data collected during Hurricane Harvey in 2017 to examine their routing responses and challenges, and this plan will help to expand this type of analyses of truck routing to other parts of the State. TxDOT plans to address both the operations of the freight system as well as infrastructure improvements in this plan and intends to develop policy recommendations for each freight mode (e.g., ports, highways, rail). The freight resiliency plan will be done in parallel to and in coordination with the development of the State's first statewide resiliency plan, which will serve as the planning/policy foundation for all of TxDOT on transportation system resiliency.

California DOT (Caltrans): Caltrans is currently working on a freight resiliency report that will inform the development of its next SFP. Statewide freight planners say resiliency has become a much higher priority in California due to the pandemic and recent wildfires, and the California FAC has identified resiliency as major priority moving forward. The findings from the ongoing freight resiliency report will feed directly into future policy and strategy development. Caltrans expects that the primary resiliency strategies developed will center on improving infrastructure and educating regional and local transportation agencies on effective climate mitigation and adaptation strategies.

2.5.2 Infrastructure Vulnerability and Risk Assessments

To prioritize their resiliency-focused actions and investments, many agencies work to identify the infrastructure most vulnerable to storm events, natural disasters, and other disruptions. Often using geographic information systems (GIS), agencies measure the probability of damage due to various weather-related risks (e.g., flooding, wildfire, mudslide, hurricane, coastal erosion) and assign risk and vulnerability scores to roadway segments to aid in project prioritization and planning. Examples include:

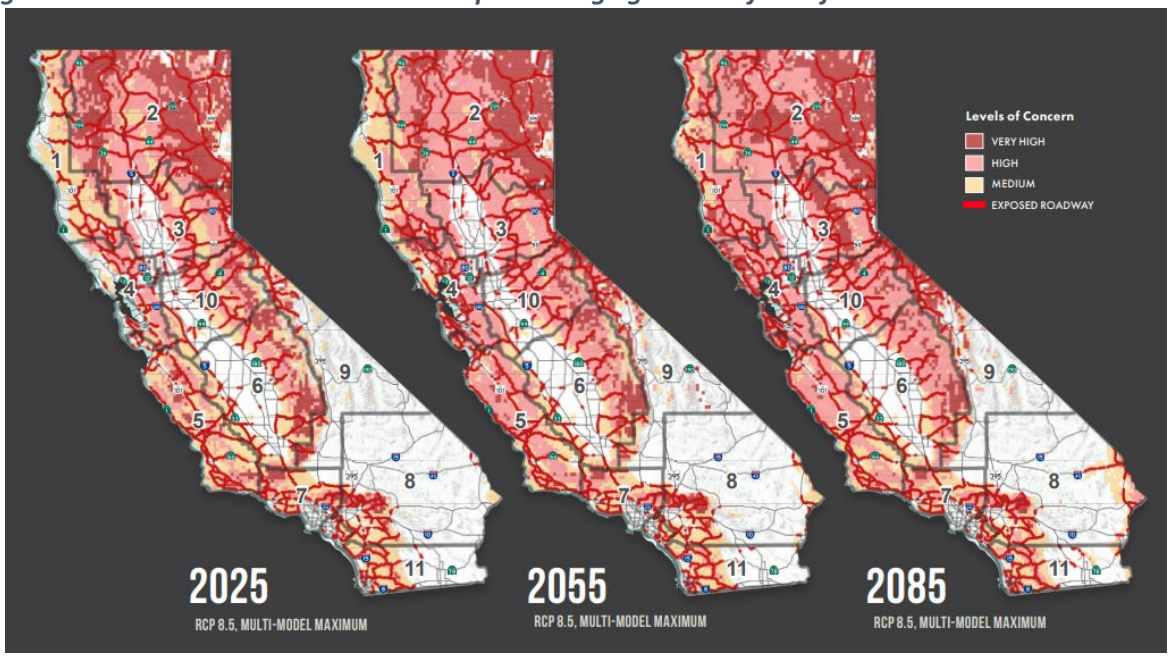
Caltrans: The Caltrans Division of Planning, Climate Change Branch developed vulnerability assessments for each Caltrans district. It also developed an interactive map to show where sea level rise and major weather events are anticipated to occur. Caltrans makes this data available through GIS layers to be used for future analyses, including the freight resiliency plan described above. Figure 2 provides example maps from the Caltrans risk assessment on wildfires for the years 2025, 2055, and 2085.

Colorado DOT (CDOT): The Department developed the CDOT Asset Resiliency Mapping Application. This GIS-based tool combines many datasets into statewide layers for planning and analysis, including freight routes, avalanche paths, geohazards, landslide risk areas, wildfire risk, drought severity, floodplains, and more. CDOT is developing a separate tool that will do real-time detour analysis for three categories of vehicles: passenger vehicles, mid-size trucks and recreational vehicles, and full-size trucks (including

oversized, overweight, or trucks carrying hazardous materials) to help communicate travel conditions and re-route trucks during roadway closures.

Rhode Island SPC: The MPO uses STORMTOOLS, an online mapping product built by academic and non-profit agencies to research the effects of sea level rise on the Rhode Island coast. The Rhode Island State DOT and the SPC use the data in this tool to filter proposed projects to examine whether freight and other transportation projects are within areas projected to experience 1-3 feet of sea level rise.

Figure 2: Caltrans Risk Assessment Example - Changing Levels of Wildfire Concern. Source: Caltrans.



2.5.3 Statewide Coordination Approaches

Some additional, less-common, approaches to freight resiliency planning include seeking expertise from a FAC and hiring a part-time resilience officer.

FDOT: Florida freight staff have undertaken several resiliency-focused studies in recent years and are currently working to translate these insights into actionable strategies. For example, in recent years FDOT has worked with a contractor to interview local agencies and engage with the Florida FAC to gather on-the-ground insights and information about recent disruptive events. FDOT expects to use the insights gathered from these interviews to identify vulnerable assets and build strategies in its next freight plan to improve freight infrastructure and system operations and address concerns raised from previous storm events. FDOT is still working to identify specific outcomes of the effort as of the writing of this report.

CDOT: CDOT hired a part-time transportation resilience officer who manages the State's resilience program and coordinates the various CDOT offices to implement statewide recommendations. CDOT freight staff work with this coordinator to identify high-risk areas requiring additional funding and attention, and to build datasets that help measure performance on the network. The CDOT Risk and Resiliency Program has built out a suite of tools and resources to help different program offices incorporate resiliency concepts into their plans and programs.

2.5.4 Strategies to Improve Freight Network Resiliency to Climate Change and Natural Disasters

Transportation agencies use both infrastructure and operations-focused strategies to mitigate and respond to storm events and natural disasters. The following examples illustrate a range of strategies that transportation agencies employ to increase freight and transportation system resiliency.

Engineering and Infrastructure Responses

Iowa DOT: In places where roadway shoulders are observed to be both under-engineered and prone to flooding, and therefore at risk of collapse, the Iowa DOT deploys *tied concrete block mats* (Figure 3). These porous concrete "blankets" help to stabilize shoulders and slopes during major storm events or flooding. The Iowa DOT finds these products to be a cost-effective strategy to limit roadway erosion.

TxDOT, example 1: Many bridges which cross highways on the freight network do not have enough clearance to meet modern highway design standards. As witnessed during recent storm events in the State, overhead clearance becomes a major supply routing issue when a roadway is flooded and trucks cannot pass. TxDOT freight staff gathered data about the impacts of low-clearance bridges on freight performance, and used these insights to help State leadership more effectively communicate the challenges posed by low-clearance bridges to decision-makers in charge of programming freight funds.

TxDOT, example 2: The State works to stagger maintenance and construction activities on parallel routes to ensure travel redundancy in the event of an emergency. TxDOT reports that this takes a lot of planning and effort to coordinate work on alternate and parallel routes, but stress that retaining mobility and connectivity during disruptions is an important resiliency consideration.

Figure 3 Example of tied concrete block mats in use in western Iowa to protect roadway shoulders from erosion caused by flooding. Source: Iowa Department of Transportation.

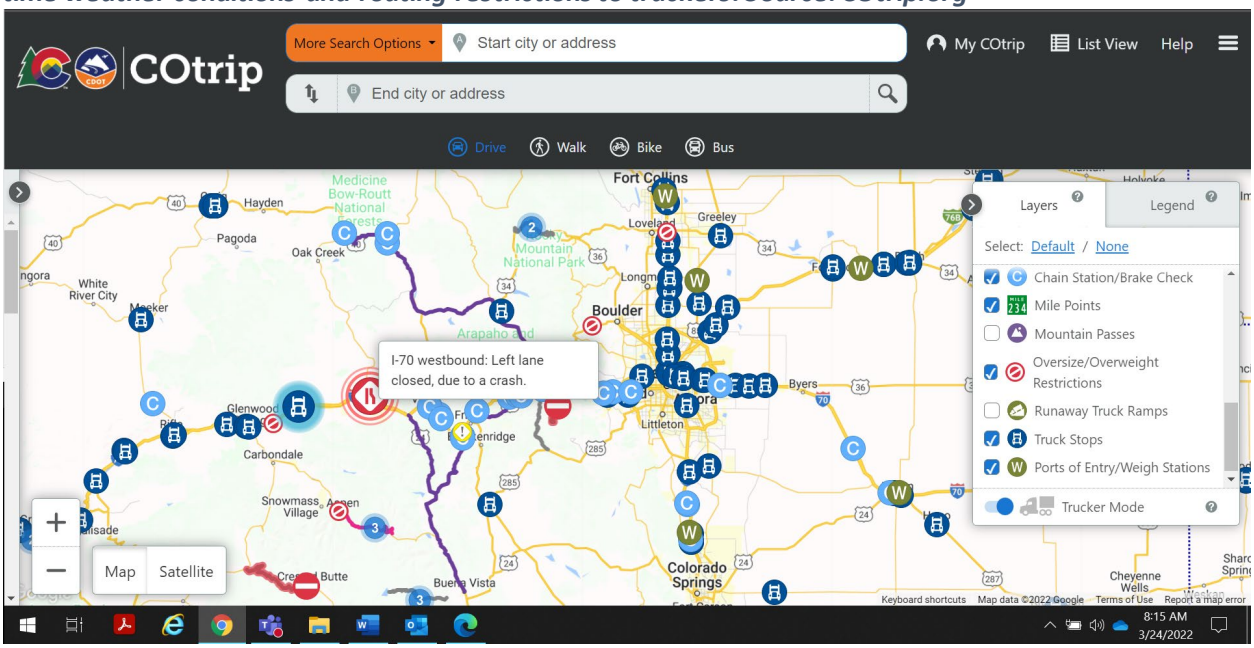
Operations Approaches

Colorado DOT: CDOT developed and operates cotrip.org, which includes a "Trucker Mode." This system shares information about construction and weather restrictions affecting freight routes (Figure 4). A trip-planning tool allows truck operators to input information regarding their truck size, expected route information, and other information to help determine what roads can be used for the trip. Weather impacts on the freight system are communicated through cotrip.org in real time to allow truckers to view live routing restrictions.

TxDOT: TxDOT freight staff found the departments' traffic camera system in Houston to be very useful for emergency operations during Hurricane Harvey. The live feeds and data collected through the system helped to identify people in need of assistance. The system also helped identify areas experiencing major flooding to determine how to route trucks in and out of the most affected areas. In the aftermath of Harvey, TxDOT has deployed similar traffic camera systems in other parts of the State to prepare for future events and respond in a similar manner.

Iowa DOT: The Iowa DOT renumbered the northern arm of I-680 as I-880 to improve the clarity in messaging during detours and emergencies. Previously, what many drivers perceived as two separate highways where both numbered as I-680. The Iowa DOT found it difficult to communicate emergency routing detours with travelers in the area during the major flooding events of 2019 because one section of I-680 was underwater while the northern half served as the evacuation route. Renaming one leg of the highway allows the agency to describe emergency routing much clearer to travelers in the region, thereby increasing the efficiency of emergency operations.

Figure 4: Screenshot of COtrip's Trucker Mode, which helps plan freight trips and communicates real-time weather conditions and routing restrictions to truckers. Source: COtrip.org



3.0 Findings and Actions for Improving Freight Resiliency Planning Practice

This research identified several opportunities for improving freight resiliency planning practice, informed by both the document review and the discussions with transportation agencies. Freight planning is still relatively new for State DOTs and MPOs, so it is perhaps not surprising that the complexities of planning for freight resilience and the changing risks of climate change and extreme weather have not yet been fully integrated. However, transportation agencies recognize this as an urgent need, and they want resiliency to be a bigger part of their approach. This section summaries ideas for improving the consideration of resiliency in freight planning.

3.1 Gaps in Public Sector Freight Resiliency Practice

The project team identified several gaps in freight resiliency practice. Below, these gaps are described in broad terms. Potential actions to fills these gaps, as suggested by agencies included in this study, are included with each:

Undefined goals for freight network resiliency outcomes. Most agencies agree that a resilient freight network is a goal for their State or region. However, few agencies have articulated what type of resiliency program or effort they are ultimately working to build, or the desired future state they are working towards. Agencies commonly describe data gaps and analyses for measuring and "doing" freight resiliency in their freight planning efforts, but with little specificity. Defining a clear vision for what freight resiliency means to them and their stakeholders is an important first step to incorporating resiliency into freight planning. As noted above, some State DOTs have recognized this and begun scoping standalone planning processes to help them define a freight resiliency mission.
Agency-defined resources needed to close this gap include:

- Clear descriptions of example freight resiliency approaches, techniques, and/or effective practices making up a freight resiliency program.
- Opportunities to discuss freight resiliency program development with peers and national experts.
- Methods and tools for more directly measuring resilient freight networks and outcomes (beyond truck travel time reliability) and for identifying critical vulnerabilities in the freight network.

Stakeholder collaboration within and beyond planning jurisdictions. State DOTs and local partners typically agree that more coordination and attention is necessary to help strengthen freight resiliency planning practice. Each transportation agency interviewed for this report explicitly mentioned groups or partners they want to engage with further. The agencies often expressed the desire to use asset management programs to coordinate resiliency strategies that harden or adapt infrastructure. Long-range transportation planning staff also expressed a desire to work more closely with operations and emergency preparedness planners to build feedback loops across mitigation, adaptation, and response strategies.

Agency-defined resources needed to close this gap include:

- Clear descriptions of example approaches to inter- and intra-agency planning coordination to amplify freight resiliency planning effectiveness.

Lack of data and information documenting planning breakdowns during disaster response. Freight bottlenecks and common network breakdowns might not be well documented during disasters. After major storm events, both Federal Emergency Management Agency (FEMA) regional staff and FHWA division offices develop after-action reports describing the effectiveness of emergency responses utilized and identify operational breakdowns that should be addressed in the future. Freight planning staff at the agencies contacted for this research are aware of these after-action reports, but few are using them to inform freight planning, and few described them as a valuable tool in identifying future priorities for freight investments.

Agency-defined resources needed to close this gap include:

- Example methodologies for using existing freight and industry data in new ways to measure freight resiliency (e.g., combining truck probe data and climate change-related data from NOAA and the U.S. Geological Survey to identify current, and predict future, network vulnerability).
- Access to better web tools that help agencies more readily identify climate-related vulnerabilities in the freight network.
- Emergency routing tools that can share real-time information with drivers delivering emergency supplies during disasters.

Operationalizing resiliency concepts, including methods for identifying "freight resiliency projects" and forecasting the anticipated benefits to the network. Without specific measures or metrics, resiliency-focused investments are difficult to quantify and justify. Transportation agencies will need to continue working to identify ways of measuring resiliency benefits of proposed projects or consider other ways of prioritizing projects which address resiliency goals.

Agency-defined resources needed to close this gap include:

- Clear descriptions of how other public agencies have effectively measured and scored resiliency investments in their freight network for inclusion in STIPs and metropolitan transportation improvement programs (TIPs).
- Opportunities to discuss performance-based freight resiliency planning with peers and national experts.

4.0 Conclusion

The last several years have illustrated the massive impact freight disruptions can have on the lives of everyday Americans. State and regional agencies have firsthand knowledge of the infrastructure and operational challenges that have contributed to these disruptions and are prioritizing their mitigation as a key goal for their freight programs. As public sector freight planning continues to mature at the State and local levels, better and more wide-spread resiliency practices will help to improve the system. FHWA has clear opportunities to provide direct technical assistance, education, and tools to its partners to help advance the state of practice in freight resiliency planning and contribute to this development over the next several years.

Appendix A: Additional Literature

Enhancing resiliency at the State and regional scales has become a hot topic at USDOT in the last several years. The supply chain crises of 2020-21, along with the passage of the BIL and its expanded climate resiliency functions, have added freight at as a central theme of these conversations. The efforts below may be valuable in defining future efforts in coordination with partner offices across USDOT:

Building Resilience into Freight Transportation Systems: Actions for State Departments of Transportation. *Chilan Ta, Anne Goodchild, and Barbara Ivanov. Transportation Research Record: Journal of the Transportation Research Board, No. 2168. Transportation Research Board of the National Academies, Washington, D.C., 2010, pp. 129-135. DOI: 10.3141/2168-15.* The authors describe the concept of freight resiliency in the context of the freight transportation planning process and highlight the efforts of the Washington State Department of Transportation to highlight real world success stories.

Development of a State Wide Freight System Resiliency Plan. *Chris Caplice, James B. Rice Jr., Barbara Ivanov, and Elizabeth Stratton (no date).* Using research conducted by the Washington State Department of Transportation, this paper proposed a framework for develop a Freight System Resiliency Plan.

FHWA Vulnerability Assessment and Adaptation Framework, 3rd Edition. *Federal Highway Administration, 2018.* A manual to help transportation agencies and their partners assess the vulnerability of transportation infrastructure and systems to extreme weather and climate effects. It also can help agencies integrate climate adaptation considerations into transportation decisionmaking.

Incorporating Resilience into Transportation Planning and Assessment. *Sarah Weilant, Aaron Strong, Benjamin Miller. Rand Corporation, 2019.* Building on FHWA's Vulnerability Assessment and Adaptation Framework (VAF), this report describes methods of incorporating resiliency concepts into transportation decision-making. This is not a freight-specific publication but includes similar concepts that could easily be applied to the freight transportation planning process.

Appendix B: Plans Reviewed

The following plans were reviewed to inform this report.

Alaska

- Alaska State Freight Plan (2016)
- Let's Keep Moving 2036 Statewide Long Range Transportation Plan (2016)
- Alaska Transportation Asset Management Plan (2019)
- State Hazard Mitigation Plan (2018)
- Alaska Disaster Response Plan (2018)

California

- California Freight Mobility Plan (2020)
- California Long Range Transportation Plans (2021)
- Transportation Asset Management Plan (2019)
- State of California Hazard Mitigation Plan (2018)
- State of California Emergency Plan (2017)

Colorado

- Colorado Freight Plan (2019)
- Transportation Matters Statewide Transportation Plan 2040 (2015) and associated Action Plan
- Transportation Asset Management Plan (2019)
- Colorado Enhanced Hazard Mitigation Plan (2018)
- Statewide Emergency Operations Plan (2019)
- I-70 Corridor Risk and Resilience Pilot (2017)
- Colorado Statewide Resiliency Framework (2020)

Connecticut

- Connecticut Statewide Freight Plan (2017)
- Connecticut's Statewide Long Range Transportation Plan 2018-2050 (2018)
- Highway Transportation Asset Management Plan (2019)
- Connecticut Natural Hazard Mitigation Plan (2018)
- State Response Framework Version 4.2 (2019)
- Connecticut Department of Transportation Climate Change and Extreme Weather Vulnerability Pilot Project (2014)

Florida

- Florida Freight Mobility and Trade Plan (2020)
- Florida Long Range Transportation Plan (2020)
- Transportation Asset Management Plan (2019)
- Hazard Mitigation Plan (2018)
- Statewide Emergency Response Plan (2020)

Iowa

- State Freight Plan (2017)
- Iowa in Motion 2045 State Long Range Transportation Plan (2017)
- Transportation Asset Management Plan (2019)

- Iowa Hazard Mitigation Plan (2018)
- Statewide Emergency Response/Transportation System Management and Operations Plan (2019)

Minnesota

- Statewide Freight System and Investment Plan (2018)
- Statewide Multimodal Transportation Plan 2017 to 2036 (2017)
- Transportation Asset Management Plan (2019)
- Statewide Hazard Mitigation Plan (2019)
- Minnesota Emergency Operations Plan (n.d.)

New Hampshire

- New Hampshire Statewide Freight Plan (2019)
- State Long Range Transportation Plan (2010)
- New Hampshire Transportation Asset Management Plan for Pavements & Bridges on the National Highway System (2019)
- Statewide Hazard Mitigation Plan (2018)
- Statewide Emergency Response Plan (2019)

North Carolina

- North Carolina Multimodal Statewide Freight Plan (2017)
- NC Moves 2050 Range Transportation Plan (2021)
- Transportation Asset Management Plan (2019)
- State Hazard Mitigation Plan (2018)
- Statewide Emergency Operations Plan (2020)

North Dakota

- State Freight Plans (2015)
- State Long Range Transportation Plan (2021)
- Transportation Asset Management Plan (2018)
- Statewide Multi-Hazard Mitigation Plan (2013)
- Statewide Emergency Response Plan (2013)

Oregon

- Oregon Freight Plan (2017)
- Oregon Transportation Plan (n.d.)
- Oregon Transportation Asset Management Plan (2019)
- Oregon Natural Hazards Mitigation Plan (2020)
- Statewide Emergency Response Plan (2017)

Texas

- Texas Freight Mobility Plan (2018)
- Texas 2050 State Long Range Transportation Plan (2020)
- Texas Transportation Asset Management Plan (n.d.)
- Texas Hazard Mitigation Plan (2019)
- State of Texas Emergency Management Plan (2020)

Washington

- Washington State Freight System Plan (2017)
- State Long Range Transportation Plan (2020)
- Transportation Asset Management Plan (2019)
- Washington State Enhanced Hazard Mitigation Plan (2018)
- State Comprehensive Emergency Management Plan (2019)