MDOT

MARYLAND DEPARTMENT
OF TRANSPORTATION

TRANSPORTATION RESILIENCE IMPROVEMENT PLAN

2024

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EXECUTIVE SUMMARY

The Infrastructure Investment and Jobs Act (IIJA), also known as the Bipartisan Infrastructure Law, was signed into law in November 2021. The law authorizes $1.2 trillion for transportation and infrastructure spending, with $550 billion designated for "new" investments and programs. Within the IIJA, $8.7 billion was designated for the creation of the Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) program.

PROTECT is administered by the U.S. Department of Transportation (USDOT) Federal Highway Administration (FHWA). In total, the PROTECT Formula Program offers $7.3 billion in funding, and the PROTECT Discretionary Grants Program offers $1.4 billion in competitive grants for the years 2022 to 2026. Maryland is expected to receive $107 million in federal cost-share formula funding through the 5-year authorization period. The main distinction between the two funding mechanisms is that Formula Program funds are distributed directly to states, whereas eligible recipients under the Discretionary Grant Program must compete for the approximate $1.4 billion in discretionary funds. The purpose of both programs is to help states and communities improve the resilience of their surface transportation infrastructure to natural hazards. Specifically, the PROTECT funds support resilience-focused activities across four main areas of focus:

- **Planning:** Resilience planning activities to assess surface transportation infrastructure vulnerabilities from the impacts of natural hazards.

- **Resilience Improvements:** Improve the ability of existing surface transportation infrastructure to withstand extreme weather events and other natural hazards to support rapid recovery.

- **Community Resilience and Evacuation Routes:** Strengthen and protect evacuation routes, including community resilience, to support continued or rapid recovery from weather events and natural disasters.

- **At-risk Coastal Infrastructure:** Harden, stabilize, elevate, or relocate existing surface transportation infrastructure to improve resilience. Enhance natural infrastructure systems to protect surface transportation infrastructure while improving ecosystem conditions.

Planning grants administered through the PROTECT Discretionary Grant Program include 100% federal cost share. In addition, the PROTECT Formula Program requires each state to use a minimum of 2% each fiscal year for planning-related activities, including the development of a resilience improvement plan, resilience planning, predesign or design, technical capacity building, and evacuation planning and preparation.

For over a decade, Maryland has been at the forefront of identifying and deploying a variety of climate resilience strategies. Together, the State of Maryland and the Maryland Department of Transportation (MDOT) have sought resilience measures through strategic investments in projects, programs, and at-risk infrastructure. MDOT will continue to work with partners to ensure expanded alignment of resilience measures. It is important to note that project-related work under the PROTECT program must comply with *Code of Federal Regulations* **Title 23 requirements**.

In alignment with these efforts, MDOT has developed this Transportation Resilience Improvement Plan (TRIP) to guide strategic investments in critical infrastructure, proactively identify and address actions, and align adaptation and mitigation efforts with MDOT's resilience objectives. This plan adheres to federal requirements and guidelines outlined in the 2022 FHWA PROTECT Formula Program Implementation Guidance, specifically Section G (3) (FHWA 2022b), which focuses on the development of resilience improvement plans. MDOT's approach to the TRIP development aimed to be inclusive of other modes of transportation, ensuring that interdependencies, as well as potential co-benefits of projects, were addressed.

This TRIP represents a crucial progression in MDOT's resilience strategy. It offers insight into MDOT's current position within various resilience initiatives, outlines the agency's desired direction, identifies opportunities and next steps, and presents an overview of the agency's existing processes, available data, technical information, and growth prospects. Through the TRIP, MDOT is setting a clear path to inform both present and future endeavors. Even though some modal administrations are not eligible for PROTECT funds, these administrations can use the TRIP as a guide for how to incorporate resilience into their practices. Furthermore, MDOT is in the process of developing a Climate Action Plan, which will focus on both carbon reduction and system resilience. The Climate Action Plan will expand upon initiatives outlined in the TRIP and in MDOT's approved Carbon Reduction Strategy.

1 INTRODUCTION AND OVERVIEW

The Maryland Department of Transportation's (MDOT) Transportation Improvement Plan (TRIP) provides a guide for strategic investment in Maryland's critical infrastructure and proactively identifies actions that can be taken to align adaptation and mitigation efforts throughout MDOT. The TRIP follows guidance from the Federal Highway Administration (FHWA) related to Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) funding and considers ways to include other transportation modes when addressing resilience to strive towards achieving MDOT's resilience-related objectives and goals. Through the development of the TRIP, other MDOT plans and processes were considered and incorporated to ensure a holistic, comprehensive approach has been outlined.

1.1 Background

Climate resilience is a longstanding area of emphasis within MDOT because of the state's coastal location and the multiple natural threats that can impede normal operations, including hurricanes, extreme weather events, and winter storms. Between 2011 and 2021, Maryland experienced 10 climate disaster declarations, ranking it 18th out of 50 states in terms of Federal Emergency Management Agency (FEMA) and U.S. Department of Housing and Urban Development post-disaster relief spending (referenced in Stebbins 2023). In addition, a recent FEMA case study revealed that a 100-year flood event, which has a 1% probability of occurrence in any given year, could result in over $8 billion in economic losses to the state (FEMA 2021). Another study completed in 2021 by the Pew Foundation noted that approximately 20% of state-maintained roadways in Maryland are prone to flooding (Fuchs 2021). Of the 2,771 flood-related incidents reviewed for this study, 78% happened outside of the 100- and 500-year FEMA mapped flood zones, indicating that MDOT may have vulnerabilities in areas not currently anticipated.

To address the rising concern of transportation system resilience nationwide, in July 2022, the U.S. Department of Transportation (USDOT) FHWA released guidance for the new PROTECT program. This initiative provides $7.3 billion in formula funding, in addition to $1.4 billion allocated for discretionary or grant funding during federal fiscal years (FFY) 2022 to 2026. PROTECT's primary objective is to assist states and communities in their efforts to prepare for and respond to severe weather events and the effects of climate change. This first-of-its-kind program addresses the impacts of extreme weather and climate change on the nation's surface transportation infrastructure, such as roads, bridges, and rail lines. The program originates from the Infrastructure Investment and Jobs Act (IIJA), a $1.2 trillion legislative package passed by the U.S. Congress and implemented by the Biden-Harris Administration in 2021. Subsequently, in April 2023, USDOT issued a Notice of Funding Opportunity, authorizing $848 million in discretionary grants for FFY 2022 and 2023 (USDOT n.d.).

The PROTECT Formula Program designates specific funding allocations to states for the period spanning FFY 2022 to 2026 intended to facilitate the planning and implementation of resilience improvements for surface transportation assets and vulnerable highway infrastructure (FHWA 2022a). Based on formula funding alone, Maryland anticipates receiving approximately $107 million in total, including at least 2% for eligible planning activities each fiscal year. Maryland also has the option to pursue PROTECT discretionary grants available through the PROTECT program.

This TRIP serves as a roadmap for a data-driven investment strategy to address the resilience of critical infrastructure by proactively identifying and managing risks through adaptation and mitigation measures that will support MDOT's overall resilience goals. The TRIP was prepared in alignment with federal requirements and guidelines established in the PROTECT Formula Program Implementation Guidance released by the FHWA (2022b). Specifically, the TRIP was developed in accordance with Section G (3), which outlines the development of resilience improvement plans. The TRIP's alignment with these federal requirements is provided in **Appendix A**.

The MDOT TRIP's primary purpose is to establish the framework to expand upon existing workflows and tools to embed climate and extreme weather considerations into project planning and design, investment, prioritization, and life-cycle planning across all modal administrations to support Maryland's sustainable transportation future. MDOT also aims to integrate climate risk assessment into decision making across all critical asset classes and project life cycles and to provide strategies for defending against, accommodating, or planning for transformative adaptation from climate related hazards.

Sections 1.2 through **1.5** provide an overview of MDOT's transportation system, identify key threats to the system, and discuss the critical interdependencies among infrastructure sectors. In addition, a comprehensive list of acronyms and abbreviations used throughout the TRIP is provided in **Appendix B**.

1.2 Overview of the MDOT Transportation System

MDOT oversees and manages the state's comprehensive transportation system, which encompasses a range of transportation modes, infrastructure, and services that facilitate the movement of people and goods within Maryland. This system includes highways and roads, bridges and tunnels, public transit, short line freight rail and regional commuter rail, ports and harbors, airports, toll facilities, bicycles and pedestrian infrastructure, and light rail. **Figure 1.1** provides a high-level overview of MDOT's transportation system.

Figure 1.1: Overview of Maryland Department of Transportation's System

Maryland's Major Statewide Transportation System

Legend:
- MDOT MVA Service Locations
- MDOT MVA Vehicle Emission Inspection Stations
- State-owned Airports
- Port of Baltimore
- Passenger Rail
- Major Roadways - Freight Network

17,143 state maintained lane miles of roadways

2 state airports

9 toll facilities

66 local bus routes, one light rail line, one metro line

38 commuter bus routes

24 MDOT MVA Service Locations

18 Maryland Vehicle Emissions Inspection Program Stations

700 miles of sidewalks along MDOT SHA-owned roadways

68 MDOT SHA-owned bicycle lanes

343 Maryland rail-trail miles

171 miles of short line freight rail and Maryland Area Regional Commuter (MARC) rail service

7 State-owned public cargo terminals

1 international cruise terminal at the Port of Baltimore

MDOT also supports 33 public use airports in the State through federal grant programs, provides technical assistance for transit systems in 23 counties, and is a funding partner of the regional Washington Metropolitan Area Transit Authority (WMATA).

Source: *MDOT, 2019. | MVA = Motor Vehicle Administration | SHA = State Highway Administration*

The State of Maryland ranks as the 42nd largest state in landmass but the 19th most populous state in the United States. Between the 2010 and 2020 census, Maryland's population increased 7%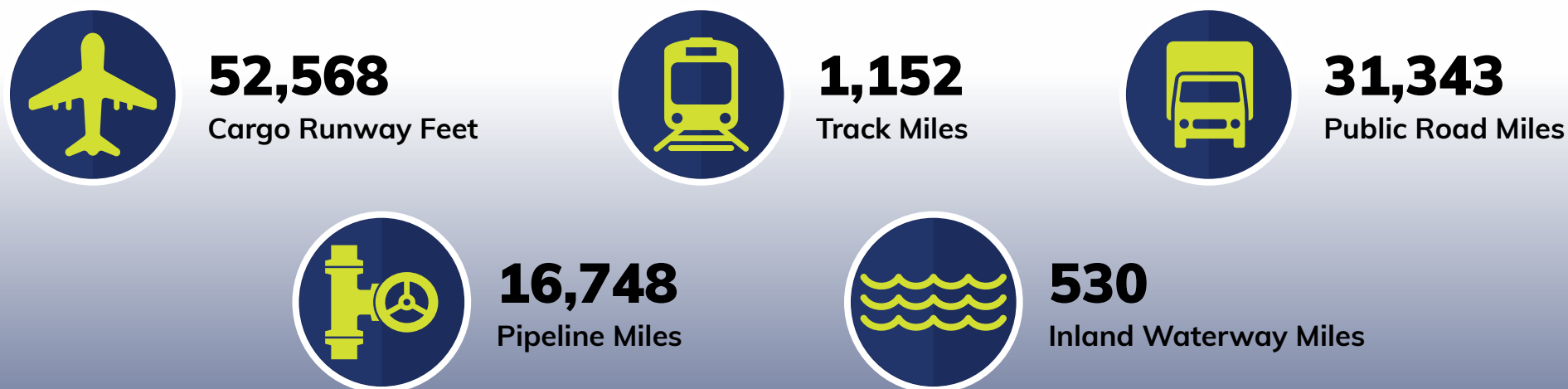. As population increases, there is generally an increase in demand for products and services that influence goods movement. As a result, goods moving into, out of, and within Maryland have been continuously growing. An overview of the State's freight network is provided in **Figure 1.2**. Freight moving to, from, or within Maryland amounted to nearly 281 million tons, valued at nearly $376 billion in 2020 (MDOT 2022). By 2050, freight tonnage is expected to increase by 53% to nearly 429 million tons, at an estimated value of $781 billion. These estimates do not reflect pass-through freight, which has historically accounted for nearly two thirds of the total goods carried via Maryland's multimodal freight transportation system (MDOT 2022). Maryland's roadways collectively handled approximately 78% of the total freight tonnage and 76% of the total freight value, worth approximately $286 billion (MDOT 2022). These statistics demonstrate the sheer size of MDOT's freight network and demonstrate the potential impacts to freight movement that could occur during major natural hazard events.

MDOT's purpose is to deliver safe, sustainable, intelligent, exceptional, and inclusive transportation solutions to connect its customers to life's opportunities. Four goals identified in the 2050 Maryland Transportation Plan (MTP) help MDOT achieve this vision and mission:

- **Enhance Safety and Security:** Protect the safety and security of all residents, workers and visitors.

- **Deliver System Quality:** Deliver a reliable, high-quality, integrated transportation system.

- **Serve Communities and Support The Economy:** Expand transportation options to allow Maryland's diverse communities to access opportunities and to support the movement of goods.

- **Promote Environmental Stewardship:** Minimize and mitigate the environmental effects of transportation.

Figure 1.3 provides the MDOT mission statement.

Figure 1.2: Overview of Freight Network

52,568 Cargo Runway Feet

1,152 Track Miles

31,343 Public Road Miles

16,748 Pipeline Miles

530 Inland Waterway Miles

Source: *MDOT State Freight Plan (2022)*

Figure 1.3: Maryland Department of Transportation Mission Statement

MISSION STATEMENT

The Maryland Department of Transportation is a customer-driven leader that delivers safe, sustainable, intelligent, exceptional, and inclusive transportation solutions in order to connect our customers to life's opportunities

Source: *MDOT, n.d.b.*

1.3 MDOT Modal Administrations and Authority

MDOT is composed of the Transportation Secretary's Office (TSO), five modal administrations (Maryland Transit Administration [MTA], Maryland Aviation Administration [MAA], Maryland Port Administration [MPA], State Highway Administration [SHA], and Motor Vehicle Administration [MVA]), and one authority (Maryland Transportation Authority [MDTA]). The five modal administrations and MDTA are each headed by an administrator or executive directly responsible for managing their respective transportation sector programs. A high-level overview of each mode follows:

- **MTA** manages and operates public transit services across the State of Maryland, including buses, light rail, subway, and commuter rail services. MTA oversees the maintenance and development of transit infrastructure and aims to provide safe, reliable, and efficient transportation options to residents and visitors.

- **MAA** oversees and manages Maryland's airports and aviation-related activities, including the state's major airports such as Baltimore/Washington International Thurgood Marshall Airport and Martin State Airport, as well as regional aviation airports. MAA works closely with the Federal Aviation Administration to implement and enforce safety regulations and standards at Maryland's airports.

- **MPA** oversees the administration, operation, and promotion of Maryland's public marine terminals, primarily focusing on the Port of Baltimore. MPA facilitates the efficient and secure movement of cargo throughout these ports and works to contribute to the economic development of the region by attracting new businesses and cargo to the Port of Baltimore.

- **SHA** is responsible for the planning, construction, maintenance, and management of the state's road and highway network. SHA focuses on safety, traffic management, sustainability, and the overall improvement of the state's transportation network to meet the needs of residents and businesses.

- **MVA** manages various aspects of motor vehicle registration, driver licensing, and safety throughout the state. MVA focuses on safety, compliance with state and federal regulations, and providing essential services to the residents of Maryland.

- **MDTA** manages and operates various toll facilities and transportation infrastructure assets, including bridges and tunnels. The MDTA's responsibilities encompass toll collection, infrastructure maintenance, financial stewardship, and various measures to confirm the safety and efficiency of its facilities.

Each modal administration has taken action to assess and improve transportation resilience to climate change. For example, many modal agencies are conducting vulnerability and risk assessments and developing tools and plans to assess and analyze the impacts of climate change on statewide transportation infrastructure.

Across these modes, MDOT has been working to harmonize and incorporate these efforts into business practices to adapt and manage climate risk, as well as to integrate the knowledge into agency-wide decision making. The MDOT Office of Climate Change Resilience and Adaptation (OCCRA), housed within MDOT's TSO, is collaborating with the modal administrations and MDTA to integrate climate change mitigation, resilience, adaptation, and risk management into policies, planning, project and program development, asset management, maintenance, design, construction, and operations. Additionally, OCCRA helps to coordinate funding from the PROTECT program for eligible projects.

1.4 Threats to MDOT's Transportation System

Maryland faces a variety of threats to its transportation system that can impact the safety, functionality, and resilience of the infrastructure. These threats can range from natural disasters to human-induced events. The Maryland Department of Emergency Management (MDEM) recently released a State Hazard Mitigation Plan (Maryland Emergency Management Agency 2021), which identifies potential hazards, vulnerabilities to these hazards, and mitigation strategies to reduce future damages. As part of the plan, MDEM conducted a thorough analysis to identify the current and future hazards that are likely to negatively impact Maryland.

The main threats to MDOT's transportation system identified in MDEM's analysis are included in **Table 1.1**.

Table 1.1: Relevant Hazards for Maryland

Natural Hazards	
Coastal hazards	Thunderstorms
Dam failures	Tornadoes
Drought	Wildfires
Extreme temperatures	Wind
Floods	Winter storms
Soil movement	Public health emergencies
Human-caused Hazards	
Terrorism	Civil unrest
Active shooters	Cyberattacks
Nuclear incidents	Transportation accidents

Source: *Maryland Emergency Management Agency, 2021.*

Following hazard identification, MDEM rated the hazards using a probability assessment. Probability was defined as the likelihood of the hazard occurring, in general descriptors (for example, unlikely, likely, highly likely); historical frequencies; statistical probabilities (for example, 1% chance of occurrence during any given year); and/or hazard probability maps. The hazards probability ratings are included in **Table 1.2**.

Table 1.2: Hazards Probability Rating

Rating	Probability	Maryland Identified Hazards	
1	**Unlikely (hazards generally ranked as low)** Hazard event is likely to occur less than once every 30 years.	N/A*	
2	**Likely (hazards generally ranked as medium)** Hazard event is likely to occur less than once every 5 years but more often than once every 30 years.	• Dam failures • Drought • Extreme temperatures • Human-caused hazards	• Public health emergencies • Soil movement • Tornadoes • Wildfires
3	**Highly Likely (hazards generally ranked as high)** Hazard event is likely to occur more than once every 5 years.	• Coastal hazards • Floods • Thunderstorms	• Winter storms • Wind

Source: *Maryland Emergency Management Agency, 2021.*
*Hazards that were deemed unlikely were screened out during the initial hazard identification planning process phase.
N/A = not applicable

The threats cited that are most likely to impact MDOT's transportation system include coastal hazards, flood hazards, extreme temperatures, soil movement, and severe weather. A high-level overview of these threats in Maryland is provided in the following sections. The in-depth risk and vulnerability data and analysis conducted for each hazard listed in **Table 1.1** can be found in MDEM's State Hazard Mitigation Plan (Maryland Emergency Management Agency 2021).

1.4.1 COASTAL HAZARDS

Coastal hazards can take many forms, such as tropical depressions, tropical storms, hurricanes, storm surge and tide, coastal floods, nuisance floods, and sea level rise. Maryland's coastal zone encompasses two thirds of the state's land area and is home to almost 70% of Maryland residents; coastal hazards are a top threat to MDOT's system. Maryland also has an extensive shoreline, which is particularly vulnerable to direct impacts from coastal hazards. As such, the state's coast frequently experiences flooding and erosion caused by coastal hazards, which are exacerbated by sea level rise.

For example, Hurricane Sandy in 2012 was one of the most impactful hurricanes the state has experienced. The immediate effects of the storm were felt for several days throughout the state as it produced heavy rains, strong winds, and snow. It ultimately resulted in loss of life for 11 people and led to significant coastal flooding along the Chesapeake Bay. Although every county suffered some level of damage from the storm, Somerset County was the most impacted. The initial damage estimate in Somerset County was $40 million. The overall damage estimate throughout the state was close to $43 million.

In 2003, Hurricane Isabel caused historic damage to downtown Annapolis, and hundreds of homes and businesses were declared uninhabitable because of major flood damage. The National Weather Service estimated over $400 million in damage statewide. According to an MDEM report, between 1993 and 2010, coastal storm events accounted for $109 million in property damage and $193,215 in crop damage (MCCC n.d.).

Furthermore, Maryland is particularly vulnerable to coastal inundation because of rising seas and sinking land. The state is projected to face an estimated 0.8 meter of sea level rise by 2100, with a likely range of 0.62 meter to 1.08 meters (UMCES 2023). According to SHA, Maryland has approximately 7,920 linear miles of roadways. Of those that are state maintained, 158 miles will be threatened by sea level rise in 2050, and 356 miles will be threatened by sea level rise by 2100 (MCCC n.d.). **Figure 1.4** depicts the overall coastal inundation of Maryland as depicted in the state's Climate Ready Action Boundary (CRAB).

Additionally, communities across coastal zones are experiencing increased disturbances from nuisance flooding, also known as high-tide flooding or sunny-day flooding. This problem is evident by the number of flood days in the cities of Annapolis and Baltimore, which have increased in frequency by 920% since 1960 (Maryland Emergency Management Agency 2021). Additionally, in 2019, the Annapolis and Tolchester Beach (Baltimore) tidal stations broke records for the number of nuisance flood days. The average number of flood days was 2 days in 2000 for each location; in 2019, the record was 18 and 17 days, respectively. By 2030, the National Oceanic and Atmospheric Administration (NOAA) projects that these numbers will increase to 15 days to 25 days at each location and by 2050 to 55 to 170 days in Annapolis and 50 to 160 days in Baltimore (Maryland Emergency Management Agency 2021). Given the density of population and travel in these two major metropolitan areas, the social, environmental, and economic impacts of nuisance flooding is estimated to be substantial.

Figure 1.4: Coastal Inundation Areas
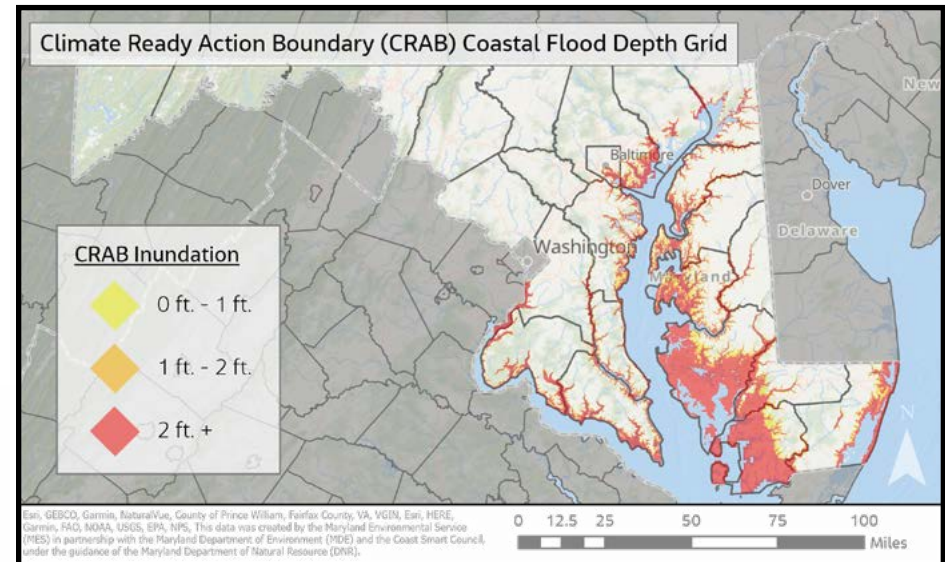
Source: *Maryland Coast Smart, 2023.*
ft = foot (feet)

Coastal hazards impact MDOT's transportation system through damage and accelerated deterioration to roads and bridges, loss of connectivity in transportation routes, disruption to port and harbor operations, and evacuation challenges. Life-cycle cost assessments to reflect the repeated damage or loss of service of such facilities and the full costs of such events are critical to right size investments and assist in establishing risk tolerance thresholds.

1.4.2 FLOOD HAZARDS

Flood hazards can also be categorized in several ways. In Maryland, the main flood hazards include general flooding, flash flooding, and heavy rain events. MDEM defines general flooding as events that come from prolonged, steady rain and tend to affect larger streams and rivers. MDEM defines flash flooding as events that come after short periods of heavy rain and most often affect smaller streams and creeks (Maryland Emergency Management Agency 2021).

Flooding is a major threat to MDOT's system, as Maryland experienced 583 general flooding events, 454 flash flooding events, and 215 heavy rain events since from 2016 to 2021 (National Oceanic and Atmospheric Administration [NOAA] n.d.a). Maryland has also experienced three flood-related disasters since 2016. Climate change is exacerbating flooding, making the probability of this threat highly likely in Maryland. **Figure 1.5** displays flood events from Ellicott City in 2018 (top) and from Smith Island (bottom).

Flooding impacts MDOT's transportation system in the form of severe damage, debris blockages, temporary closure of transportation routes, and the potential inability of the stormwater system to handle floodwater during a severe event. Additionally, washed out roads, erosion, and localized landslides can result from flood events and cause further damage. Bridges can be damaged through high-velocity movement of water, including potential risk to bridge piers and abutments, accelerating bridge deterioration or potentially leading to structural integrity concerns. Bridge overtopping is also a concern for Maryland given the increases in rainfall intensity and coastal inundation concerns. Overtopping can damage bridge approach slabs and abutments, leading to physical asset losses, safety concerns, and service disruption.

Figure 1.5: Displays Flood Events From Ellicott City in 2018 (top) and From Smith Island (bottom)

Source: *Climate.gov*

Source: *NOAA*

1.4.3 EXTREME TEMPERATURES

Extreme temperatures encompass both extreme cold and excessive heat events. Maryland experiences both extremes, which pose threats to critical infrastructure assets and public health. In the northeast United States, it is projected that winters will be milder, with fewer cold extremes, and that the number and duration of summer heat waves will increase in the coming decades. Extreme heat is exacerbated in dense areas, where the built environment can increase temperatures through the urban heat island effect. According to the Maryland Department of Health, the National Weather Service will issue a Heat Advisory when the heat index value is expected to reach 105 to 109 degrees Fahrenheit; the current highest temperature recorded in Maryland history is 109 degrees Fahrenheit. Extreme heat events can impact most infrastructure, including electrical systems found in traffic management systems and transit operations systems, as well as infrastructure structural integrity in materials such as pavements and rail tracks. The potential disruptions to transportation operations can impact essential services and increase public health risks for both Maryland residents and MDOT employees and contractors responsible for service delivery.

Although the probability of increased excessive heat events is more likely in the future, Maryland has a long history of hazardous winter weather, which can take the form of snow, freezing rain, cold temperatures, or a combination of events. Hazards of winter weather include blizzards, wind chill, freezing fog, frost, heavy snow, ice storms, sleet, and winter storms, which all pose threats to MDOT's system. Additionally, Maryland is prone to "nor'easters" because of the region's strong northeast winds. These storms are often accompanied by heavy rain or snowfall and may cause coastal flooding and erosion. **Figure 1.6** displays an ice event at Baltimore Harbor from 2015.

Extreme temperatures and winter weather events impact MDOT's transportation system in the form of damage to roads and bridges, temporary closure of mass transit, power outages, and interruptions to aboveground power and communication systems.

Figure 1.6: Baltimore Harbor Ice Event (2015)

Source: *MPA*

These extreme heat effects on transit rail systems can cause rail tracks to expand, warp, or buckle. Extreme heat can also strain the electrical systems that power transit rail network by overheating wires, substations, and other equipment. Extreme heat can lead to structural impacts on other rail infrastructure, bridges, and tunnels as it causes expansion and contraction of materials. These extreme heat effects on transit systems can lead to derailments, safety hazards, signal failures, and service disruptions.

Furthermore, extreme heat disproportionately affects vulnerable populations, including those who rely on public transit. High temperatures can pose health risks to passengers waiting for buses or trains and may impact passenger comfort, particularly in non-air-conditioned vehicles or stations.

1.4.4 SOIL MOVEMENT

In Maryland, soil movement hazards encompass landslides, sinkholes, and coastal erosion. Of these hazards, coastal erosion is the most likely to occur in Maryland, particularly in communities along the state's coastline. Maryland is especially prone to coastal erosion because of Maryland's location within the Chesapeake Bay watershed, the largest estuary in the United States. NOAA estimates that Maryland has approximately 3,190 miles of coastal and Chesapeake Bay tidal shoreline susceptible to coastal erosion (Maryland DNR 2013).

Rockslides and rockfall are typically caused by natural weathering, freeze-thaw cycles, vegetation, earthquakes, rainfall, and other conditions. Rockfall events often result in significant impacts to the traveling public. Significant safety concerns are posed by large rocks falling near or on vehicles, as well as drivers avoiding these rocks or maneuvering to reroute, creating additional hazards. Maryland has experienced several notable rockfall events in the past, including incidents along Interstate 68 and U.S. Route 40. These events have led to road closures, extensive cleanup efforts, and sometimes injuries. In 2015, Maryland Route 135 was affected by a significant rockfall that left the road operating with one way traffic for a quarter-mile section. A section of the same road experienced another rockfall in 2016, which impacted industrial trucks that frequently travel the road.

Landslides are rare in Maryland but do occur in the mountainous western part of the state. Urban areas where human-caused soil movement has occurred are also prone to landslide activity. Similarly, several areas throughout the state are more prone to sinkholes. As with landslides, these areas more often occur in regions west of the Chesapeake Bay. With an increase in heavy rains and flood events, these two hazards may occur more frequently.

Soil movement impacts MDOT's transportation system in the form of damage to roads and bridges, temporary closure of transportation routes, the potential inability of the stormwater system to handle floodwaters, and loss of power.

1.4.5 SEVERE WEATHER

Severe weather hazards encompass thunderstorms, tornadoes, wildfires, and wind events. Thunderstorms, unlike other hazards, impact the entirety of Maryland. Although thunderstorms are more frequent in the summer months, they can occur year-round with damaging hail or lightning events. Thunderstorms are classified as severe when they produce hail that is 1 inch in diameter or larger, wind gusts exceeding 50 knots, or a tornado, or some combination of these conditions. In the summer, Maryland averages one thunderstorm event every 5 days.

From 2010 to 2018, a total of 24 weather disasters affected the state. Severe storms were the most prevalent of these events, with a total of 13 affecting Maryland between 2010 and 2018. In 2018 alone, 6, separate billion-dollar disaster events affected Maryland. In May 2018, a derecho event—a widespread long lived windstorm—caused significant high-wind damage in Maryland, New Jersey, New York, Pennsylvania, Virginia, West Virginia, Massachusetts, and Connecticut, with total costs of $1.74 billion (NOAA n.d.b).

Similarly, Maryland is vulnerable to the impacts of tornado events. Maryland averages 10 tornadoes annually, with events affecting all regions of the state. Wildfires also occur throughout the state, with occurrences peaking in the spring. According to the Department of Natural Resources, the Maryland Forest Service responds to an average of 325 wildfires per year, which burn 3,200 acres of land total (Maryland Emergency Management Agency 2021). The future increase in extreme heat temperatures will likely contribute to increased wildfire events and longer fire seasons.

Maryland also experiences wind events across the state and is particularly vulnerable to synoptic scale winds* and thunderstorm winds. Wind events may result in dangerous debris, fallen trees, and disruptions to overhead electrical and communications infrastructure.

Severe weather events impact MDOT's transportation system in the form of fire caused by lightning strikes, roof and vegetation damage from hail, interruptions to aboveground power and communication systems, impacts from blowing debris, and road detours and closures.

1.4.6 CLIMATE CHANGE

These potential impacts include increases in extreme precipitation, increases in river and fluvial flooding, increase of tidal waters due to global warming, greater prevalence of heat waves, and exacerbated air quality and environmental justice (EJ) problems. To demonstrate the economic impacts of weather and climate-related disasters, the Maryland Commission on Climate Change (MCCC) completed a study in 2022 providing evidence of the recent costs to Maryland, which are presented in **Table 1.3**.

Considering these climate change impacts, it is imperative for MDOT to proactively adapt its strategies and infrastructure planning to ensure the resilience and sustainability of the state's transportation systems for the well-being of Maryland's residents and the continued growth of its economy.

1.5 Critical Interdependencies

Understanding interdependencies and vulnerabilities across infrastructure sectors is vital to confirming the resilience and reliability of transportation systems. Cross-sectoral interdependencies include, at minimum, the following sectors:

- Energy
- Water and wastewater
- Communication
- Public health
- Supply chain
- Critical manufacturing
- Finance
- Government and emergency services

Table 1.3: Increasing Incidence and Damages From Climate and Weather-Related Disasters in Maryland

Time Period	Number of Billion-Dollar Disasters	Events per Year	Cost	Percent of Total Cost
1980s (1980–1989)	7	0.7	$1.0–$2.0 billion	11.2%
1990s (1990–1999)	13	1.3	$2.0–$5.0 billion	17.5%
2000s (2000–2009)	10	1.0	$2.0–$5.0 billion	25.9%
2010s (2010–2019)	27	2.7	$5.0–$10.0 billion	38.9%
Last 5 years (2017–2021)	19	3.8	$2.0–$5.0 billion	13.0%
Last 3 years (2019–2021)	11	3.7	$500 million–$1.0 billion	6.2%
Last Year (2021)	5	5.0	$250–$500 million	2.5%
All Years (1980–2022)*	70	1.6	$10.0–$20.0 billion	100%

Source: *MCCC, 2022.*
* Statistics valid as of October 11, 2022.

For instance, MDOT's infrastructure relies heavily on energy sources, particularly for fueling vehicles and operating transit systems. Disruptions in the energy sector, such as power outages or fuel supply shortages, can directly impact the operation of MDOT transportation networks, leading to service interruptions, traffic congestion, and reduced mobility.

Because cross-sectoral interdependencies are inevitable, it is important for MDOT to continue conducting comprehensive risk assessments, engaging in contingency planning, and collaborating with other critical infrastructure sectors. Recognizing and addressing these interdependencies can enhance the resilience and adaptability of transportation systems in the face of various threats and challenges.

To help account for these interdependencies in decision making, MDOT has established an initial criteria and screening process to evaluate potential projects for PROTECT funding. The criteria and screening process is based on categories of information, including funding eligibility, scope component evaluation, equity considerations, vulnerable areas, community impact evaluation, and alignment with existing MDOT, metropolitan planning organization (MPO), or state priorities. The screening process and identified criteria development is informed by ongoing processes and will continually be improved as the program and its operations evolve. Establishing a screening process, identifying key touch points, and establishing an

approach to resilience incorporation allows MDOT to maximize federal and state funding to receive the most benefit and identify projects that do not have a resilience component but would benefit from one. The approach is intended to provide consistency in how funding is applied to projects while also actively working to support enhanced and expanded resilience integration across MDOT.

It is important to highlight MDOT's Resiliency Task Force, which functions as a community of practice dedicated to enhancing resilience, performance, and collaboration within and between the modal administrations. The Resiliency Task Force supports MDOT's ongoing resilience improvement program by providing a structured platform for identifying efficiencies, interdependencies, documenting vulnerability, and identifying resource gaps. Additionally, it recommends strategies and projects for improving resilience and promotes enhanced collaboration to facilitate quicker implementation of resilience measures.

The Resiliency Task Force holds regular meetings and has played a pivotal role in integrating resilience considerations in operations across the modal administrations. In the future, the task force will continue to provide these services and evaluate their approach and outcomes on an annual basis to confirm alignment with the TRIP and best practices adopted across MDOT.

The TRIP aims to build upon ongoing planning processes outlined in existing statewide and regional plans and programming documents. These documents identify projects and strategies that enhance the resilience of transportation infrastructure in the State of Maryland. Relevant transportation planning and programming documents are described herein. Each agency, ranging from counties and municipalities, MPOs, and MDOT, has a role in identifying and supporting the development of projects and processes that improve resilience across the transportation systems.

2.1 Statewide

Statewide documents together guide MDOT's priorities and future investments. Integrated long-range and strategic plans, such as the Maryland Transportation Plan (MTP), the Statewide Freight Plan, Statewide Hazard Mitigation Plan, and State Transportation Asset Management Plan, create an opportunity for MDOT to connect statewide goals with its overall mission.

The **Maryland Transportation Plan, or the 2050 MTP** (MDOT 2024) will be the new 20-year, long-range statewide transportation plan guiding transportation policies and investment priorities. The MTP's guiding principles, goals, and objectives inform, and are informed by, the transportation reports and plans in Maryland, creating a family of plans. MDOT is poised to develop an updated family of plans better suited to a future governed by new state law and policy priorities for 2023 and beyond.

The current 2050 MTP highlights MDOT's commitment to providing a safe, secure, and resilient transportation system. MDOT identifies several approaches to provide a resilient multimodal system by anticipating and planning for changing conditions and hazards, whether natural or artificial. The MTP provides much of the strategic direction that informed the development of the TRIP, as its scope covers all five modal administrations and the MDTA (**Figure 2.1**).

Figure 2.1: Maryland Transportation Plans

MARYLAND DEPARTMENT OF TRANSPORTATION — MARYLAND AVIATION ADMINISTRATION

- MDOT MAA Strategic Plan

Maryland Transportation Authority (MDTA)

- Strategic Plan

MARYLAND DEPARTMENT OF TRANSPORTATION — STATE HIGHWAY ADMINISTRATION

- Context Driven Guide
- Transportation Asset Management Plan
- Transportation Systems Management and Operations (TSMO) Strategic Plan
- Pedestrian Safety Action Plan

Metro

- WMATA Strategic Transformation Plan (2023)

MARYLAND DEPARTMENT OF TRANSPORTATION

- Maryland Transportation Plan
- Maryland Consolidated Transportation Program
- Maryland's Annual Attainment Report on Transportation System Performance
- State Freight Plan
- Maryland State Rail Plan
- Maryland Strategic Asset Management Plan
- Maryland Bicycle and Pedestrian Master Plan
- **MDOT Transportation Resilience Improvement Plan (TRIP) under development (2024)**
- Carbon Reduction Strategy (2024)

(More information can be found at www.mdot.maryland.gov/climate)

MARYLAND DEPARTMENT OF TRANSPORTATION — MOTOR VEHICLE ADMINISTRATION

- MDOT MVA Strategic Plan
- Maryland Strategic Highway Safety Plan
- Maryland Connected and Automated Vehicle Strategic Framework

MARYLAND DEPARTMENT OF TRANSPORTATION — MARYLAND TRANSIT ADMINISTRATION

- Maryland Statewide Transit Plan
- Central Maryland Regional Transit Plan
- MDOT MTA Draft Transit Plan (2022)
- MDOT MTA Strategic Plan (2020)
- MARC Growth and Transformation Plan

MARYLAND DEPARTMENT OF TRANSPORTATION — MARYLAND PORT ADMINISTRATION

- MDOT MPA Strategic Plan

Source: *MDOT, n.d.*
WMATA = Washington Metropolitan Area Transit Authority

The 2050 MTP is consistent with the **2023 MDOT Climate Pollution Reduction Plan**; the TRIP; and other members of the Maryland family of transportation plans. The 2050 MTP Guiding Principles align the mission, values, and capabilities and serve as overarching, cross-cutting ideas that MDOT strives for through each of the goals, as depicted on **Figure 2.2**.

Figure 2.2: Maryland Transportation Plan Draft Vision, Guiding Principles, and Goals

Moore-Miller Administration Priorities

Federal Priorities

MDOT and Modal Administration Plans

Draft Vision, Guiding Principles, Goals, Objectives, and Strategies

MPO Plans

Public & Stakeholder Input

Peer State Plans

Source: MDOT, n.d.

The **Maryland Consolidated Transportation Program (CTP)** is Maryland's 6-year capital budget for transportation projects and programs across MDOT that is updated annually. A main theme within the CTP is MDOT's effort to maintain its transportation assets in a State of Good Repair by allocating funds toward system preservation first. Each year, the **Attainment Report on Transportation System Performance (AR)** provides an evaluation of the performance of the state's transportation system and reports on progress toward reaching the key goals listed in the current MTP. The CTP, AR, and MTP form the **State Report on Transportation**, also published annually. MDOT's collective statewide planning timeframes for updating these documents related to resilience initiatives are listed in **Table 2.1**.

Table 2.1: MDOT Statewide Planning Timeframes for Documents Related to Resilience Initiatives

Document	Published	Planning Timeframe
Maryland Transportation Plan	2019	2020–2040 (20 years)
Maryland Consolidated Transportation Program	2022	FY 2023–FY 2028 (6-year capital budget)
Maryland Statewide Transportation Improvement Program	2021	FY 2022–FY 2025 (4-year, fiscally constrained, prioritized projects)
State Report on Transportation	2023	2023 (AR, CTP, and MTP)
Attainment Report on Transportation System Performance	2023	2023
Bicycle and Pedestrian Master Plan	2019	2020–2040 (20 years)
Transportation Systems Management & Operations Plan	2018	2018
State Hazard Mitigation Plan	2021	N/A

FY = fiscal year

Projects within the CTP work to expand or significantly improve facilities or services throughout MDOT's transportation system and may involve planning, environmental studies, design, right-of-way acquisitions,

construction, or the purchase of essential equipment related to the facility or service. The Maryland Statewide Transportation Improvement Program (STIP) is a 4-year, fiscally constrained, prioritized set of transportation projects that are compiled from statewide, local, and regional plans. The STIP development process includes the Annual Consultation Process, known as the Fall Tour, in which the CTP is presented to each of the local jurisdictions.

MDOT also produces the annual Climate Action Status Report, which illustrates the progress made toward reducing transportation sector greenhouse gases and is submitted to the MCCC and the Maryland General Assembly.

2.1.1 MARYLAND TRANSIT ADMINISTRATION RESILIENCE PLANNING EFFORTS

MTA published the **A Regional Transit Plan for Central Maryland (RTP) in 2020**, a 25-year plan for improving public transportation in central Maryland by addressing traditional transit service and exploring new mobility options and technologies. Within the plan, MTA encourages Maryland transit agencies to identify and protect vulnerable assets to provide continuity of service through flooding and other climate events. These projects are among several public transit projects that are currently being considered for PROTECT formula funds. MTA published Maryland's first draft **Statewide Transit Plan** in January 2022, which provides a 50-year vision of coordinated local, regional, and intercity transit across the state.

2.1.2 MARYLAND PORT ADMINISTRATION RESILIENCE PLANNING EFFORTS

The 2019 **MPA Strategic Plan** provides an overview of cargo and non-cargo goals metrics, sector conditions, and recommended actions. Two identified recommended actions are to implement guidelines for MPA climate change resilience and to study the feasibility of parking structures to add capacity for automobiles and roll-on/roll-off cargo ships.

The **Hurricane Preparedness Plan**, published in 2022, establishes procedures for protecting personnel and securing MPA property and equipment in preparation for hurricane or tropical storm force weather. The goal is to minimize potential deaths, injuries, and property damage and return MPA facilities to normal operations as quickly as possible after a hurricane impacts the Baltimore area.

2.1.3 MARYLAND RAIL RESILIENCE PLANNING EFFORTS

The 2022 **Maryland State Rail Plan** is a 25-year plan outlining investment needs for public and private passenger and freight rail in Maryland while also emphasizing the need for a resilient rail system that anticipates and plans for changing natural or artificial conditions and hazards, including future climate impacts.

2.1.4 RESILIENCE FREIGHT PLANNING EFFORTS

The 2022 **Maryland State Freight Plan** assesses Maryland freight movements and reflects new requirements introduced by IIJA, including freight resilience and environmental impacts. MDOT emphasizes a focus on enhancing the state's multimodal transportation infrastructure resilience as part of a comprehensive approach that includes understanding and assessing transportation system vulnerabilities and integrating climate adaptation and resilience into MDOT's business processes.

2.1.5 INCORPORATING RESILIENCE INTO ASSET MANAGEMENT PLANS

MDOT's 2019 **Strategic Asset Management Plan** establishes a commitment to principles for managing assets including a holistic approach to operations asset management. The MDOT Asset Management Program relies on cross-functional collaboration of knowledgeable staff from each modal administration and MDTA. The program supports MDOT's goals of system preservation, safety and security, quality of service, and fiscal responsibility by committing appropriate resources to asset management. The **Transportation Asset Management Plans** for each mode strategically manage assets through asset inventory, condition assessment, and minimum data standards for assets. The planning timeframes for these plans are provided in **Table 2.2**.

2.1.6 STATEWIDE HAZARD PLANNING

The **State Hazard Mitigation Plan** works to reduce loss of life and property by minimizing the impact of disasters. A set of mitigation strategies are organized into long-term solutions to increase the resilience of the state's assets. Mitigating hazards and their capacity for system disruption supports a resilient and sustainable transportation system. Future investments, such as electric vehicle charging infrastructure, can simultaneously align with and function as hazard mitigation measures.

Table 2.2: MDOT Modal Administrations Planning Timeframes

| Document	Agency	Published
A Regional Transit Plan for Central Maryland	MTA	2020
Statewide Transit Plan	MTA	2022 (draft)
Climate Action Initiatives Summary Report	MTA	2022
MPA Strategic Plan	MPA	2019
Hurricane Preparedness Plan for Marine Terminals	MPA	2022
State Freight Plan	MDOT	2022
State Rail Plan	MDOT	2022
Statewide Truck Parking Study	MDOT	2020
Strategic Asset Management Plan	MDOT	2019
Asset Management Plan	SHA	2021

2.2 Regional

MDOT recognizes the need for a coordinated regional approach to provide maximum benefits of resilience initiatives. The significant regional planning activities led by the MPOs provide an existing structure and partnership network for MDOT to collaborate with and confirm that there is alignment in making the investments required to enhance transportation resilience. Each MPO has its own mission, vision, and goals for how to accomplish its priorities, and MDOT works closely with each of them to confirm alignment in approach, decision making, goals, and identifies commonalities when possible.

Long-range transportation plans (LRTPs) provide information on the region's transportation goals and policies, as well as socioeconomic, environmental, and other factors that affect the operation of the transportation system over 20- to 30-year periods. LRTPs include a list of planned major federally funded capital projects, their estimated costs, and the revenues reasonably expected to be available to fund these projects. LRTPs are generally updated every 4 years by their respective MPOs. **Table 2.3** highlights the current LRTP for each of Maryland's MPOs.

Table 2.3: Maryland MPO LRTP Planning Timeframes

MPOs	Current Planning Period	Adopted
Cumberland Area MPO (CAMPO)	**2050Plan**	March 2021
Hagerstown-Eastern Panhandle MPO (HEPMPO)	**Direction2050**	May 2022
National Capital Region Transportation Planning Board (NCRTPB)	**Visualize 2045**	June 2022
Baltimore Regional Transportation Board (BRTB)	**Maximize 2045**; **Resilience2050**	July 2019; July 2023
Wilmington Area Planning Council (WILMAPCO)	**2050 Regional Transportation Plan**	March 2023
Salisbury/Wicomico MPO (S/WMPO)	**Connect 2050**	December 2019
Calvert – St. Mary's Metropolitan Planning Organization (C-SMMPO)	**Moving Forward 2045**	March 2020
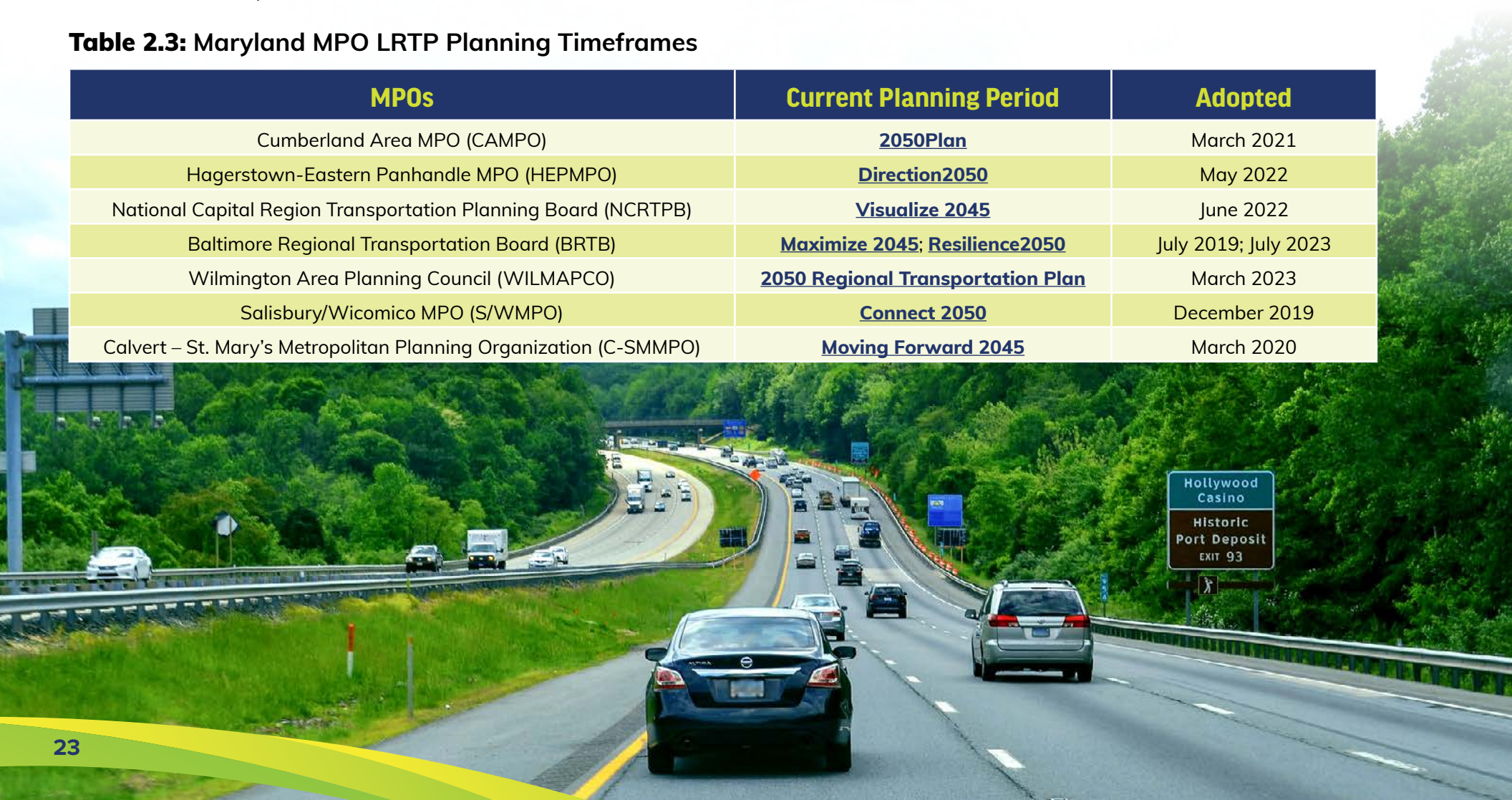
Transportation Improvement Programs (TIPs), which are generally updated every year, provide a 4-year listing of federally funded transportation projects. The TIP is the programming element of the LRTP, listing projects with committed funds and schedules. **Table 2.4** highlights the current TIP for each of Maryland's MPOs.

Table 2.4: Maryland MPO TIP Planning Timeframes

MPO	Current Planning Period	Adopted	Update Planning Period
CAMPO	**FY 2022–2025**	March 2021	FY 2023–2026
HEPMPO	**FY 2023–2026**	May 2022	FY 2025–2028
NCRTPB	**FY 2023–2026**	June 2022	FY 2024–2027
BRTB	**FY2024–2027**	July 2023	FY 2025–2028
WILMAPCO	**FY 2023–2026**	May 2022	FY 2024–2027
S/WMPO	**FY 2023–2026**	December 2022	FY 2024–2027
C-SMMPO	**FY 2021–2024**	June 2020	FY 2024–2027

Coordination is ongoing between MDOT and the MPOs to identify preferred PROTECT-eligible projects to prioritize for funding. Ultimately, a project must be included in the STIP or an MPO TIP, or both, for PROTECT funding to be obligated. Together, the LRTP and TIP provide an overview of each MPO's transportation planning and programming efforts.

Annually, each county in Maryland and Baltimore City submits a letter of their **Transportation Priorities** to MDOT, highlighting transportation needs and opportunities for their jurisdiction. MDOT reviews these priority letters and kicks off an annual tour in the fall to meet with each county and Baltimore City and share the draft CTP. The CTP is revised based on the priority letters, state needs, state goals, and funding availability. These priority letters provide an important opportunity for identification of local priorities and an understanding of the future needs and opportunities for eligible resilience projects.

In addition to the TIP and annual MDOT CTP tour season, MPOs lead working groups centered on resilience planning and climate change mitigation. For instance, **Metropolitan Washington Council of Governments' Transportation Resilience Working Group** is composed of regional stakeholders that provide input and feedback on key milestones during the development of the Transportation Planning Board's TRIP. The working group collaboratively works toward the completion of a vulnerability assessment, requests resilience project proposals for inclusion in the TRIP, completed a 2023 Resiliency Forum to build knowledge of climate risks and develop resilience solutions, and will draft and finalize the TRIP.

The Maryland Department of Natural Resource developed a **Nuisance Flood Plan Development Guidance** recognizing that communities throughout the State of Maryland face increasing disturbances from episodic nuisance flooding, which can cause roads to be temporarily closed because of high water, overwhelm engineered and natural drainage, and inundate fields and yards.

In addition to the State Hazard Mitigation Plan (Maryland Emergency Management Agency 2021), there are local hazard mitigation plans under the Disaster Relief and Emergency Assistance Act that provide local context, with practical knowledge and strategies that empower citizens, first responders, and government officials to prepare for and respond to natural disasters. MDEM tracks all local hazard mitigation plans and nuisance flood plans on a public facing **map**.

3 DESCRIPTION OF RISK-BASED VULNERABILITY ASSESSMENT

Risk-based vulnerability assessments are a crucial component of well-informed and effective resilience decision making. MDOT and its modal administrations have been conducting vulnerability assessments since 2010. Although these efforts have not consistently followed the same approach or scope, they collectively aim to assess the vulnerability of the transportation system to climate stressors and extreme weather events and identify opportunities for mitigation measures. Additionally, the vulnerability assessments support the development tools and resources that can inform subsequent assessments. Although no single vulnerability assessment can provide all the essential information, when reviewed and evaluated collectively, they can paint a comprehensive picture of MDOT's needs.

As evidence of this, MDOT has worked with its modal administrations to incorporate climate change-based decision making, which are outlined in the sections below. MDOT is in the process of developing standard operating procedures that will outline steps, responsible parties, intended outcomes, and timelines to identify and fund PROTECT eligible projects. The standard operating procedures will help ensure consistency and compliance with federal programs, funding, and MDOT goals across the modal administrations.

3.1 Maryland Transit Administration

MTA published a **Climate Action Initiatives Summary Report** in 2022 that highlights an Adaptation and Resiliency Toolbox (ARToolbox), designed to aid in implementing adaptation measures at sites previously identified as priority locations in **MTA's Climate Change Vulnerability Assessment** (2016, re-evaluated in 2019 to 2020). The ARToolbox provides a central repository for all efforts leading to the implementation of adaptation and resilience measures that may be applied to MTA assets. In addition, the toolbox provides a comprehensive database of potential adaptation measures that can be implemented at the asset level, assisting designers, planners, engineers, and maintenance staff with the resources needed to establish a proactive approach to a changing climate.

3.2 Maryland Port Administration

The MPA underwent a vulnerability assessment for their port assets in 2010. The conclusions of this assessment were three-pronged: (1) migrate marine terminal infrastructure away from floodplains when possible, (2) elevate MPA facilities above the floodplains, and (3) mitigate damage by improving their resilience to flooding events. MPA is currently updating this vulnerability assessment using funds awarded as part of the Building Resilient Infrastructure and Communities grant.

3.3 State Highway Administration

SHA adopted a similar approach as MPA in 2016 for an adaptation and vulnerability assessment of their own, scoring roadway assets on their vulnerability to different threats, such as storm surge and sea level rise. In 2018, SHA took part in the FHWA **Asset Management, Extreme Weather, and Proxy Indicators Pilot program**. SHA refined and expanded their vulnerability assessment of state assets and implemented specific opportunities to integrate the results into existing asset management, planning, and other processes. The assessment identified 33 bridges highly vulnerable to sea level changes, 172 bridges highly vulnerable to storm surge, and 102 bridges highly vulnerable to precipitation change. SHA currently maintains the **Climate Change Vulnerability Viewer**, an online tool that analyzes a variety of threats, such as coastal sea level rise, storm surge, and nuisance inundation, across multiple assets. Though its primary focus is to inform stakeholders, the viewer also serves as a powerful reminder of what MDOT has already accomplished for risk and resilience planning, along with stakeholder outreach. This tool, however, is just the first step in an overarching plan to move from qualitative risk assessments to quantitative risk assessments.

3.4 Maryland Department of Transportation

Utilizing geospatial information science and digital data stewardship, MDOT is working towards a digitized, geospatial asset inventory that will drive quantitative risk assessments that consider asset location, condition, and design parameters, as well as threat likelihood to support asset level

risk assessment. Quantitative risk-based assessments will draw data from existing systems, such as the Climate Change Vulnerability Viewer, Climate Ready Action Boundaries, FEMA Flood Insurance Rate Maps, as well as maintenance records to provide financial risk and system resilience information to support project prioritization. SHA has pilot tested this approach in 2019 along US 50 and MD 450 to further support quantitative benefit cost analyses of a range of engineering strategies for improving system resilience. This pilot provided SHA with a system criticality map (**Figure 3.1**) to better understand which sections of their overall system are most critical from an operations lens taking into account system redundancy, demand, and social vulnerability among other factors. **Figure 3.2** shows the total annual risk costs on MD 450 and US 50, according to this pilot study. Total annual risk is a combination of owner's risk related to asset failures and repairs and user risk related to rerouting around affected assets. Outputs like these are useful tools to understand system risks and help identify potential projects to increase resilience and reduce risk costs to MDOT and travelers.

With threats of climate and hazard-related incidents on the rise, MDOT is committed to using a systematic approach to identify at-risk assets on its system. Furthermore, the envisioned approach will prioritize assets and investments considering annualized risk that incorporate social, economic, and financial impacts such as those derived through the 2019 pilot. The data-driven approach will support enhanced decision-making regarding investments to support benefit-cost assessments of both capital and operationally focused project alternatives.

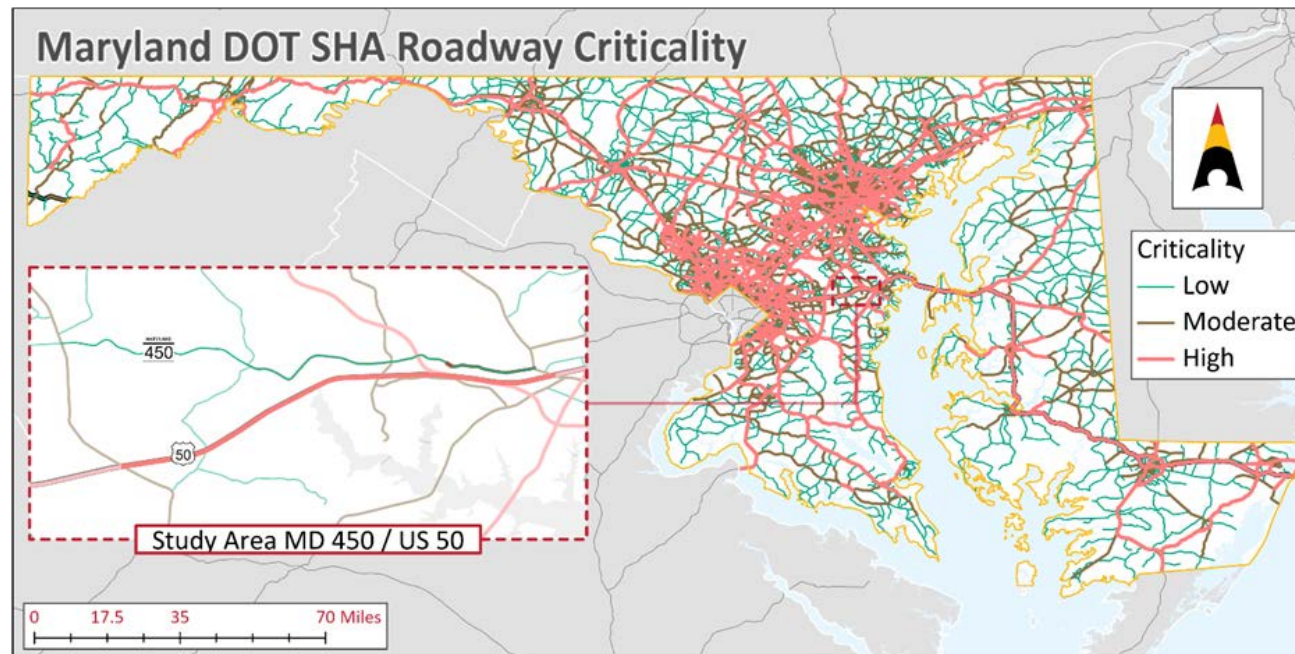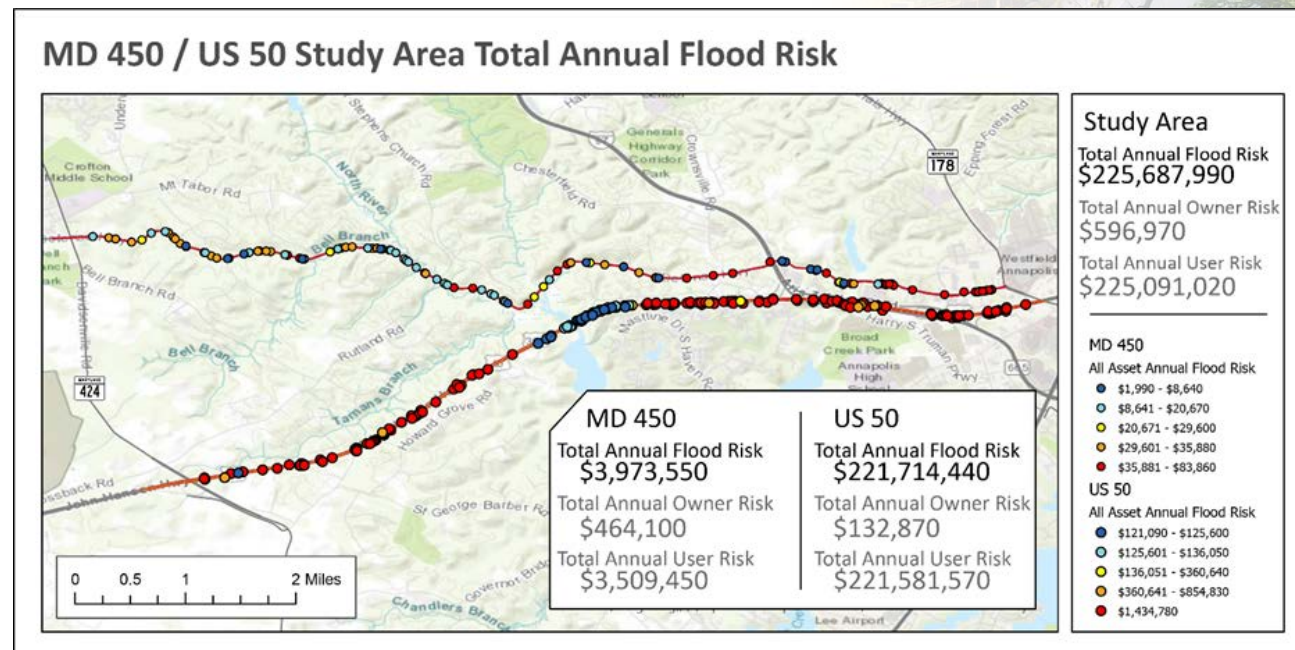**Figure 3.1:** MDOT SHA Roadway Criticality Map

Figure 3.2: Total Annual Flood Risk Costs on MD 450 and US 50

4 RECOMMENDED PRIORITY AREAS FOR RESILIENCE INVESTMENTS

MDOT is committed to promoting resilience through fortifying assets to common threats, implementing natural infrastructure, improving connectivity and redundancy, and confirming resilience incorporation in policy and project development, all while ensuring investments incorporate social and economic considerations.

Maryland has unique geography, which makes the state vulnerable to a wide range of threats. There is no shortage of opportunity to improve resilience, whether it be along the eastern shore to protect from sea level rise, along the Patapsco River to reduce the impacts of riverine flooding, or in Allegany County to reduce threats from rockfall. This unique geography creates a need for thoughtful and creative solutions to prioritize resilience investments.

4.1 Eligible Projects

Activities eligible for PROTECT funds include the following:

- **Planning:** Developing a resilience improvement plan; resilience planning, predesign, design, or the development of data tools to simulate transportation disruption scenarios, including vulnerability assessments; technical capacity building to facilitate the ability of the state to assess the vulnerabilities of its surface transportation assets and community response strategies under current conditions and a range of potential future conditions; or evacuation planning and preparation. States are required to use at least 2% of their PROTECT Formula Program funding each federal fiscal year for resilience-related planning activities, such as developing a resilience improvement plan; resilience planning, predesign, or design; technical capacity building; or evacuation planning and preparation.

- **Resilience Improvements:** Improving the ability of an existing surface transportation asset to withstand one or more elements of a weather event or natural disaster, or to increase the resilience of surface transportation infrastructure from the impacts of changing conditions, such as sea level rise, flooding, wildfires, extreme weather events, and other natural disasters.

- **Community Resilience and Evacuation Routes:** Strengthening and protecting evacuation routes that are essential for providing and supporting evacuations caused by emergency events, including resilience improvements if they will improve evacuation routes and projects to confirm the ability of the evacuation route to provide safe passage during an evacuation and reduce the risk of damage to evacuation routes as a result of future emergency events.

- **At-Risk Coastal Infrastructure:** Strengthening, stabilizing, hardening, elevating, relocating or otherwise enhancing the resilience of highway and non-rail infrastructure, including bridges, roads, pedestrian walkways, and bicycle lanes, and associated infrastructure, such as culverts and tide gates, to protect highways that are subject to, or face increased long-term future risks of, a weather event, a natural disaster, or changing conditions, including coastal flooding, coastal erosion, wave action, storm surge, or sea level rise, to improve transportation and public safety and to reduce costs by avoiding larger future maintenance or rebuilding costs.

To identify eligible projects, MDOT is coordinating with MPOs and the modal administrations to develop a candidate list of resilience activities and projects from the following sources:

- The Consolidated Transportation Program
- Transportation Improvement Program
- The Statewide Transportation Improvement Program
- Modal-specific asset management plans
- Long Range Transportation Plans
- County priority letters
- Direct communication with modal administrations

MDOT will continue this coordination to maintain an up-to-date list of eligible projects on an annual basis. This list will be used to optimize and prioritize the use of PROTECT formula funds from FFY 2024 to 2026. FFY 2022 and FFY 2023 funds will be focused on eligible projects that are implementation ready or that can deliver immediate resilience benefits. Project-related work under PROTECT will have to comply with *Code of Federal Regulations* **Title 23 requirements**.
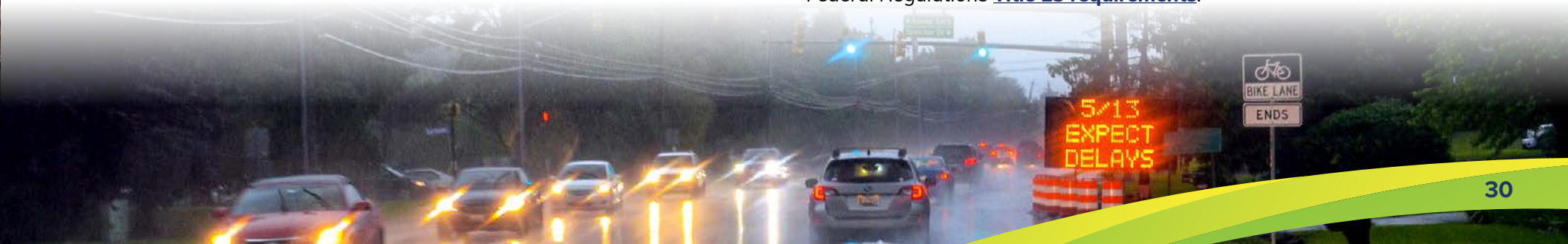
4.2 Immediate Prioritization Strategies

For future funding years beyond FFY 2023, MDOT will incorporate several additional factors to prioritize investments to improve system climate resilience. MDOT has established an internal group, including staff from OCCRA and SHA, that will help accelerate PROTECT funding obligations. This internal group is finalizing the Climate Focused Funding Opportunity Program Strategy, which combines the PROTECT Program Strategy with the recently developed Carbon Reduction Strategy to help prioritize investments that improve the agency's climate readiness by reducing carbon emissions and strengthening the system's resilience. The proposed Climate Focused Funding Opportunity Strategy consists of four phases from program development through project obligation and an anticipated timeframe of six months. The intention of further refinement is to move toward quantifiable metrics, including the anticipated risk reduction and improvements in system resilience from each project.

In the next round of project selection, MDOT will review projects considering the following additional factors:

- Project type
- Status of project funding for obligation and inclusion in the STIP/TIP
- Project readiness for implementation
- Asset vulnerability/annual risk to MDOT and users from applicable threats
- Expected asset life cycle
- System resilience and community resilience
- System redundancy, reliability and service needs
- Project advances Justice40 Initiative and regional equity considerations
- Project co-benefits to the health or safety of Maryland's communities
- Community support for project
- Project advances the goals of the Climate Solutions Now Act of 2022
- Project alignment with future land uses

Many strategies exist for addressing system climate resilience from capital investments that seek to harden assets from relevant threats to nature-based solutions to reduce impacts from future events to planning for operational strategies to prepare for impending events. Each project type carries with it a range of pros and cons in terms of costs, time to deliver and resources available to achieve. Considerations regarding the optimal time for investments to improve resilience based on asset life cycle, criticality to system resilience, and annual risk to both MDOT and users are also under development.

Equity is paramount to incorporating the whole-of-community approach to resilience. Maryland has several resources available for incorporating equity into the prioritization process:

- The Maryland Department of Environment EJ Screening Tool provides an EJ score as an overall evaluation of an area's conditions, including pollution burden exposure, pollution burden environmental effects, sensitive populations, and socioeconomic indicators.

- The University of Maryland School of Public Health Center for Community Engagement, Environmental Justice, and Health works to develop and participate in partnerships with community based organizations, environmental advocacy groups, health practitioners, and policymakers to reduce local contamination, improve environmental quality, and enhance community health and sustainability.

- The Justice40 Initiative pairs with IIJA to confront and address decades of underinvestment in disadvantaged communities by bringing resources to communities most impacted by climate change, pollution, and environmental hazards. Justice40 is an opportunity to address gaps in transportation infrastructure and public services by working toward the goal that at least 40% of the benefits from many federal grants, programs, and initiatives flow to disadvantaged communities.

4.3 Tracking Progress

A final consideration in prioritizing resilience investments is to align projects with other initiatives at the local, state, and national level. Some of the on-going efforts to incorporate resilience into project development, policy, and standards within Maryland include:

- The Chesapeake Bay Critical Area Protection Program controls future land use development within 1,000 feet of the tidal influence of the Chesapeake Bay.

- The Coast Smart Construction Program requires that, if a State or local capital project meets certain funding criteria and includes the construction of a structure or highway facility, it shall be constructed to withstand a category 2 (Saffir-Simpson hurricane wind scale) storm surge.

- In 2021, the Maryland General Assembly passed the Tree Solutions Now Act to plant and maintain 5 million native trees by 2031, including 500,000 trees in underserved areas. Additional programs include MDOT's **Urban Tree Grant Program** with the Maryland Urban and Community Forest Committee, SHA's **reforestation and tree planting programs**, and several local initiatives.

The listed factors will be considered in MDOT's data-driven, defensible, and transparent project selection process to be deployed by early Spring 2024. The process plans for iterative reviews over time that will ensure continued alignment with statewide resilience goals and incorporate the development of quantifiable metrics, including risk reduction, system resilience improvements, and benefit-cost assessments.

Online GIS-based tools will be leveraged to provide for consistent assessment of landscape-based evaluation factors. MDOT intends to bring together GIS data layers and project information to ensure that project selection and development align with the various needs of the communities and transportation system. Informing data sources may include existing system vulnerabilities, the annual risk to MDOT and its users, equity, demographics, justice40, infrastructure conditions, and more. Project evaluation will also incorporate existing system resilience and annual risk to MDOT and our users as well as return on investment over the life cycle of the project to optimize PROTECT investments.

Finally, MDOT envisions an accessible online platform to provide updates on specific climate actions across the enterprise. This dashboard would include projects funded through PROTECT and other state and federal funding sources that demonstrate the extent of climate-focused investments in MDOT's portfolio.

Beyond identifying existing projects in various stages of planning or design, MDOT may develop projects individually or in collaboration with the modal administrations, local agencies, nonprofits, or other organizations. This will serve to create unique uses of PROTECT funds and incorporate co-benefits beyond resilience improvements. MDOT may use such projects as examples of what is possible with the new sources of funding and demonstrate a commitment to Maryland residents. Examples that MDOT may wish to explore include nature-based features such as coastal wetlands, marshes, dunes, oyster reefs, living shorelines, bioswales, urban tree canopies, and permeable pavements.

5 IMPLEMENTATION AND NEXT STEPS

*As described throughout the TRIP, MDOT understands the importance of institutionalizing resilience across the state and is working closely with each of the modal administrations. Additionally, MDOT recognizes the value in confirming the strategies outlined in the TRIP are aligned with and incorporated into regional and other statewide planning documents and processes, including the MTP, LRTP, TIP, State Hazard Mitigation Plan, and other plans outlined on **Figure 2.1**. MDOT will continue coordinating with SHA regarding their recently published Climate Change Resilience Strategy to ensure best practices are shared between both efforts.*

MDOT also recognizes the importance of resilience training to equip staff with the skills and tools needed to address challenges and disruptions, such as extreme weather events or funding fluctuations. MDOT is working to identify opportunities for training available through resources, such as the National Highway Institute, and is encouraging staff participation in new course work. MDOT is also working to develop training for staff that will support critical decision making related to the design of resilient systems, the use of nature-based solutions, and the implementation of economic assessment methods to support the analysis of design alternatives.
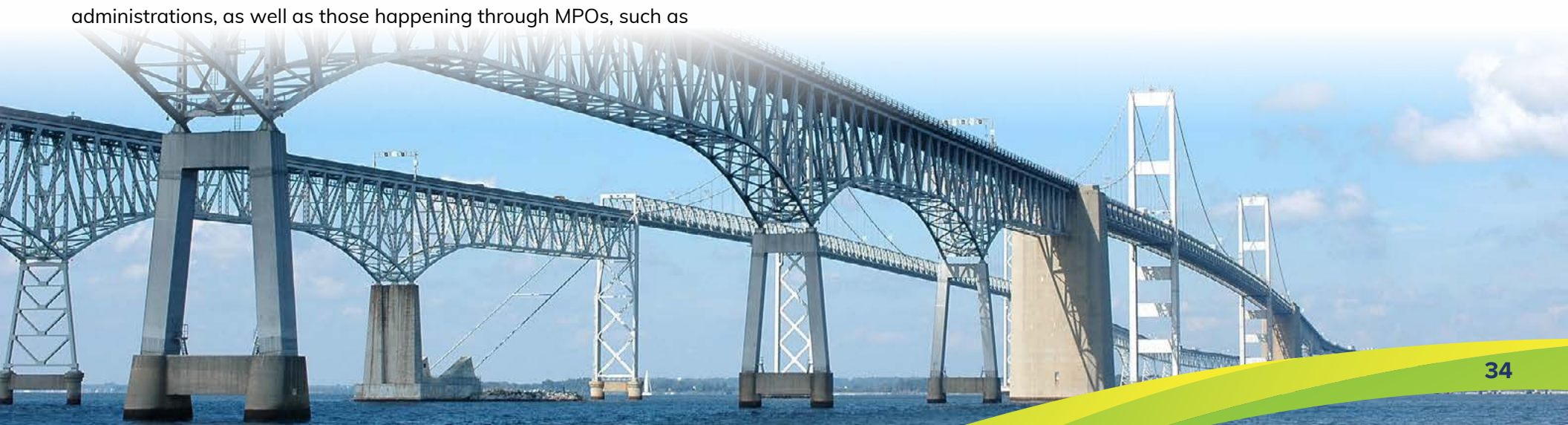
Training is especially vital for project and fund managers, as they play a crucial role in confirming the effective planning, execution, and management of transportation projects. The anticipated training will help them anticipate potential risks and vulnerabilities and develop proactive strategies to mitigate them. This approach could safeguard project timelines and budgets while enhancing MDOT's ability to maintain critical transportation infrastructure, providing continued mobility and safety for the public.

MDOT plans to revise the TRIP at least once every 4 years, with interim updates as needed. Serving as a coordinator across the modal administrations and statewide resilience planning efforts, MDOT will work closely with key partners and stakeholders to confirm alignment and coordination among resilience planning documents and processes. This coordination will include the efforts underway through the modal administrations, as well as those happening through MPOs, such as

the Metropolitan Washington Council of Governments Transportation Resilience Work Group and the Baltimore Metropolitan Council (BMC). BMC has developed three key resources to support regional resilience efforts: (1) the **Climate Change Resource Guide** and accompanying toolkit, (2) the **Climate Resilience Guidance for Local Jurisdictions**, and (3) **Recommendations for Interjurisdictional Coordination**. This holistic approach to the development of the TRIP and subsequent updates will allow MDOT to ensure the best use of resources to address transportation system resilience.

MDOT will work with partners to identify and select projects and activities that leverage PROTECT funding and improve transportation resilience. The analysis described throughout the TRIP outlines the process, tools, and methodology MDOT will use to identify priority projects or activities eligible for funding under PROTECT, including planning, enhancing community resilience, and improving overall transportation infrastructure resilience and ability to withstand extreme weather events and other natural hazards. As described in **Section 4**, MDOT will actively coordinate with MPOs and modal administrations to develop a list of potential resilience activities and projects that are eligible and priorities for using PROTECT funding.

MDOT is also aware that the field of resilience is evolving and will monitor research initiatives and best practices so that future iterations of the TRIP incorporate these innovations and others, including additional analysis and potential weighting for social vulnerabilities and other co-benefits.

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APPENDIX A

TRIP Alignment with Federal Requirements

Appendix A: TRIP Alignment with Federal Requirements

TRIP Requirements	Section(s) in TRIP	Additional Comments
Will do the following:		
Encompass immediate and long-range planning activities and investments	Sections 4 and 5	N/A
Demonstrate a systemic approach to surface transportation system resilience	Sections 3 and 4	N/A
Be consistent with state and local hazard mitigation plans	Sections 2 and 5	These sections describe the relationship between the TRIP and other Statewide and MDOT planning efforts related to resilience and sustainability. The TRIP will be integral to these planning efforts in Maryland.
Include a risk-based assessment of vulnerabilities to current and future weather events and natural disasters	Section 1 and 3	N/A
Will, as appropriate, do the following:		
Describe improved ability to respond promptly to impacts of weather events and natural disasters and be prepared for changing conditions	Section 3	N/A
Describe codes, standards, and regulatory framework	Sections 2 and 5	N/A
Consider natural infrastructure	Section 4	N/A
Assess resilience of other community assets, including buildings and housing	N/A	Some related information is provided in Section 4.
Use a long-term planning method	Sections 4 and 5	N/A
Include other information	Sections 1 and 2	Ensures collaboration and coordination with federal, state, and local partners

Appendix A: TRIP Alignment with Federal Requirements (Continued)

TRIP Requirements	Section(s) in TRIP	Additional Comments
Will, as appropriate, do the following:		
Evacuation routes	N/A	Though a major consideration for resilience planning, this information is not specifically included in this version of the TRIP.
Emergency response plans	N/A	Though a major consideration for resilience planning, this information is not specifically included in this version of the TRIP.
Resilience-related policies	N/A	This will be addressed in MDOT's Climate Action Plan.
Investment plan and prioritized projects	Section 4	Section 4 describes MDOT's strategy for prioritization of projects, including eligibility criteria, risk-based vulnerability assessments, equity considerations, and alignment with other MDOT initiatives.
Use of science and data, including sources of data and methodologies	N/A	This is an overarching theme for many references and information discussed, but it is not directly addressed.

MDOT = *Maryland Department of Transportation*
N/A = *not applicable*
TRIP = *Transportation Resilience Improvement Plan*

APPENDIX B

Acronyms and Abbreviations

Appendix B: Acronyms and Abbreviations

Abbreviation	Description
AR	Attainment Report on Transportation System Performance
ARToolbox	Adaptation and Resiliency Toolbox
BMC	Baltimore Metropolitan Council
BRTB	Baltimore Regional Transportation Board
C-SMMPO	Calvert – St. Mary's Metropolitan Planning Organization
CAMPO	Cumberland Area Metropolitan Planning Organization
CRAB	Climate Ready Action Boundary
CTP	Consolidated Transportation Program
EJ	Environmental Justice
FEMA	Federal Emergency Management Agency
FY	Fiscal Year
FFY	Federal Fiscal Year
FHWA	Federal Highway Administration
HEPMPO	Hagerstown/Eastern Panhandle Metropolitan Planning Organization
IIJA	Infrastructure Investment and Jobs Act
LRTP	Long-Range Transportation Plan
MAA	Maryland Aviation Administration
MCCC	Maryland Commission on Climate Change
MDEM	Maryland Department of Emergency Management
MDOT	Maryland Department of Transportation

Abbreviation	Description
MDTA	Maryland Transportation Authority
MPA	Maryland Port Administration
MPO	Metropolitan Planning Organization
MTA	Maryland Transit Administration
MTP	Maryland Transportation Plan
MVA	Motor Vehicle Administration
N/A	Not Applicable
NCRTPB	National Capital Region Transportation Planning Board
NOAA	National Oceanic and Atmospheric Administration
OCCRA	Office of Climate Change Resilience and Adaptation
PROTECT	Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation
RTP	Regional Transit Plan
SHA	State Highway Administration
STIP	Statewide Transportation Improvement Program
S/WMPO	Salisbury/WICOMICO Metropolitan Planning Organization
TIP	Transportation Improvement Program
TRIP	Transportation Resilience Improvement Plan
TSO	Transportation Secretary's Office
USDOT	U.S. Department of Transportation
WILMAPCO	Wilmington Area Planning Council

TRANSPORTATION RESILIENCE IMPROVEMENT PLAN

2024

MDOT MARYLAND DEPARTMENT OF TRANSPORTATION

MARYLAND AVIATION ADMINISTRATION