Memorandum

To: The Transportation Planning Board

From: ICF

Date: December 1, 2021

Re: Resiliency Planning Factor: Adaptation Planning and Coordination Technical Memorandum of Framework and Findings

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Summary

This memorandum describes the process and findings resulting from the National Capital Region Transportation Planning Board's (TPB) effort to identify existing resilience efforts in the transportation sector among a subset of the TPB member jurisdictions. For the purpose of this paper, resilience is "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions."[1] Although such disruptions to the region's transportation system can have many causes, this project focuses on disruptions relating to natural hazards, such as extreme heat or cold, extreme storm events, and flooding of all kinds – coastal flooding, flooding from rivers and streams, and flash floods that can occur away from bodies of water.

After creating a framework for information-gathering, the consultant team ("study team") conducted research on the TPB member actions to support transportation infrastructure resilience. The study team completed a desktop review of relevant documents from a subset of member agencies, conducted targeted outreach to complete the framework, and identified infrastructure that should be considered for future evaluation.

This memorandum describes this process, summarizes the information collected, and identifies next steps in this effort. A separate Microsoft Excel file contains the framework data, and a bibliography lists the resources reviewed. A separate white paper provides a public-facing summary of resilience planning in the region's transportation planning.

As a caveat, the findings of this research are based solely on publicly available materials. Many agencies have ongoing work relating to the topic that they are not ready to share publicly yet. This research also shares goals (and other details) stated in existing public documents, but these goals (and other information) should not be taken to reflect formally adopted positions of the agencies.

Please contact the TPB long-range planning staff if you would like to request the Framework spreadsheets.

[1] United States Department of Transportation (USDOT) Federal Highway Administration (FHWA). December 2014. "FHWA Order 5520." Available at: https://www.fhwa.dot.gov/legsregs/directives/orders/5520.cfm#par6.

Background

The TPB is conducting research, with consultant support, to document activities that TPB members and select partners are undertaking to prepare for the transportation system to be resilient in the face of natural disasters. The purpose of this work is to respond to one of the federal Planning Factors and to advance important planning work and regional coordination on the topic of resiliency, one of TPB's policy priorities. This study is referred to as the TPB Resiliency Study.

As context to this effort, it should be noted that the TPB and the Metropolitan Washington Council of Governments (COG) are conducting or have conducted numerous efforts regarding climate change and resiliency. For the purposes of clarification, these efforts are noted below. This list is not comprehensive of all TPB and COG activities but is provided for the purpose of background. For more information about the studies listed here, please view the January 2021 memorandum that can be accessed online at: https://www.mwcog.org/file.aspx?&A=Uq856Jo%2f9rWyw9gxFjO9%2fHGe%2b8yQ3Jm7zbuAC0jQjBM%3d

- In 2010, the TPB joined COG's action to set greenhouse gas (GHG) reduction targets to mitigate the impact of climate change.
- Over the last decade the TPB completed and participated in two studies to evaluate strategies to address these targets, including the 2010 What Would It Take scenario analysis and the 2016 Multisector Working Group study that identified the various types of projects, programs, and policies that have the greatest potential to reduce GHG in the transportation sector.
- In October, the COG Board approved the 2030 Regional Climate and Energy Action Plan. The TPB issued a resolution endorsing the climate goals in this plan.

As of 2021, the TPB is advancing the following two studies.

- TPB Climate Change Mitigation Study. Staff plan to conduct additional climate planning work that would examine specific strategies to develop estimates of the levels of outcomes needed to help reduce the transportation sector's GHG emissions commensurate with the region's GHG reduction goals for 2030. (Please see link above for more information)
- TPB Resiliency Study, described in this memorandum.

Terms

This section covers terminology and key references used in this memo. Please note, Visualize 2045, the TPB's long-range transportation plan, is the region's Metropolitan Transportation Plan.

Federal Planning Factor. the Fixing America's Surface Transportation (FAST) Act Transportation Planning Rule (May 2016) added:

- Metropolitan Transportation Plan must assess capital investment and other strategies that reduce the vulnerability of existing transportation infrastructure to natural disasters (23 CFR450.324(f)(7)).
- Metropolitan planning organizations (MPOs) recommended to consult with agencies and officials responsible for natural disaster risk reduction when developing Plan and TIP (23 CFR 450.316(b)).
- New planning factor on improving the resiliency and reliability of transportation system (23 CFR 450.206(a) and 23 CFR450.306(b)), which is:
    - Improve the resiliency and reliability of the transportation system and reduce or mitigate stormwater impacts of surface transportation

Priority infrastructure. As the TPB's role in metropolitan Washington is to focus on regional priorities, this study did not look at all types of infrastructure. Instead, this study attempts to focus on infrastructure that facilitates regional transportation, which is "priority" infrastructure from a regional perspective.

Resilience. As defined by the Federal Highway Administration (FHWA), resilience is "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from

disruptions," For the purpose of this research, the project focused on disruptions relating to natural hazards, which are expected to increase in intensity, duration and frequency (IDF) due to climate change.

Vulnerable infrastructure. For the purposes of this technical memo, the term "vulnerable infrastructure" refers to infrastructure that has been identified by an agency as having been exposed to natural hazards and potential climate risks.

Note: While this study is focused on the definition of resiliency as provided above, the TPB acknowledges that the resilience of the transportation system can be viewed through other lenses, for example, the transportation system plays an important role in emergencies ranging from everyday traffic incidents to major disasters. Many events over the years, notably the attacks of September 11, 2001, serve as reminders that the region must be as prepared as possible. Preparedness and security are key concerns of and have been longstanding planning activities part of COG and TPB. Visualize 2045 both supports and reflects a wider-ranging set of emergency preparedness planning activities. The TPB coordinates efforts with the COG's Homeland Security and Public Safety program, which brings together emergency preparedness and public safety officials from across the region. Together, COG and TPB help facilitate coordination across the region to ensure the preparedness, resiliency, and safety of our transportation system. Federal, state, and regional homeland security requirements are fulfilled through numerous COG committees that convene transportation and public safety subject matter experts, especially COG's Transportation Emergency Preparedness Committee. For more information, visit mwcog.org/public-safety-and-homeland-security/.

Framework Overview

The study team developed a Microsoft Excel spreadsheet framework to guide the data collection process. This framework included questions in the following topic areas:

- Goals and objectives
- Analysis
- Data and information – infrastructure and vulnerabilities
- Strategies
- Project development
- Stormwater
- Coordination
- Challenges
- Equity

Throughout each step of the research process, the study team used this framework to document findings.

Research Process

Due to time and budget limitations, this research project prioritized researching the resilience activities of the TPB's regional members, state agencies, and counties. Due to the diverse nature and responsibilities of those listed in the outreach group, the types and extent of resiliency planning activities may vary. The agencies included in this research include:

- TPB member transportation agencies.
    1. Virginia: Office of Intermodal Planning and Investment (OIPI), Department of Rail and Public Transportation (DRPT), Virginia Department of Transportation (VDOT).
    2. DC: District Department of Transportation (DDOT), Office of Planning (DCOP).

3. Maryland: Maryland Department of Transportation (MDOT) and its transportation business units: Maryland Transit Administration (MDOT MTA), Maryland Transportation Authority (MDTA), and the State Highway Administration (MDOT SHA).
4. Washington Metropolitan Area Transit Authority (WMATA).
5. Virginia Railway Express (VRE).
6. U.S. National Park Service (NPS).
7. National Capital Planning Commission (NCPC).

- Selected local city and counties' transportation departments.
    1. Arlington County, VA.
    2. City of Alexandria, VA.
    3. Charles County, MD.
    4. Fairfax County, VA.
    5. Frederick County, MD.
    6. Loudoun County, VA.
    7. Montgomery County, MD.
    8. Prince George's County, MD.
    9. Prince William County, VA.

- Non-TPB member agencies:
    1. Northern Virginia Transportation Authority (NVTA)

ICF conducted the following activities to complete the Framework and generate the content for this technical memo and the accompanying white paper:

- Document review of material gathered via online research, COG TPB materials, and materials provided by the region's jurisdictions.
- Outreach to member jurisdictions via FAQ sessions and the following interviews:
    - Open FAQ session for all TPB members within the scope of this study was held on February 18, 2021. Attendees included:
        - Zack Bishop, Prince George's County, GIS Specialist.
        - Bob Brown, Loudoun County.
        - Josh Foster, MDOT Manager of Transportation Climate Risk.
        - Claudia Glen, WMATA Office of Sustainability.
        - Beth Groth, Charles County Sr. Planner.
        - Sandy Hertz, MDOT Assistant Director, Office of the Environment.
        - Meagan Landis, Prince William County DOT, Analyst.
        - Elissa McDade, WMATA Office of Sustainability.
        - Sree Nampoothiri, NVTA, Senior Transportation Planner.
        - Mark Rawlings, DDOT Regional Planner.
        - Kari Snyder, MDOT Regional Planner.
        - Malcolm Watson, Fairfax County DOT Liaison to the TPB.
        - Victor Weissberg, Prince George's County, Major Projects Manager.
    - Interview with Maryland DOT was held on April 5, 2021. Attendees included:
        - Kari Snyder, MDOT Regional Planner.
        - Josh Foster, MDOT Manager of Transportation Climate Risk.
        - Sandy Hertz, MDOT Assistant Director, Office of the Environment.
    - Interview with DDOT was held on April 9, 2021 with Austina Casey, Environmental Program Manager.
    - Interview with VDOT and OIPI was held on April 16, 2021. Attendees from VDOT and OIPI included:

        - Chris Swanson, Assistant State Location & Design Engineer (VDOT).
        - Regina Moore, Transportation Specialist in the Northern Virginia (NOVA) District Planning Office (VDOT).
        - John (Alex) Foraste, Water Resources Program Manager (VDOT).
        - Jitender Ramchandani, VTrans Program Manager (OIPI).
        - Norman Whitaker, Transportation Planning Director in the NOVA District Planning Office (VDOT).
- Application of resiliency expertise and research to identify infrastructure for potential future evaluation.

Summary of Framework Findings

Detailed findings from the review can be found in the spreadsheet file of the Framework. This memo contains some high-level summaries of the findings.

As a caveat, the findings of this research are based solely on publicly available materials. Many agencies have ongoing work relating to the topic that they are not ready to share publicly yet. This research also shares goals (and other details) stated in existing public documents, but these goals (and other information) should not be taken to reflect formally adopted positions of the agencies or work that may be under development, but incomplete.

Goals and Objectives

Many jurisdictions have goals and objectives that either directly mention or relate to climate resilience. These goals and objectives can help the TPB understand what is motivating its members to work on resilience.

The types of goals vary. Many jurisdictions have goals that focus on building awareness and a deeper understanding of the climate hazards that region faces – demonstrating that many jurisdictions are in a knowledge-building stage of resilience planning. Other goal areas included ensuring a reliable system, identifying strategies for addressing climate risks, and facilitating stakeholder coordination. The most valuable next step is to share a consolidated set of the goals and objectives to raise awareness of how others are thinking about this topic.

Table 1. Types of Goals

Goals and Objectives	Jurisdiction
Build awareness and understand climate hazards, vulnerabilities, and risks	MD, VA NCPC Charles County, Frederick County, Montgomery County, Prince George's County
Investigate and select actions and strategies relating and/or responding to climate risks	MD, VA WMATA Charles County
Assist communities and practitioners in identifying tools to plan for climate change impacts	MD, VA
Ensure safe, secure, resilient system	MD, VA City of Alexandria, Charles County

Goals and Objectives	Jurisdiction
Improve service reliability through resilient long-term capacity	DC, VA
Facilitate stakeholder coordination	NCPC
Determine how well infrastructure is designed to handle extreme conditions	Montgomery County

The most cited reason for working to address climate risks was to protect transportation assets. Other reasons included responding to financial concerns, legislative mandates, safety concerns, and recurring incidents. Sharing this broad set of motivations may help others that have been struggling to justify a focus on resilience.

Table 2. Types of Reasons for Addressing Resilience

Reasons	Jurisdiction
Responding to past disaster or recurring incidents	DC, MD, VA
Responding to legislative mandate	MD, VA
Responding to financial/economic concerns	DC, VA Prince George's County
Addressing safety and security concerns	MD, VA Montgomery County
Seeking to protect transportation assets	DC, MD, VA WMATA Frederick County
Inform managed retreat decision	VA

Many jurisdictions provided definitions of resilience, which typically included language about the ability to prepare for, adapt to, and recover from changing conditions, similar to FHWA's definition. Sharing this information may be useful to those who have not yet adopted a definition or are considering refining their definition.

Table 3. Samples of How the Documents Described Resilience and the Core Components of the Definition

Agency (Document)	Definition
Arlington County (Community Energy Plan)	The ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions caused by deliberate attacks, accidents, climate change, or weather-related threats or incidents.
Charles County (Climate Resilience Action Strategy)	The ability to prepare for, recover from, and adapt to climate change impacts.
Government of D.C. (Resilient DC)	Urban resilience is the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and thrive no matter what kinds of chronic stresses and acute shocks they experience.
MDOT (2020 Annual Attainment Report)	Provide a resilient multimodal system by anticipating and planning for changing conditions and hazards whether natural or man-made.

Agency (Document)	Definition
Montgomery County (Climate Action Plan)	Ability to withstand and recover from a climate hazard.
NVRC (Resilient Critical Infrastructure: A Roadmap for Northern Virginia)[2]	Resilient systems work to "ensure that functionality is retained and/or can be re-instated despite some failures or operational disturbances."[3]

Time horizons for goals, analyses, modeling, and forecasting ranged from the short term (2 years) to much longer-term visions (2100). Meaningful changes in climate will occur between the 2050 and 2100 time frame, while shorter time-horizons are more likely to be focused on existing natural hazards. The TPB may wish to encourage that its member agencies consider both short-term and long-term risks by sharing and hosting trainings on climate change projections.

Table 4. Horizon Years and Timeframes Used for Goals, Analyses, Modeling, and Forecasting

Horizon	Jurisdiction
2-year	VA (Climate Change and Resiliency Update Commission Report and Recommendations, published in 2015 with 2-year goals)
2025	MD (Connecting Our Future: Regional Transit Plan Central Maryland)
2030	MD (Strategic Issues Facing Transportation Practitioners Guide) Prince William County (Comprehensive Transportation Plan)
2035	Montgomery County (Climate Action Plan)
2040	City of Alexandria (Environmental Action Plan 2040)
2045	VA (VTrans Vulnerability Assessment)
2050	MD (Integrating Extreme Weather and Climate Risk Into MDOT SHA Asset Management Planning; MDOT SHA Climate Change Adaptation Plan and Vulnerability Assessment) Arlington County (Energy and Climate Adaptation Advisory Report)
2100	MD (Integrating Extreme Weather and Climate Risk Into MDOT SHA Asset Management Planning; MDOT SHA Climate Change Adaptation Plan and Vulnerability Assessment), VA (Virginia Transportation Planning for Sea Level Rise) Montgomery County (Climate Action Plan)

For additional detail on the goals and objectives, see rows 5-9 of the Framework, which addressed the following questions:

- Is transportation resilience to climate change impacts part of the document's goals or objectives?
- Does the document give a reason for the agency wanting to address transportation resilience to climate change impacts?
- Does the document give a time frame or horizon?

[2] NVRC is not a TPB member but was added to this study due to the leadership role it has played in planning for resilience in Northern Virginia.

[3] NVRC and COG. 2018. Resilient Critical Infrastructure: A Roadmap for Northern Virginia. https://www.novaregion.org/DocumentCenter/View/11933/Resilient-Roadmap-Final-PDF

Vulnerability Analyses that Include Geographies in the TPB Planning Area

Over the past 5-6 years, the region's agencies have begun undertaking vulnerability analyses. To date, these analyses have generally involved exercises that overlay maps of a subset of natural hazards/risks with maps of a subset of transportation infrastructure types. More detailed analysis may be planned or underway at individual agencies but were not captured in our research if it was not published or if it was stated during the interviews that it was not ready to be shared with the TPB.

Several agencies have been conducting vulnerability assessments in the region.

- In 2019, DDOT published its Climate Change Adaption Plan, and the overall District of Columbia government published Resilient DC: A Strategy to Thrive in the Face of Change. DDOT's plan included a vulnerability analysis that overlaid maps of DDOT's existing assets with climate hazards such as temperature, precipitation, sea level rise, and storms. By identifying potential impacts from these hazards, DDOT was then able to identify potential adaptation strategies it could take to improve resilience to those hazards.
- Maryland DOT develops annual Climate Change Status Reports to describe its work on adaptation and mitigation. In 2019, the MDOT State Highway Administration (MDOT SHA) published its final report – Integrating Extreme Weather and Climate Risk into MDOT SHA Asset Management and Planning – about its experience in conducting vulnerability assessments as part of an FHWA pilot program initiated in 2014. To help transportation agencies identify risks to existing and proposed transportation infrastructure, MDOT SHA developed an interactive online map called "Climate Change Vulnerability Viewer" in 2018 with ongoing updates. This viewer covers the Maryland portion of the TPB's planning area but is limited in the types of risks and infrastructure considered, so there is opportunity to conduct additional analyses for these areas and the transportation infrastructure within them.
- As part of preparing the Commonwealth of Virginia's Transportation Plan, VTrans, OIPI, has conducted a vulnerability assessment of Virginia's major roadways, bridges, and culverts. Vulnerability scores are being developed based on exposure to hazards and how essential the asset is to the transportation network. As of spring 2021, the work is ongoing, and the findings will inform development of the plan.

Such overlay-based vulnerability assessments can provide lists of vulnerable infrastructure, but given the vast amount of infrastructure that has the potential for exposure, a recommended next step is to focus resources and planning efforts on identifying exposed infrastructure that is most important regionally. This list could help the region and its jurisdictions prioritize how to spend its resilience efforts.

Table 5 summarizes the Framework data in lines 10-12, which addressed the following questions:

- Does this document reference any analysis or studies (e.g., a vulnerability assessment) that the agency has undertaken regarding transportation infrastructure resiliency?
- What types of transportation infrastructure were covered by the vulnerability assessment or study of climate risks to types of infrastructure?

Table 5. Types of Analyses by Jurisdictions

Analysis	Jurisdictions
Document references analyses or studies that the agency has undertaken regarding transportation infrastructure resiliency.	DC, MD, VA NVRC, WMATA Charles County, Frederick County, Montgomery County, Prince George's County
Agency's vulnerability assessment or study covers roads.	DC, MD, VA NVRC, NCPC

Analysis	Jurisdictions
	City of Alexandria, Charles County, Fairfax County, Frederick County, Montgomery County, Prince George's County, Prince William County
Agency's vulnerability assessment or study covers bridges.	DC, MD, VA NVRC Charles County, Montgomery County, Prince George's County
Agency's vulnerability assessment or study covers drainage and culverts.	DC, MD, VA NVRC Charles County, Frederick County
Agency's vulnerability assessment or study covers transit stations (rail or bus stops)	MD, VA NVRC, NCPC, WMATA Charles County, Fairfax County, Frederick County, Montgomery County, Prince George's County
Agency's vulnerability assessment or study covers tunnels.	DC NVRC

Vulnerability Analyses: Infrastructure and Hazards Assessed

To improve resiliency in the region, it can be helpful to know what disruptions are possible to the regional transportation system. The research team sought to identify whether the region's transportation agencies had identified (a) priority infrastructure, (b) potential hazards, and (c) whether the priority infrastructure was exposed to the potential hazards ("vulnerable infrastructure"). The research team looked at whether the priority infrastructure was provided as a list of individual assets, or a blanket categorical consideration for specific asset-types (e.g., bridges). Most documents analyzed infrastructure categorically, and only a few resources named specific individual assets, which are noted in Table 17.

Agencies throughout the region have been conducting vulnerability analyses of varying natures. Some focus on climate vulnerabilities; others have focused on hazard mitigation. Some analyses look at all the infrastructure in a particular jurisdiction; other analyses have been conducted within a particular agency or focused on a particular type of infrastructure. The region's jurisdictions use several different approaches to conduct assessments of infrastructure vulnerable to natural hazards, including the stakeholder input approach, indicator-based desk review approach, engineering-informed assessments, and hybrid approaches.

Several jurisdictions identified high-priority or critical transportation infrastructure. However, there was a wide range in the level of detail provided (i.e., some mentioned infrastructure that had been impacted by prior natural hazards, while other had conducted detailed, ranked inventories of critical infrastructure). Table 6 summarizes the Framework data in lines 13-18, which addressed the following questions: Does the document identify transportation infrastructure that is high priority or critical?

Each of the following summary tables includes asterisks to indicate agencies that included maps (or other indications of GIS data) in the documents reviewed. A few agencies had the GIS data available (e.g., MDOT's Vulnerability Viewer), but in general the GIS is not organized or available in any centralized location. Even within a given document, the GIS data often came from multiple sources and used multiple approaches to defining geographic areas, infrastructure types, or hazard types.

Table 6. Priority Infrastructure Referenced in Analyses and Studies

Priority Infrastructure (rows 13-15)	Jurisdictions
Agency documents identify transportation infrastructure that is high priority or critical.	MD, VA* NVRC* Charles County, Fairfax County, Frederick County, (Prince George's County's list was redacted)
Roads and highways	MD, VA Charles County, Fairfax County
Bridges	MD, VA* NVRC*
Drainage and culverts	Charles County
Transit infrastructure	MD NVRC* Frederick County
Evacuation routes	MD Fairfax County, Frederick County*

Jurisdictions referenced hazards including stormwater impacts, coastal inundation, landslides and weather-related erosion, and extreme temperatures. Table 7 addresses the following question from the framework: Does the document reference any data (historical or forecasted) relating to stormwater impacts, including extreme precipitation and flooding, coastal inundation, landslides, or impacts from extreme temperatures?

Table 7. Hazards Referenced in Analyses and Studies

Type of Hazards	Jurisdictions
Stormwater impacts, including extreme precipitation and flooding	DC, MD*, VA* NCPC, NVRC*, WMATA City of Alexandria, Charles County*, Fairfax County*, Frederick County*, Montgomery County*, Prince George's County, Prince William County*
Coastal inundation, including sea level rise and storm surge	DC, MD*, VA* NVRC*, NCPC Charles County*, Fairfax County, Prince George's County*
Landslides and other weather-related erosion of earth/materials supporting transportation structures	DC, MD*, VA* Charles County*, Frederick County*
Impacts from extreme temperatures, including heat and cold	DC, MD*, VA NVRC*, WMATA Charles County*, Frederick County*, Montgomery County
Other	DC*, VA* Montgomery County*, Prince George's County*

Several jurisdictions identified roads and transit infrastructure as vulnerable, in addition to bridges, drainage, and culverts. Of the major infrastructure types reviewed (e.g., roads, bridges, public transit, active transportation, and airports), all were found to have at least some level of vulnerability to extreme heat, extreme winter conditions, flooding (both coastal and inland), and severe storms. That vulnerability may vary based on location. Agencies have indicated that Intensity-Duration-Frequency (IDF) curves are being updated to use in future vulnerability analyses.

Table 8 summarizes the Framework data in rows 19-27, which addresses the following question: Does the document identify transportation infrastructure that is vulnerable to extreme weather and climate change impacts?

Table 8. Vulnerable Infrastructure

Vulnerable Infrastructure	Jurisdictions
Roads	DC, MD*, VA* NVRC*, NCPC City of Alexandria, Charles County, Fairfax County, Frederick County, Montgomery County, Prince George's County, Prince William County*
Bridges	DC, MD*, VA* NVRC* Charles County, Montgomery County, Prince George's County
Drainage and culverts	DC, MD*, VA NVRC Charles County, Frederick County
Transit infrastructure	MD*, VA NVRC*, NCPC, WMATA* Charles County, Fairfax County, Frederick County*, Montgomery County, Prince George's County
Tunnels	DC NVRC*

Strategies to Address Vulnerabilities

The research team attempted to determine whether the vulnerability analyses resulted in any strategies to address the vulnerabilities that had been identified. Many resiliency strategies might be underway at agencies but not captured in this study; for example, most agencies' stormwater management efforts could be considered a resiliency strategy, but those activities were generally not presented in the documentation as being selected to reduce vulnerability.

Table 9 summarizes the Framework data in rows 28-33, which addressed the following questions:

- Has the document identified or evaluated strategies to address the identified vulnerabilities?
- Has the document selected or adopted any strategies to address the identified vulnerabilities?
- Of the selected strategies, does the document indicate that the agency has begun to implement any?

The documents provided little detail on adoption or implementation status. Therefore, this table summarizes the types of strategies that appear to be in progress at these agencies. Many of the documents identified additional potential strategies that could be pursued with additional time or resources.

Many jurisdictions are in the early stages of resiliency planning, so action items often included developing more specific strategies and plans. Other strategies included conducting research, coordinating with other departments or agencies, and adapting existing infrastructure. The TPB staff may consider compiling information on how vulnerability assessment results can be integrated into agency actions to raise awareness of these options.

Table 9. Types of Resilience Strategies Documented

Type of Strategies	Jurisdictions
Development of plans and lists of potential strategies to pursue	MD, DC, VA NVRC, WMATA Charles County, Fairfax County, Frederick County, Montgomery County
Research and studies, including enhanced data efforts	DC, MD, VA WMATA, NVRC Charles County, Frederick County
Coordination	DC WMATA Charles County, Montgomery County
Establishment of new staff or departments to address	MD, VA WMATA Charles County, Fairfax County
Legislative and regulatory changes	DC, MD Charles County
Funding and incentive strategies	Charles County
System management and operations	MD WMATA Frederick County
Asset management program strategies	MD Frederick County
Adapt existing infrastructure	MD WMATA City of Alexandria, Charles County, Frederick County, Montgomery County

Project Development

In the document review and interviews, the research team inquired about how resiliency considerations influence the agencies' selection, funding, and design of transportation projects. Incorporating resiliency considerations into project development will ensure that the region's major transportation investments are working to improve resiliency of the transportation system.

Most documents reviewed did not contain full descriptions of how the agencies select projects. Improved transparency in the project development process could help identify potential improvements for meeting regional goals, including resiliency. A few agencies included information about project selection criteria, design guidelines, and other project screening processes.

Table 10 summarizes the Framework data in rows 34-42, which addressed the following questions:

- Does the document talk about how the agency selects, funds, or design/builds transportation projects?
- Does the document describe whether there is a process for screening proposed transportation projects to identify any that are in locations that are particularly vulnerable to climate impacts?
- Within the document's account of the agency's process for selecting and prioritizing transportation projects, is there any consideration of resilience?
- Does the document include any criteria for funding transportation projects include anything relating to resilience?
- Does the document include any guidelines/standards for project design or engineering that are designed to improve transportation resilience?

Table 10. Project Development Strategies

Project Development Strategies	Jurisdictions
Screening of projects	MD, VA Fairfax County
Project selection criteria	MD, VA Charles County
Project funding criteria	MD
Project design guidelines	MD, VA Fairfax County
Environmental review	MD, VA

Stormwater and Other Infrastructure Systems

Stormwater impacts are often recurring events that are worsening with climate change. Most stormwater management strategies are also resiliency strategies, but many agencies might not yet be characterizing them as such. Therefore, the research team sought specific information relating to stormwater impacts.

Among the jurisdictions studied, flooding and extreme precipitation are the primary concerns for culverts and other stormwater infrastructure. Frequent intense downpours could overload drainage systems and increase stormwater runoff. Failing culverts affect the performance and safety of roads.

Many jurisdictions have managed stormwater for many years and have begun to identify strategies for improving stormwater infrastructure. Multiple jurisdictions have identified high-priority stormwater infrastructure. Several jurisdictions have identified strategies for reducing or mitigating stormwater runoff and/or adapting how they build infrastructure. Table 11 summarizes the Framework data in rows 43-44, which addressed the following question: Does the agency have activities, analysis, plans, or strategies for reducing or mitigating the transportation system's contribution to stormwater impacts?

Asterisks are used to indicate agencies that appear to have GIS or other detailed data available for this topic, either from the agency or from a source that they used.

Table 11. Stormwater Activities

Stormwater Activities	Jurisdictions
Analysis	MD, VA Charles County, Frederick County*
Plans	MD, VA NCPC Charles County, Loudoun County
Strategies for reducing or mitigating stormwater runoff	DC, VA NCPC, WMATA Arlington County, Charles County, Fairfax County, Frederick County, Montgomery County
Integrate with planning for other infrastructure (e.g., electric grids)	MD NCPC
Adapting built infrastructure (e.g., improving pumping capacity, adapting hydraulic openings for culverts/bridges)	DC, VA NCPC, WMATA Arlington County, Charles County, Fairfax County, Montgomery County, Prince George's County
Erosion control or other "green infrastructure"	DC, VA WMATA Arlington County, Charles County, Montgomery County
Damage assessment	WMATA

The transportation system also relies on other infrastructure systems such as electrical power grids and communications networks. The researchers attempted to identify whether the transportation agencies were working across sectors to improve resiliency. Table 12 summarizes the Framework data in rows 45-46, which addressed the following question: Is there any discussion of the interrelationships between stormwater, electrical power grids/infrastructure, and communications networks?

Table 12. Interrelationships With Other Infrastructure

Interrelationships With Other Infrastructure	Jurisdictions
Electrical power grids/infrastructure*	DC, MD Arlington County, Fairfax County, Montgomery County
Communications networks	MD Montgomery County
Water supply	DC, MD

**Some jurisdictions in the region produce have produced Energy Assurance Plans, this plan type is an area for future research.*

Coordination

Improving metropolitan Washington's resiliency will require coordination across a broad range of partners and stakeholder agencies. Many of the documents reviewed for this research involved collaborations with

other jurisdictions and/or with non-transportation agencies. Documents often cited federal, state DOT, local government, and regional partners. Utilities, universities, and private sector partners were also mentioned. The TPB could build upon these existing partnerships as it works to further resiliency in the region.

Table 13 summarizes the Framework data in rows 47-50, which addressed the following questions:

- Does the document reference that the agency has any partners with which it is working on transportation resiliency?
- Does the document indicate that another document or plan (by another agency or department) directs the transportation work related to any of the above resiliency areas in some way?

Table 13. Jurisdictions That Document That They Coordinate With Partners on Transportation Resiliency

Agency Partners	Jurisdictions
Federal partners	MD, VA Montgomery County, WMATA
State DOTs	MD WMATA Charles County, Frederick County, Montgomery County
Other state departments	DC, MD, VA WMATA
Regional Agencies	MD, VA WMATA Charles County, Frederick County, Montgomery County, Prince George's County, Prince William County
Local governments	MD, VA WMATA Charles County, Fairfax County, Frederick County, Montgomery County, Prince George's County, Prince William County, City of Alexandria, Arlington County, Loudoun County
Private sector	VA
Academic/ universities	MD, VA Charles County
Utilities	WMATA

Challenges

In the interviews and documentation, the research team asked about the challenges the agencies faced in improving the resiliency of the transportation system. Securing adequate funding, coordinating amongst a variety of stakeholders, and accessing data were often cited as challenges. In identifying roles to play, the TPB could focus on roles that help to address these challenges. More thoughts on this is provided in the Next Steps section.

Table 14 summarizes the Framework data in row 51, which addressed the question: What is the agency's biggest challenge (if stated) for addressing transportation resiliency? Money, time, designated staff, technical expertise, other?

Table 14. Challenges

Challenges	Jurisdictions
Financial/funding	MD, VA Charles County, Montgomery County
Time	MD, VA Montgomery County
Identifying integration points	MD, VA
Data gaps	MD, VA Montgomery County
Training	VA, WMATA
Coordination amongst varying agencies and business units	MD, VA, City of Alexandria, Loudoun County, Montgomery County
Prioritizing in the face of such a large and complex problem	MD, VA Charles County, Montgomery County Most agencies reflected this challenge in discussions

Agency Contacts

To help the TPB in its identification of potential speakers or stakeholders to invite to resiliency activities, the research team documented the contact information provided with the documents reviewed. Table 15 summarizes the Framework data in row 52, which asked whether the document named a contact person at the agency.

Table 15. Agency Contacts Listed in Documents Reviewed

Agency	Contact Info
City of Alexandria	Bill Eger, bill.eger@alexandriava.gov Ellen Eggerton, ellen.eggerton@alexandriava.gov Jennifer Slesinger, jennifer.slesinger@alexandriava.gov
Arlington County	Rich Dooley, Community Energy Coordinator Dennis Leach, Transportation Division Chief
Charles County	Beth Groth, GrothB@CharlesCountyMD.gov Mark Belton, County Administrator
FHWA	Elizabeth Habic (previously with MDOT, Office of Planning and Preliminary Engineering, now with FHWA: Elizabeth Habic (FHWA), Elizabeth.habic@dot.gov)
MDOT	Virginia Burke, Vburke@mdot.maryland.gov Elizabeth Habic (FHWA), Elizabeth.habic@dot.gov, (410) 533-8471 Josh Foster, jfoster@mdot.state.md.us, (443) 960-3249 Sandy Hertz, Assistant Dir., Office of Environment, shertz@mdot.Maryland.gov, (410) 865-2780 Toria Lassiter, tlassiter@mdot.maryland.gov, (410) 545-5731

Agency	Contact Info
	Lisa Lowe, Senior GIS Systems Specialist, lisa.lowe@maryland.gov Eddie Lukemire, Program Manager, Office of Environment, Elukemire@mdot.Maryland.gov, (410) 865-2770 Michel Ney Sheffer, MSheffer@mdot.maryland.gov, (410) 545-5537
NCPC	Karin Schierhold, karin.schierhold@ncpc.gov, (202) 482-7268
Old Dominion	Emily Steinhilber, esteinhi@odu.edu
VDOT	Bridget M. Donaldson (VTRC Project Manager) Michael Hibbard (VDOT)
Virginia OIPI	Jitender Ramchandani, (804) 489-4295, Jitender.Ramchandani@oipi.Virginia.gov Katie Schwing, (804) 217-1165, Kathryn.Schwing@oipi.Virginia.gov Chris Wichman, (804) 316-4278, Chris.Wichman@oipi.Virginia.gov
Virginia Institute of Marine Science (VIMS)	Mark Luckenbach, luck@vims.edu Sea level data and Tidewatch Maps ©: Dr. Molly Mitchell, molly@vims.edu Planning, policy, local ordinances comprehensive planning: Pam Mason, mason@vims.edu GIS tools and data: Marcia Berman, marcia@vims.edu General Information on ADAPTVA: adaptva@vims.edu
Virginia Coastal Policy Center	Elizabeth Andrews, eaandrew@wm.edu
University of Maryland (UMD)	Joanne Throwe, jthrowe@umd.edu Dan Nees, dnees@umd.edu
WMATA	Gregory T. Edwards, GTEdwards@wmata.com Elissa McDade, EMcDade@wmata.com Denton Rourke, drourke@wmata.com

Equity

Climate hazards have the potential to disproportionately impact communities and populations that may already be marginalized and underrepresented. The research, therefore, sought to identify whether the resiliency activities conducted in the region were considering equity. Table 16 summarizes the Framework data in row 53, which addressed the question:

- Does the document address equity in relation to transportation infrastructure or resilience in any way?

Some member agencies in the region are already incorporating equity into their transportation planning. For example, the Montgomery County, Maryland established its Resilience Ambassador Program in 2020 to further understand and improve solutions around inequality within the County's transportation, equity, climate, energy justice program areas, as well as provide COVID-19 pandemic support for the most vulnerable communities. The program aims to increase representation of Black, Indigenous, and People of Color (BIPOC); low-income communities; and immigrants in the county's programs to better incorporate

racial equity and social justice in climate planning process. Other agencies have conducted outreach activities and modified project selection processes to help make the planning process more equitable.

Table 16. Equity Considerations Related to Transportation Infrastructure or Resilience

Equity in Transportation Resilience	Jurisdictions
Planning consideration	MD, VA
Project selection/prioritization	VA City of Alexandria
Outreach	Charles County
Data	MD Prince George's County
Statement acknowledging relationship between climate change and equity	MD

Infrastructure for Future Evaluation

Agency documents that were reviewed by the research team are an important starting point for identifying infrastructure for future evaluation of resiliency efforts and needs. Table 17 displays a selection of primary documents for each agency that mentioned a categorical type of asset or a specific named asset (marked with an asterisk) as vulnerable to different hazards. The full list of documents reviewed that address vulnerabilities to hazards by asset type can be found in the Framework. This sheet in the Framework contains a list of hazard types down one axis and a list of infrastructure types down another axis. The internal cells of the framework show the names of agencies that have analyzed the vulnerability of that type of infrastructure to that type of hazard.

Table 17. Hazards to Infrastructure Referenced in Resources – Primary Documents Listed for Each Agency

Hazard	Roads	Bridges	Drainage/Culverts	Transit
Stormwater impacts, including extreme precipitation and flooding	**DC -** 2019 Climate Change Adaptation Plan **MD -** SHA 2014 Climate Change Adaptation Plan* **VA -** VTrans 2021 Update: Long-Term Needs, Vulnerability Assessment* **NVRC -** Utilizing Regional Collaboration to Build Community Resilience* **NCPC -** 2016 Comprehensive Plan **Charles County -** 2020 Climate Resiliency Action Strategy Draft **Frederick County** - 2017 Hazard Mitigation Plan **Fairfax County -** 2020 Comprehensive Plan **Montgomery County -** 2018 Hazard Mitigation Plan **Prince George's County -** 2018 Climate Change Vulnerabilities **Prince William County -** 2021 Route 28 Project*	**DC -** 2019 Climate Change Adaptation Plan **MD -** 2020 Climate Change Adaptation Strategies* **VA -** DRPT 2020 Long Bridge Project* **NVRC -** Utilizing Regional Collaboration to Build Community Resilience* **Charles County -** 2021 Nuisance and Urban Flood Plan **Montgomery County -** Office of Legislative Oversight 2021 Measuring Climate Resilience	**DC -** 2019 Climate Change Adaptation Plan **MD -** 2019 Integrating Extreme Weather and Climate Risk into Asset Management Planning* **VA -** VTrans 2021 Update: Long-Term Needs **Charles County -** 2021 Nuisance and Urban Flood Plan	**MD -** 2018 Climate Status Report*, NAP 2017 Improving the Resilience of Transit Systems Threatened by Natural Disasters* **NVRC -** Utilizing Regional Collaboration to Build Community Resilience* **NCPC -** 2018 Flood Risk Management Planning Resources* **WMATA -** 2017 Flood Emergency Response Plan* **Charles County -** 2018 Hazard Mitigation Plan **Frederick County -** 2017 Hazard Mitigation Plan* **Fairfax County -** 2020 Comprehensive Plan 2017 Edition: Transportation **Montgomery County -** 2020 Climate Action Plan Draft
Coastal inundation, including sea level rise and storm surge	**DC -** 2019 Climate Change Adaptation Plan **MD -** SHA 2014 Climate Change Adaptation Plan * **VA -** Coastal Resilience Master Plan, VTrans 2021 Update: Long-Term Needs, VTrans Vulnerability Assessment* **NVRC -** 2019 Utilizing Regional Collaboration to Build Community Resilience* **NCPC -** 2016 The Comprehensive Plan for the National Capital **Charles County -** 2021 Nuisance and Urban Flood Plan **Fairfax County -** 2020 Comprehensive Plan	**DC -** 2019 Climate Change Adaptation Plan **MD -** 2020 Climate Change Adaptation Strategies* **VA -** DRPT 2020 Long Bridge Project* **NVRC -** 2019 Utilizing Regional Collaboration to Build Community Resilience in Northern Virginia* **Charles County** - 2021 Nuisance and Urban Flood Plan, 2018 Hazard Mitigation Plan	**DC -** 2019 Climate Change Adaptation Plan **MD -** SHA 2014 Climate Change Adaptation Plan* **VA -** 2019 Incorporating Potential Climate Change Impacts in Bridge and Culvert Design **Charles County -** 2021 Nuisance and Urban Flood Plan	**NVRC -** 2019 Utilizing Regional Collaboration to Build Community Resilience* **NCPC -** 2016 The Comprehensive Plan for the National Capital **Charles County -** 2018 Hazard Mitigation Plan
Landslides and other weather-related erosion	**DC -** 2019 Climate Change Adaptation Plan **Charles County -** 2018 Hazard Mitigation Plan **Frederick County -** 2017 Hazard Mitigation Plan	**DC -** 2019 Climate Change Adaptation Plan **VA -** DRPT 2020 Long Bridge Project* **Charles County -** 2018 Hazard Mitigation Plan	**DC -** 2019 Climate Change Adaptation Plan	**MD -** 2018 Climate Status Report* **VA –** 2019 Hazard Mitigation Plan **Charles County -** 2018 Hazard Mitigation Plan
Impacts from extreme temperature, including heat and cold	**DC -** 2019 Climate Change Adaptation Plan **NVRC -** 2019 Utilizing Regional Collaboration to Build Community Resilience* **Charles County -** 2018 Hazard Mitigation Plan **Frederick County -** 2017 Hazard Mitigation Plan **Montgomery County -** 2018 Hazard Mitigation Plan	**DC -** 2019 Climate Change Adaptation Plan **NVRC -** 2019 Utilizing Regional Collaboration to Build Community Resilience* **Charles County -** 2018 Hazard Mitigation Plan **Montgomery County -** Office of Legislative Oversight 2021 Measuring Climate Resilience	**DC -** 2019 Climate Change Adaptation Plan	**MD –** 2018 Climate Status Report* **VA –** 2019 Hazard Mitigation Plan **NVRC -** 2019 Utilizing Regional Collaboration to Build Community Resilience* **Charles County -** 2018 Hazard Mitigation Plan **Montgomery County –**2020 Climate Action Plan Draft

*indicates that this document identified some specific assets

Next Steps

Based on our preliminary assessments of the data gathered, the TPB may want to offer technical assistance on the following topics:

- What is resilience, and why is it important for transportation planning?
- What type of analysis and data are available to support resilience planning?
- What types of strategies can be used to improve resilience?
- How can we integrate resilience into:
    - Project development processes?
    - Planning?
    - Operations (this topic seems the most advanced in the current state of the practice)?
    - Asset management?
- How can we coordinate efforts with other agencies to reduce the burden of resiliency planning?
- How do we prioritize in the face of such a daunting list of to-do items?
- What are some funding opportunities for addressing resiliency?
- How can our work on resiliency also be used to further our other priorities, such as equity?

The audiences for each topic will vary. Some agencies or staff at those agencies have very advanced understanding, while others have not had the availability to develop that expertise.

The TPB has several methods available for improving member jurisdictions' technical capability in this area. These methods generally build off of the TPB's ability to convene people from various departments and jurisdictions. Strategies include:

- Workshops, peer exchanges, roundtables, and other forums for group discussion or facilitation.
- Online resources such as one-pagers, white papers, and checklists.
- Incorporating relevant data in the TPB's data clearinghouse.