Appendix G
Process for Evaluating Criticality, Sensitivity, and Adaptive Capacity of Assets

Vulnerability Assessment Criteria: Criticality of all Assets

Criteria Sources:

Subject Matter Experts (SME) elicitation

Federal Highway Administration (FHWA), Vulnerability Assessment and Adaptation Framework, 3rd Edition, FHWA-HEP-18-020, December 2017

Criticality Scoring Scale Guide:

Low	1	Medium	5	High	10

The Highest Score in a given category determines the asset Criticality.

ASSET CRITICALITY

Indicator	Description and Rationale	Potential Data Source(s)	Indicator Unit	Value Range		Score
Identified as a Critical Transportation Asset	Determine if the asset was identified in a Hazard Mitigation Plan as a critical transportation asset	• Hazard Mitigation Plans	Critical Asset? (Yes/No)	No	=	1
				Yes	=	10
	An asset was identified as critical or somewhat critical during Technical Advisory Committee (TAC) interviews.	• Notes from Technical Advisory Committee (TAC) Interviews	Critical Asset? (Yes/No)	No	=	1
				Yes	=	5
Magnitude of connections/volume of ridership	Identified as having a high volume of ridership or traffic, including congestion, or major rail line.	• NJTPA Plan 2045 (page 38)	Delay Ratios (percent)	< 25%	=	1
				25 to 50 %	=	3
				50% to 75 %	=	7
				> 75%	=	10
Emergency Function of Routes	Identified by presence of evacuation routes (bridges, roadways and culverts)	• GIS layer showing evacuation routes • Notes from Technical Advisory Committee (TAC) Interviews • Hazard Mitigation Plans	Evacuation Route? (Yes/No)	No	=	1
				Yes	=	10

Vulnerability Assessment Criteria: Sensitivity and Adaptive Capacity of Bridges

Criteria Sources:

Subject Matter Experts (SME) elicitation

Federal Highway Administration (FHWA), Vulnerability Assessment and Adaptation Framework, 3rd Edition, FHWA-HEP-18-020, December 2017

U.S. Department of Transportation (DOT), Vulnerability Assessment Scoring Tool (VAST), June 2015

Sensitivity Scoring Scale Guide:	**Low**	**1**	**Medium**	**5**	**High**	**10**					
Adaptive Capacity Scoring Scale Guide:	**High**	**1**	**Medium**	**5**	**Low**	**10**					

The Highest Score in a given category determines the asset Sensitivity and Adaptive Capacity.

Items highlighted in [ ] indicate potential unavailability of data. This will be confirmed, and if the data is not available, the criterion will be removed.

BRIDGES: ASSETS SENSITIVITY

Sensitivity to Extreme Heat Events

Indicator	Description and Rationale	Potential Data Source(s)	Indicator Unit	Value Range			Score
Past Experience with Heat Events	Road segments that already experience rutting may experience worsening problems as the temperature increases.	• Notes from Technical Advisory Committee (TAC) Interviews • Hazard Mitigation Plans • Resource documents reviewed under Task 1	Damaged in past? (Yes/No)	No	=		1
				Yes	=		5
Truck Traffic	If a road or bridge experiences high volumes of truck traffic, this is an indicator of how likely it may experience rutting, shoving, or other compromised integrity under extreme temperature conditions. Pavement experiences greater stress from heavy vehicle traffic. As temperatures increase, rutting may occur on segments of road with high volumes of truck traffic.	• NJTPA Bridge Data • National Bridge Inventory, Item 109 (Average Daily Truck Traffic)	Average Daily Truck Traffic	0	5000	=	1
				5000	10000	=	5
				10000	+	=	10
Movable Bridge	Movable bridges can be more susceptible to damage during heat waves due to moving components, electrical, and mechanical components.	• National Bridge Inventory, Item 43b (Structure Type)		Movable			10
				Not Movable			1

Sensitivity to Extreme Precipitation Events, Sea Level Rise, and Storm Surge

Past Experience with Precipitation

Bridges that have experienced damage during past heavy rain events are more likely to be damaged if exposed in the future.

- Notes from TAC Interviews
- Hazard Mitigation Plans
- Resource documents reviewed under Task 1

Damaged in past? (Yes/No)

No	1
Yes	5

Bridge Age

Older bridges may have been built to outdated design standards, rendering them more sensitive to precipitation events than bridges designed more recently.

- National Bridge Inventory, Item 27 (Year Built)

Age (years)

0	25	=	1
25	75	=	5
75	+	=	10

Navigational Clearance of Bridge

Bridges with less clearance above the waterway are more likely to experience storm surge heights that reach their deck and cause damage.

- National Bridge Inventory, Item 39 (Navigation Vertical Clearance)

Navigational Clearance (feet)

0	5	=	10
5	15	=	5
15+	20	=	1

Elevation of Asset

The higher the elevation of the asset, the less likely it will be inundated.

- GIS Maps & LiDAR data

elevation (feet above base flood elev.)

0	5	=	10
5	15	=	5
Not a water crossing **OR** 15+		=	1

BRIDGES: ADAPTIVE CAPACITY

Adaptive Capacity for Extreme Heat Events

Preventive Plan for Cooling Moveable Bridges

The owner/operator has a plan for dealing with moveable bridges during extreme heat periods.

- Notes from TAC Interviews
- Hazard Mitigation Plans
- Resource documents reviewed under Task 1

Yes	1
No	5

Adaptive Capacity for Extreme Precipitation Events, Sea Level Rise, and Storm Surge

Replacement Cost

Replacement costs for each asset are used as a rough proxy for the ease in which assets could be repaired or replaced. Resources are assumed to be more easily mobilized for lower cost repairs, and replacement costs may indicate overall complexity, size, and expense of the asset itself.

- Replacement Cost = Bridge Deck Area X $450 / sq. ft (FHWA average cost for NJ)

Replacement cost (USD)

0	$1,000,000	=	1
$1,000,000	$10,000,000	=	5
$10,000,000	+	=	10

Detour Length (not affected)

Detour length is used as an indicator of redundancy in the system. Bridges with longer detour lengths assumed to have less adaptive capacity than bridges with shorter detours.

- National Bridge Inventory provides detour length for bridges in the database (Item 19)

Detour length (km)

0	10	=	1
10	30	=	5
30	+	=	10

Disruption Duration	Disruption duration is used to indicate the timeframes necessary to restore service to assets following impacts of each of the variables. Length of time for the disruption to clear is an indicator of how well the system can deal with the climate impact.	• Notes from TAC Interviews • Hazard Mitigation Plans • Resource documents reviewed under Task 1	Hours	1
			Days	5
			Weeks	10
Parallel Structures	Should there be parallel bridge structures, and one of them is affected and taken out of service, the other bridge structure can be used temporarily to carry traffic in both directions while the other bridge is being repaired. However, if one of the parallel structure is vulnerable to a hazard, it is likely both will be affected.	• GIS Maps • NJTPA Bridge Database	Yes	1
			No	5
Preventive Maintenance and Preservation Practices	Bridge assets that receive preventive maintenance and undergo preservation, are more likely to recover faster	• Notes from TAC Interviews • Hazard Mitigation Plans • Resource documents reviewed under Task 1	Yes	1
			No	5

Vulnerability Assessment Criteria: Sensitivity and Adaptive Capacity of Culverts

Criteria Sources:

Subject Matter Experts (SME) elicitation

Sensitivity Scoring Scale Guide:	**Low**	**1**	**Medium**	**5**	**High**	**10**
Adaptive Capacity Scoring Scale Guide:	**High**	**1**	**Medium**	**5**	**Low**	**10**

The Highest Score in a given category determines the asset Sensitivity and Adaptive Capacity.

CULVERTS: ASSETS SENSITIVITY

Sensitivity to Extreme Heat Events

Not Applicable. Culverts are buried underground and near streams and stay cooler than the road surface. They are therefore not directly affected by extreme heat events.

Sensitivity to Extreme Precipitation Events, Sea Level Rise, and Storm Surge

Past Experience with Precipitation	Culverts that have experienced damage or functionality/performance disruption during past heavy rain events are more likely to be damaged if exposed in the future.	• Notes from Technical Advisory Committee (TAC) Interviews • Hazard Mitigation Plans • Resource documents reviewed under Task 1	Damaged or performance disruption in past? (Yes/No)	No	1
				Yes	5
Overtopping	If water level exceeds road surface level, depending on the structural condition of culvert and velocity of water, there could be damage to the culvert and, as a result, damage to the roadway. As a conservative assumption, if water surface reaches the road surface level, it is considered a high sensitivity asset.	• National Hydraulic Map, Location of Culverts	Does water level reach road surface level?	No	1
				Yes	10

CULVERTS: ADAPTIVE CAPACITY

Adaptive Capacity for Extreme Heat Events

Not Applicable. Culverts are buried underground and near streams and stay cooler than the road surface. They are therefore not directly affected by extreme heat events.

Adaptive Capacity for Extreme Precipitation Events, Sea Level Rise, and Storm Surge

Culvert Length

Replacement costs for each asset are used as a rough proxy for the ease in which assets could be repaired or replaced. Resources are assumed to be more easily mobilized for lower cost repairs, and replacement costs may indicate overall complexity, size, and expense of the asset itself.

For size of culverts, since the diameter is unknown, only the roadway width over the culvert, as an indication of the length of culver along the centerline of stream is considered as a measure of size.

- GIS showing culvert locations
- National Hydraulic Map, Location of Culverts

Roadway width over culvert

30 ft or less	1
More than 30 ft	5

Vulnerability Assessment Criteria: Sensitivity and Adaptive Capacity of Facilities

(Covers all facilities, including, but not limited to: administrative, maintenance, stations, parking, bus depots)

Criteria Sources:

Subject Matter Experts (SME) elicitation

Sensitivity Scoring Scale Guide:	**Low**	**1**	**Medium**	**5**	**High**	**10**
Adaptive Capacity Scoring Scale Guide:	**High**	**1**	**Medium**	**5**	**Low**	**10**

The Highest Score in a given category determines the asset Sensitivity and Adaptive Capacity.

Items highlighted in [ ] indicate potential unavailability of data. This will be confirmed, and if the data is not available, the criterion will be removed.

FACILITY: ASSET SENSITIVITY

Sensitivity to Extreme Heat Events

Indicator	Description and Rationale	Potential Data Source(s)	Indicator Unit	Value Range	Score
Past Experience with Heat Events	Facilities) that already experience damage and/or disruption during heat events may experience worsening problems as the temperature increases.	• Notes from Technical Advisory Committee (TAC) Interviews • Hazard Mitigation Plans • Resource documents reviewed under Task 1 • Subject matter expertise (substations)		No Yes	1 10

Sensitivity to Extreme Precipitation Events, Sea Level Rise, and Storm Surge

Indicator	Description and Rationale	Potential Data Source(s)	Indicator Unit	Value Range	Score
Past Experience with Precipitation	Assets that have experienced damage and/or disruption in the past from precipitation events are more likely to be damaged if exposed in the future.	• Notes from TAC Interviews • Hazard Mitigation Plans • Resource documents reviewed under Task 1	Damaged in past? (Yes/No)	No Yes	1 10
Access Limitation from Inundation	Determine if the facility, parking areas surrounding the facility, or access roads to the facility have been inundated due to flooding. Even if the asset itself is unaffected, if area near the asset are flooded, the ability to access and operate a facility may be impeded.	• GIS (DMS data and Hurricane Sandy data) • Based on GIS flood elevation	Access is not impaired by inundation? (Yes/No)	No Yes	1 10

FACILITY: ADAPTIVE CAPACITY

Indicator	Rationale	Potential Data Source(s)	Indicator Value	Score
Function of Facility or Asset	Assets that are difficult to replace or move have lower adaptive capacity than assets that are replaceable or movable.	• Notes from TAC Interviews • Hazard Mitigation Plans • Resource documents reviewed under Task 1	Bus stop locations	1
			Park & Ride locations	5
			Bus garages Rail yards Intermodal facilities Passenger stations, admin facilities, maintenance and electrical facilities Gas stations Schools, churches, senior care facilities Substations	10
Disruption Duration	Disruption duration is used to indicate the timeframes necessary to restore service to assets following impacts of each of the variables. Length of time for the disruption to clear is an indicator of how well the system can deal with the climate impact.	• Notes from TAC Interviews • Hazard Mitigation Plans • Resource documents reviewed under Task 1	Up to 24 Hours	1
			Up to one week	5
			More than a Week	10
Preventive Maintenance and Preservation Practices	Assets that receive preventive maintenance and undergo preservation, are more likely to recover faster	• Notes from TAC Interviews • Hazard Mitigation Plans • Resource documents reviewed under Task 1	Yes	1
			No	5

Vulnerability Assessment Criteria: Sensitivity and Adaptive Capacity of Rail Assets

Criteria Sources:

Subject Matter Experts (SME) elicitation

Federal Highway Administration (FHWA), Vulnerability Assessment and Adaptation Framework, 3rd Edition, FHWA-HEP-18-020, December 2017

U.S. Department of Transportation (DOT), Vulnerability Assessment Scoring Tool (VAST), June 2015

Sensitivity Scoring Scale Guide:	**Low**	**1**	**Medium**	**5**	**High**	**10**					
Adaptive Capacity Scoring Scale Guide:	**High**	**1**	**Medium**	**5**	**Low**	**10**					

The Highest Score in a given category determines the asset Sensitivity and Adaptive Capacity.

Items highlighted in [ ] indicate potential unavailability of data. This will be confirmed, and if the data is not available, the criterion will be removed.

RAIL: SENSITIVITY

Sensitivity to Extreme Heat Events

Indicator	Description and Rationale	Potential Data Source(s)	Indicator Unit	Value Range		Score
Past Experience with Heat Events	Rail segments that have experienced damage or disruption during extreme temperatures in the past may be sensitive to higher or more frequent periods of extreme temperatures in the future.	• Notes from Technical Advisory Committee (TAC) Interviews • Hazard Mitigation Plans • Resource documents reviewed under Task 1	Damaged in past? (Yes/No)	No	=	1
				Yes	=	10

Sensitivity to Extreme Precipitation Events, Sea Level Rise, and Storm Surge

Indicator	Description and Rationale	Potential Data Source(s)	Indicator Unit	Value Range		Score
Past Experience with Precipitation	Rail segments that have experienced damage/disruption due to drainage system performance issues are more likely to experience flooding or drainage issues from heavy rainfall events.	• Notes from TAC Interviews • Hazard Mitigation Plans • Resource documents reviewed under Task 1	Damaged in past? (Yes/No)	No		1
				Yes		10
Elevation of Asset	The higher the asset is, the less likely it will be inundated.	• GIS Maps & LiDAR data	Approximate percentage of tracks inundated	0	5%	= 1
				5%	100%	= 10

RAIL: ADAPTIVE CAPACITY

Adaptive Capacity for Extreme Heat Events

Preventive Plan for Rails	The agency has a plan for dealing with rail tracks, signals, and infrastructure during extreme heat periods	• Notes from TAC Interviews • Hazard Mitigation Plans • Resource documents reviewed under Task 1	Yes	1
			No	5

Adaptive Capacity for Extreme Precipitation Events, Sea Level Rise, and Storm Surge

Indicator	Description and Rationale	Potential Data Source(s)	Indicator Unit	Value Range	Score
Presence of Bridges along Segment	Bridges are generally more expensive to replace than rail; the speed to recover from damage to bridges along a segment of rail may therefore be longer than segments without bridges.	• GIS (Bridge Locations)	Bridge along segment? (Yes/No)	No	1
				Yes	10
Emergency Response Plans	Rail companies with a plan in place are expected to suffer less damage and recover more quickly from storms.	• Notes from TAC Interviews • Hazard Mitigation Plans • Resource documents reviewed under Task 1		Plan in place	1
				No plan	10
Disruption Duration	Service Disruption duration is used to indicate the timeframes necessary to restore service to assets following impacts of each of the variables. Length of time for the disruption to clear is an indicator of how well the system can deal with the climate impact.	• Notes from TAC Interviews • Hazard Mitigation Plans • Resource documents reviewed under Task 1		Hours	1
				Days (up to 3 days)	5
				Weeks (3 days or more)	10
Preventive Maintenance and Preservation Practices	Assets that receive preventive maintenance and undergo preservation, are more likely to recover faster	• Notes from TAC Interviews • Hazard Mitigation Plans • Resource documents reviewed under Task 1		Yes	1
				No	5

Vulnerability Assessment Criteria: Sensitivity and Adaptive Capacity of Roads

Criteria Sources:

Subject Matter Experts (SME) elicitation

Federal Highway Administration (FHWA), Vulnerability Assessment and Adaptation Framework, 3rd Edition, FHWA-HEP-18-020, December 2017

U.S. Department of Transportation (DOT), Vulnerability Assessment Scoring Tool (VAST), June 2015

Sensitivity Scoring Scale Guide:	**Low**	**1**	**Medium**	**5**	**High**	**10**
Adaptive Capacity Scoring Scale Guide:	**High**	**1**	**Medium**	**5**	**Low**	**10**

The Highest Score in a given category determines the asset Sensitivity and Adaptive Capacity.

Items highlighted in [ ] indicate potential unavailability of data. This will be confirmed, and if the data is not available, the criterion will be removed.

ROADS: SENSITIVIY

Sensitivity to Extreme Heat Events

Indicator	Description and Rationale	Potential Data Source(s)	Indicator Unit	Value Range			Score
Past Experience with Heat Events	Road segments that already experience rutting may experience worsening problems as the temperature increases, including segments of frequent road closures.	• Notes from Technical Advisory Committee (TAC) Interviews • Hazard Mitigation Plans • Resource documents reviewed under Task 1	Damaged in past? (Yes/No)	No		=	1
				Yes		=	10
Traffic	If a road or bridge experiences high volumes of traffic, this is an indicator of how likely it may be to experience rutting, shoving, or other compromised integrity under extreme temperature conditions. Pavement experiences greater stress from heavy vehicle traffic. As temperatures increase, rutting may occur on segments of road with high volumes of traffic.	• AADT data • Long Range Transportation Plan	Average Daily Traffic	0	5000	=	1
				5000	10000	=	5
				10000	+	=	10

Sensitivity to Extreme Precipitation Events, Sea Level Rise, and Storm Surge

Past Experience with Precipitation

Roads that have experienced damage/disruption during past heavy rain events are more likely to be damaged if exposed in the future, including segments of frequent road closures.

- Notes from TAC Interviews
- Hazard Mitigation Plans
- Resource documents reviewed under Task 1

Damaged in past? (Yes/No)

No	1
Yes	10

Elevation of Asset

The higher the asset is, the less likely it would be inundated.

- GIS Maps & LiDAR data

Approximate percent of roadway inundated

0	5%	=	1
5%	25%	=	5
25%	100%	=	10

ROADS: ADAPTIVE CAPACITY

Indicator	Description and Rationale	Potential Data Source(s)	Indicator Unit	Value Range			Score
Detour Length Or Redundancy	Detour length is used as an indicator of redundancy in the system. Segments with longer detour lengths assumed to have less adaptive capacity than segments with shorter detours.	• GIS data showing location of any parallel or adjoining roadways	Detour length (miles)	0	10	=	1
				10	30	=	5
				30	+	=	10
Disruption Duration	Disruption duration is used to indicate the timeframes necessary to restore service to assets following impacts of each of the variables. Length of time for the disruption to clear is an indicator of how well the system can deal with the climate impact.	• Notes from TAC Interviews • Hazard Mitigation Plans • Resource documents reviewed under Task 1		Up to 24 Hours			1
				Up to one week			5
				More than one week			10
Preventive Maintenance and Preservation Practices	Assets that receive preventive maintenance and undergo preservation, are more likely to recover faster	• Notes from TAC Interviews • Hazard Mitigation Plans • Resource documents reviewed under Task 1		Yes			1
				No			5

Vulnerability Assessment Criteria: Sensitivity and Adaptive Capacity of Transit Assets Non-Rail Track)

(Covers all "rolling stock" such as buses, trains, railcars, etc. and transit routes. This does not cover rail tracks, bus depots, park and rides, or other facilities which are under separate covers)

Criteria Sources:

Subject Matter Experts (SME) elicitation

Federal Highway Administration (FHWA), Vulnerability Assessment and Adaptation Framework, 3rd Edition, FHWA-HEP-18-020, December 2017

U.S. Department of Transportation (DOT), Vulnerability Assessment Scoring Tool (VAST), June 2015

Sensitivity Scoring Scale Guide:	**Low**	**1**	**Medium**	**5**	**High**	**10**
Adaptive Capacity Scoring Scale Guide:	**High**	**1**	**Medium**	**5**	**Low**	**10**

The Highest Score in a given category determines the asset Sensitivity and Adaptive Capacity.

Items highlighted in [ ] indicate potential unavailability of data. This will be confirmed, and if the data is not available, the criterion will be removed.

TRANSIT: SENSITIVITY

Sensitivity to Extreme Heat Events

Indicator	Description and Rationale	Potential Data Source(s)	Indicator Unit	Value Range	Score
Past Experience with Heat Events	Transit assets that already experience damage and/or disruption during heat events may experience worsening problems as the temperature increases.	• Notes from Technical Advisory Committee (TAC) Interviews • Hazard Mitigation Plans • Resource documents reviewed under Task 1 • Subject matter expertise (rolling stock)		No Yes	1 10

Sensitivity to Extreme Precipitation Events, Sea Level Rise, and Storm Surge

Indicator	Description and Rationale	Potential Data Source(s)	Indicator Unit	Value Range	Score
Past Experience with Precipitation	Assets that have experienced damage and/or disruption in the past from precipitation events are more likely to be damaged or disrupted if exposed in the future.	• Notes from TAC Interviews • Hazard Mitigation Plans • Resource documents reviewed under Task 1 • Subject matter expertise (rolling stock)	Damaged /Disrupted in past? (Yes/No)	No Yes	1 10

Impaired Access	If structures near the asset are flooded, the ability to access and operate a facility or bus service may be impeded, even if the asset itself is unaffected.	• Notes from TAC Interviews • Hazard Mitigation Plans • Resource documents reviewed under Task 1	Access is not impaired by inundation? (Yes/No)	No	1
				Yes	10

TRANSIT: ADAPTIVE CAPACITY

Adaptive Capacity for Extreme Heat Events

Not applicable.

Adaptive Capacity for Extreme Precipitation Events, Sea Level Rise, and Storm Surge

Indicator	Rationale	Potential Data Source(s)	Indicator Value		Score
Priority for Assistance	If a transit asset is designated by the U.S. Army Corps of Engineers (USACE) priority for assistance after a major weather event, it is more likely to be re-opened quickly after damage.	• Notes from TAC Interviews • Hazard Mitigation Plans • Resource documents reviewed under Task 1	On list of priorities? (Yes/No)	Yes	1
				No	10
Disruption Duration	Disruption duration is used to indicate the timeframes necessary to restore service to assets following impacts of each of the variables. Length of time for the disruption to clear is an indicator of how well the system can deal with the climate impact.	• Notes from TAC Interviews • Hazard Mitigation Plans • Resource documents reviewed under Task 1		Hours	1
				Days	5
				Weeks	10