Developing a Resilient Texas Transportation System

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Project Overview

- Explored theory of resiliency in transportation planning
- Reviewed state-of-practice in resiliency research in Texas
- Initiated discussion on developing a Texas Transportation Resiliency Framework

- Recommendations

Transportation Resiliency Forum

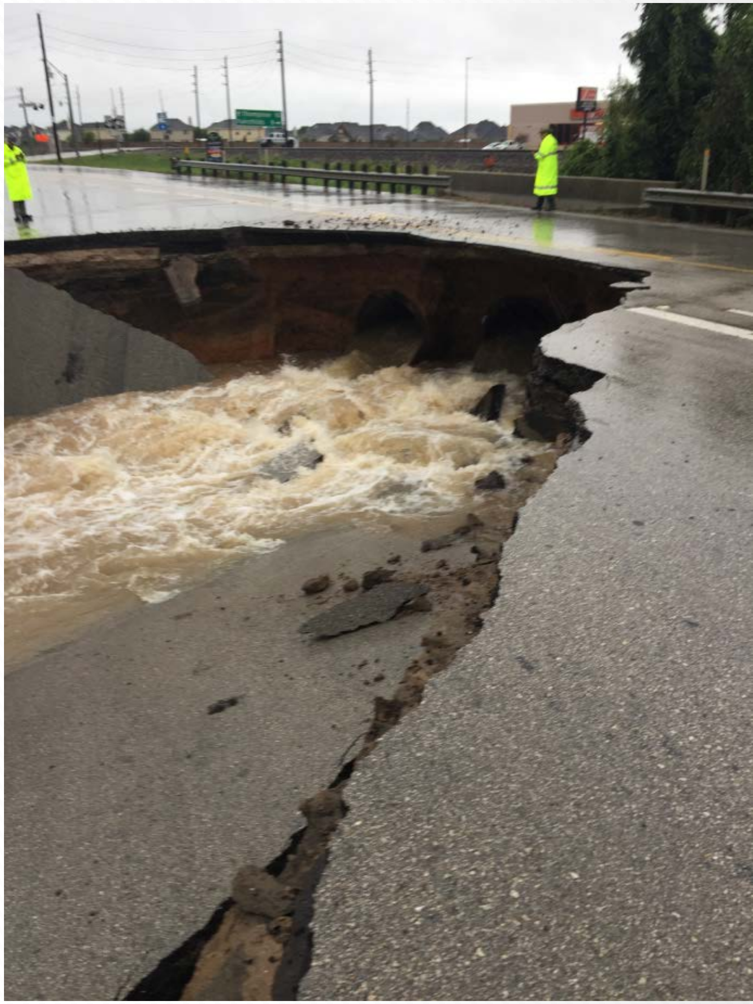
- Forum Objectives:
  - Review state-of-the-practice in resiliency research in Texas
  - Discussed Texas Transportation Resiliency Framework
  - Identify steps and research needed/ gaps in developing Texas Transportation Resiliency Framework

Transportation Resiliency Forum

- Morning Session
  - "FHWA Resiliency Framework for Extreme Weather Events" (FHWA)
  - "Ecological Resiliency: Lessons for Transportation" (TTI)
  - "Emerging Issues in Resiliency to Weather and Climate" (Texas A&M University)
  - "Network-Level Analysis of Transportation Resilience" (Texas A&M University)
  - "Transit-Oriented, High-Interaction Neighborhoods Key to a Resilient Transportation System" (Texas A&M University)
  - "Coastal Shipping Resiliency Following Major Hurricanes and Trains in Coastal Crosswinds" (Texas A&M University)
  - "Understanding the Influence of Climate Change on Texas Pavements" (University of Texas at El Paso)
  - "Combined Sustainability — Resiliency (S-R) Framework for Assessing Three Transportation Infrastructure Case Studies" (University of Texas at Arlington)

Transportation Resiliency Forum

- Afternoon Session
  - Characteristics of desired resilient transportation system
  - Vulnerable transportation system components
  - Data/tools
    - To understand, assess and predict impacts of long-term trends on resiliency
    - To quantify impacts of extreme events and options for mitigation, recovery, and adaption



Resilient Texas Transportation Planning Framework

1. Define resiliency for Texas' transportation system
2. Identify resiliency goals and objectives
3. Identify resiliency performance measures
4. Assess vulnerability of Texas' transportation system
5. Assess/quantify adaption, mitigation and recovery options

1. Define Resiliency

- Plan and develop a transportation system that can:
  - Accommodate long-term change
  - Recover and adapt from unpredictable changes (extreme events)

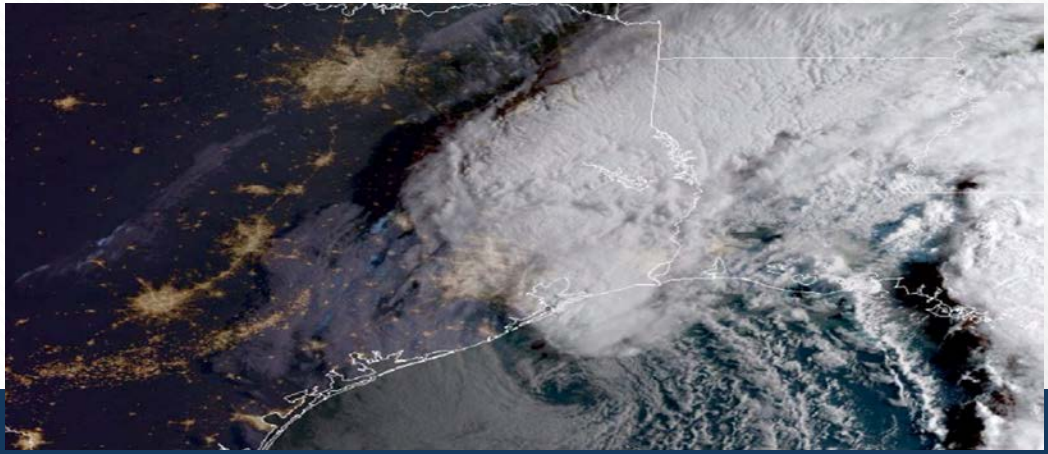
Resiliency is "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions…"

A resilient transportation system is:

- *Robust*
- *Redundant*
- *Resourceful*
- *Reliable*
- *Rapid to recover*

2. Identify Resiliency Goals/ Objectives

- Develop standalone resiliency goal
  - Maintain critical function after extreme weather event
  - Minimize recovery time
  - Minimize infrastructure damage/operational impacts
- Adapt existing planning goal to include resiliency objectives



Texas A&M Transportation Institute

3. Identify Resiliency Performance Measures

- **Minimize extreme weather event impacts**
  - Example *infrastructure* resiliency measures:
    - Lane-miles of critical highways that can withstand an extreme flooding event
    - Number of highway lane-miles in the 100-year or 500-year floodplain
  - Example *operational performance* resiliency measures:
    - Operational/functional within X hours at partial service capacity
    - Operational at reduced capacity for less than X days
    - Operational at original state/recover within X days
- **Redundancy**
  - Examples include number of reliable routes and available multimodal options

4. Assess Vulnerability

a. Identify and characterize extreme weather events of concern
b. Determine risk/likelihood of extreme weather events occurring
c. Identify vulnerable transportation system elements
d. Determine potential impact of extreme weather event if occurring
e. Identify the critical transportation assets

4a. Identify and characterize extreme weather events of concern

Projected Climate Impacts (All Texas Counties)

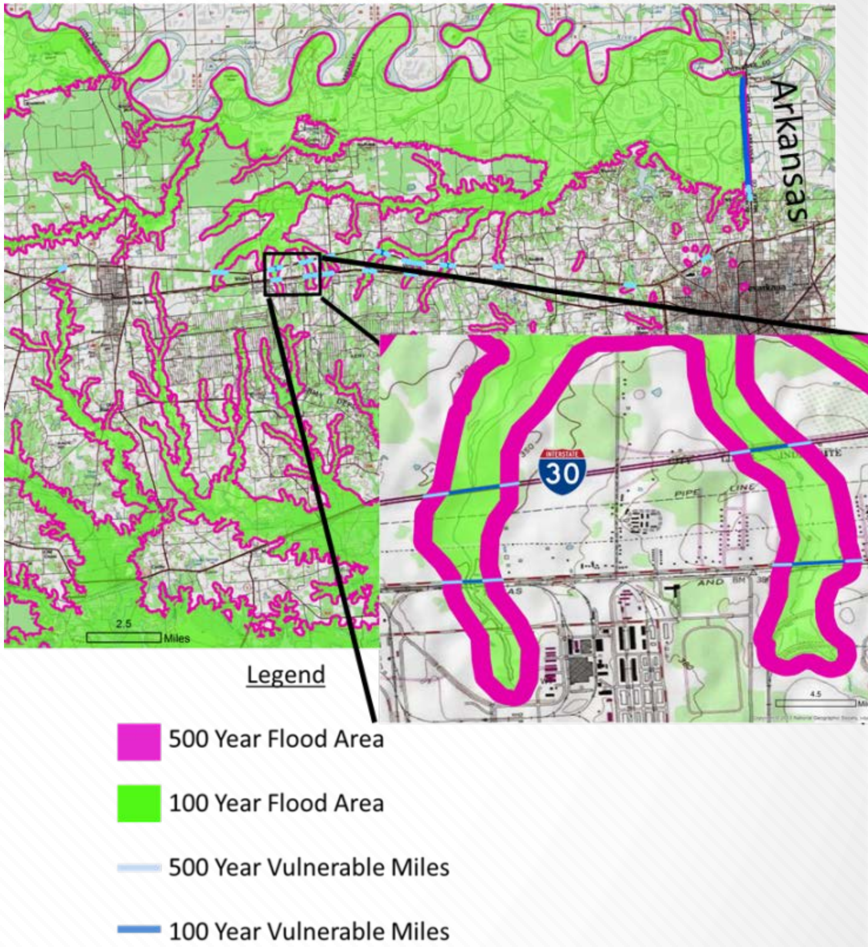
Climate Factor	Projected Impact
Precipitation	• −0.08- to 0.65-day increase in number of wettest days (low-emissions assumptions) • −0.06- to 0.70-day increase in number of wettest days (high-emissions assumptions) • −0.22- to 0.65-inch increase in monthly runoff
Extreme heat/higher temperature	• <1- to 34-day increase in the number of hottest days • 3.08°F to 6.25°F increase in annual mean maximum temperature
Drought	• <1- to 7-day increase in the number of consecutive dry days at a time • 0.008- to 0.045-inch reduction in mean annual soil storage • Potential increase in drought conditions
Extreme weather events	• Potential for more severe storms
Sea-level rise (Gulf of Mexico)	• 0 to 9 mm per year (or 0 to 3 ft per century) on Texas coast

4b. Determine risk/likelihood of extreme weather events occurring

- Understanding climate risks requires partnering with other agencies
  - Experience working with weather and climate data and use climate projections
  - Climate projections, models, and data sources are constantly evolving

4c. Identify vulnerable transportation system elements

- Overlay extreme weather risk data with transportation system assets
- Assess transportation system's exposure to extreme weather events
- Identify vulnerable system elements



Example Federal Emergency Management Agency Floodplain Map.

4d. Determine potential impact of extreme weather event if occurring

Climate Stressors	Examples of Impacts on Transportation Infrastructure and Operations
Increases in very hot days and heat waves	• Thermal expansion on bridge expansion joints and paved surfaces • Concerns about pavement degradation rates, traffic-related rutting, and migration of liquid asphalt • Rail-track deformities • Limits on periods of construction activity due to health and safety concerns
Sea level rise combined with storm surges	• Inundation of roads, rail lines and airport runways in coastal areas • Erosion of road base and bridge supports • Reduced clearance under bridges, and changes in harbor and port facilities to accommodate higher tides and storm surges • More frequent interruptions to coastal and low-lying roadway travel and rail service due to storm surges • More severe storm surges and wave heights, requiring evacuation
Increases in intense precipitation events	• Increases in weather-related delays and traffic disruptions • Increased flooding of evacuation routes • Increases in road washout, damages to rail-bed support structures, and landslides and mudslides that damage roadways and tracks • Increases in scouring of pipeline roadbeds and damage to pipelines
Increase in frequency of intense hurricanes	• Greater probability of infrastructure failures • Increased threat to stability of bridge decks • Impacts on harbor infrastructure from wave damage and storm surges

4e. Identify critical transportation assets

- Important to transportation system or network performance
  - Failure/closure has widespread social and economic implications
- Potential criteria
  - Redundancy
  - Level of use (current and future) or critical commerce or commuter corridors
  - Functional classification
  - Replacement cost
  - Element of Texas multimodal network
  - Evacuation routes

5. Identify Adaption, Mitigation, Recovery Options

- Options/strategies to
  - Increase resiliency
  - Assess and prioritize resiliency measures

HOU Roadways for Possible Raise

County	Roadway	Limits	Estimates	Description	Flood Frequency
Fort Bend	US 90 A	FM 359 to SH 99	50,000,000	evelate pavement and repace bridges	Memorial 2016, Harvey 2017
Fort Bend	FM 723	Brazos River to FM 359	100,000,000	evelate pavement	Memorial 2016, Harvey 2017
Fort Bend	SH 6	Fort Bend County Line to FM 1092	250,000,000	elevate pavement and replace bridges	Harvey 2017
Fort Bend	FM 1093	Brazos River to FM 1489	75,000,000	elevate pavement	Tax Day 2016, Memorial 2016, Harvey 2017
Harris	SH 6	Addicks Dam to Clay Road	200,000,000	bridge roadway through revisore	Memorial 2015, Tax Day 2016, Memorial 2016, Harvey 2017
Harris	I 45 N	Cypresswood to Parramatta	250,000,000	elevating pavement and rebuild two intersections	Memorial 2015 Frontage Road, Tax Day 2016 Frontage Road, Memorial 2016 Frontage Road, Harvey 2017 Frontage Road and Mainlanes
Harris	US 290	Skinnner Road to Telge Road	200,000,000	elevating pavement and rebuild two intersections	Tax Day 2016, Harvey 2017
Waller	I 10	1000' East and West Petterson Road	75,000,000	replace and build urban intersection	Harvey 2017

5. Identify Adaption, Mitigation, Recovery Options

- Build/rebuild assets to withstand anticipated environmental conditions
- Site new facilities outside floodplains or reconstruct at-risk highways considering more conservative flood frequency event assumptions
- Increase system redundancy
- More frequent maintenance schedules

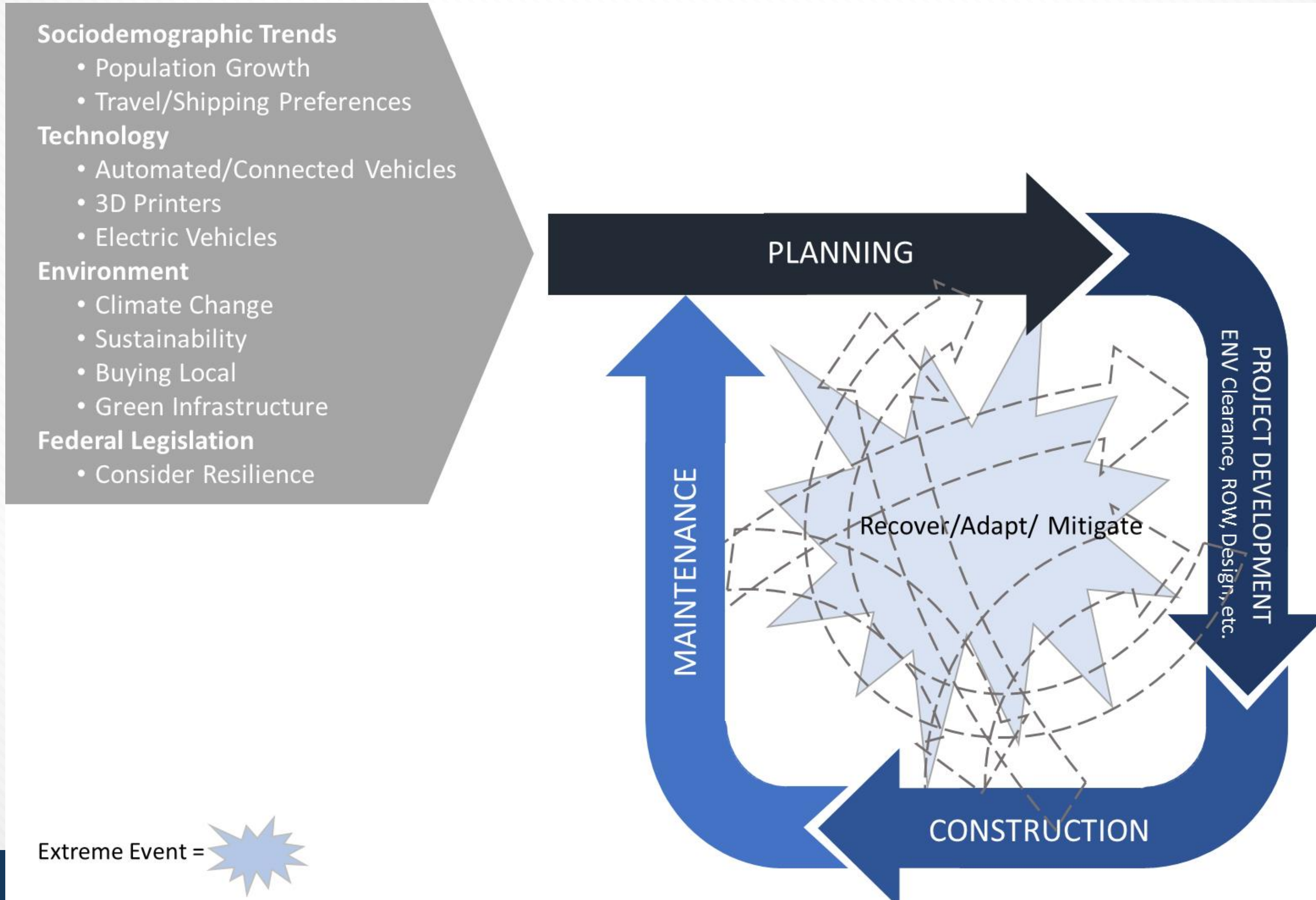
5. Identify Adaption, Mitigation, Recovery Options

- Assess and prioritize resiliency measures
  - Multi-attribute criteria analysis
  - Life-cycle cost analysis
- Approach will ultimately depend on available data and resources

Mercury News, August 29, 2017.

Inform Project Development and Management

Implementing a Resilient Texas Transportation System.



Recommendations

- Create Texas Resiliency Work Group
- Incorporate Resiliency in TxDOT's Performance-Based Planning and Programming Process
- Implement Resiliency Data Clearinghouse
- Host Resiliency Workshops
- Develop a Scenario Planning Tool

The Texas Resiliency Work Group includes:

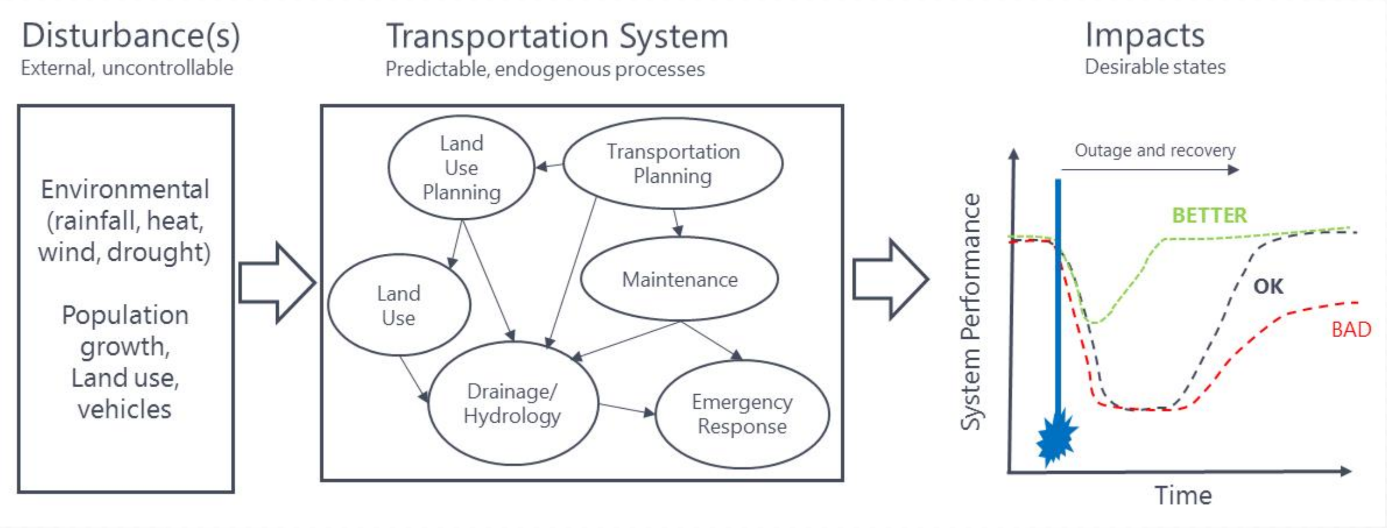
- State transportation planners.
- Multimodal planners (e.g., maritime, rail and transit).
- Asset managers.
- District planners and maintenance personnel.
- Engineers.
- Geographic information system specialists.
- Environmental planners.
- State climatologists.
- Metropolitan transportation planners.

Past and Ongoing Research

- Vulnerable Freight Infrastructure in Texas
- Applying Resilience Theory to Transportation Problems
- Update Rainfall Coefficients with 2018 NOAA Atlas 14 Rainfall Data (Ongoing)
- Developing a Resilient Texas Transportation System
- Asset Management, Extreme Weather, and Proxy Indicators (FHWA Pilot Project)
- Addressing Resiliency in Regional Transportation Plans (Ongoing)

Lessons Learned

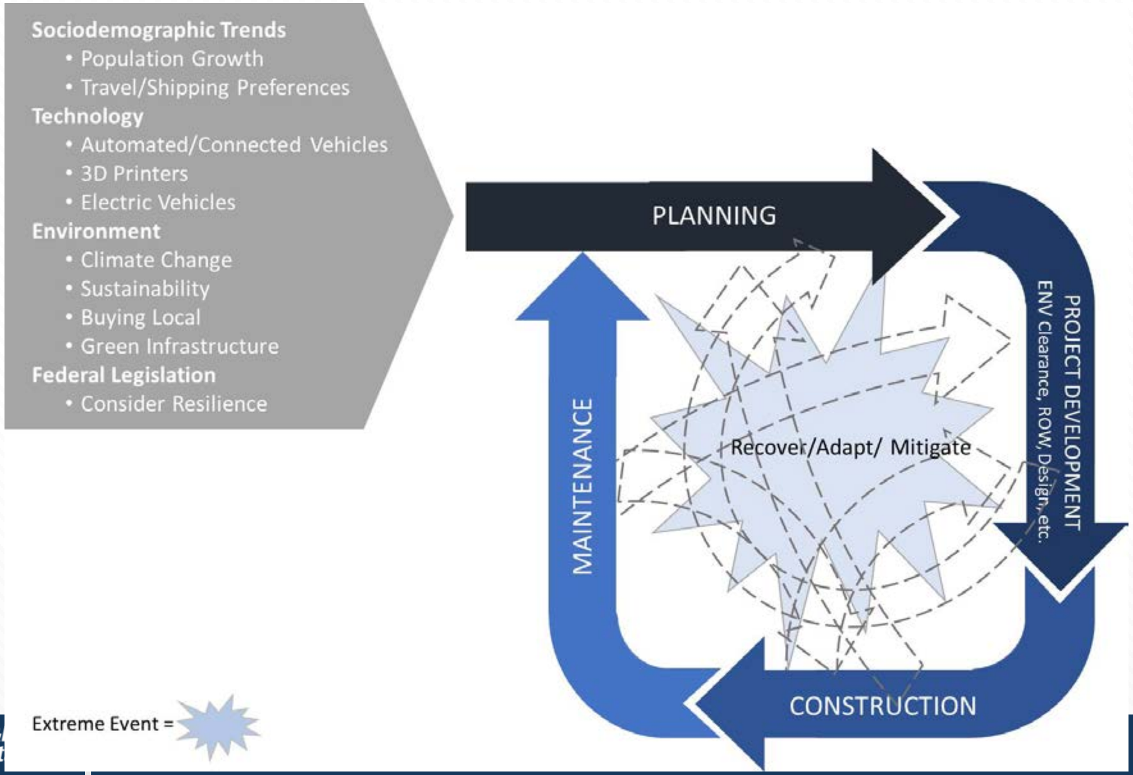
1. Frameworks are important
   - ➢ Understand and conceptualize the different components and the interaction of components of the system, as well as system performance



Resilient Transportation System

Lessons Learned

1. Frameworks are important
   - Guide planning, programming, design, construction, and maintenance of transportation system



Lessons Learned

1. Frameworks are important
   - Assess risk to specific asset classes and impacts on those asset classes (failure and disruption)

= Floodway = 100 yr. flood = 500 yr. flood

Intersect all major roads and flood risk areas

Lessons Learned

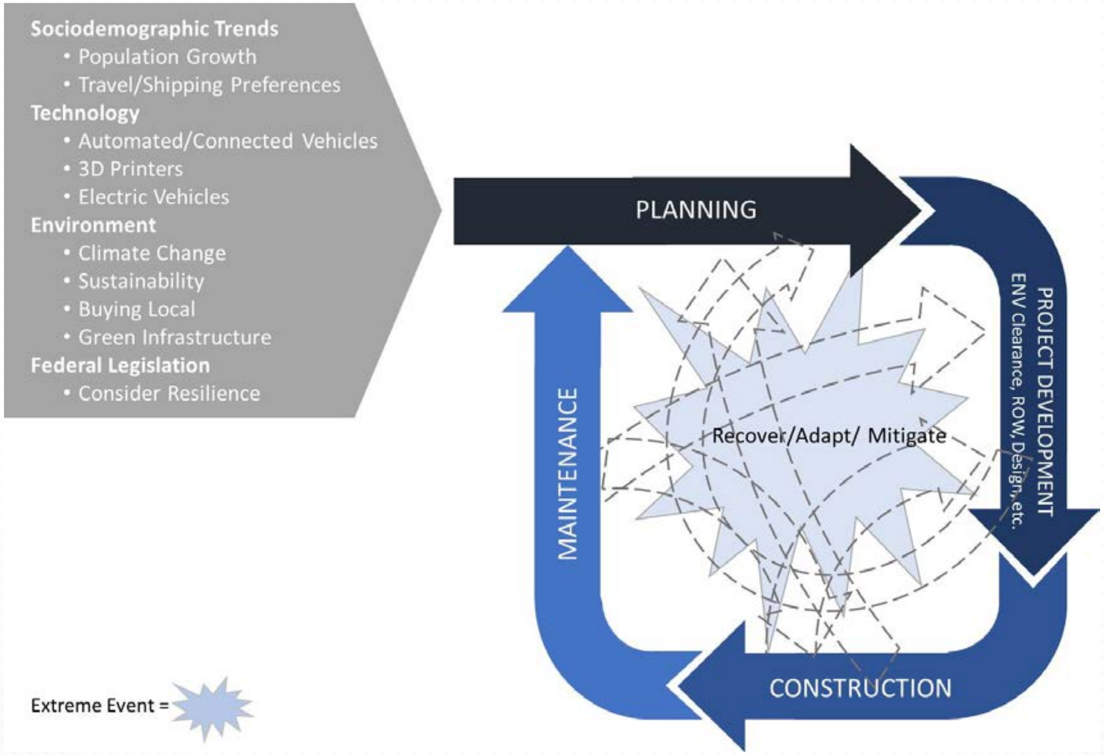
2. Cross-disciplinary collaboration is important
    - Collaboration among climatologists, hydrologists, pavement engineers, planners, and other transportation domain specialists
    - Workshops are useful to capture different perspectives, but also to share information about available data and models

Lessons Learned

3. Data and models/tools are important
   - Data (too much, not enough, not quite right ….)
   - Tools/models
     - Understanding pavement impacts - more frequent maintenance of culverts, improved drainage, adding shoulders to mitigate flooding on pavement service life (heat?)
     - Lifecycle planning analysis does not consider the cost and disruption of road closures
     - Tools to link rainfall events to flooding to inundation to pavement impacts

Lessons Learned

3. How to plan?
   - ➢ Feedback into planning process



Questions?