Climate Change and Transportation System Adaptation: Defining Characteristics from International and National Examples

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Extent of Nation's Transportation Infrastructure

Highways (public)
- 46,873 miles of Interstate highway
- 115,500 miles NHS roads
- 3,849,259 miles of other roads
- 580,000 bridges

Airports
- 5,270 public use airports

Rail
- 95,664 Class 1 miles
- 15,388 regional miles
- 29,197 local miles
- 23,000 Amtrak miles

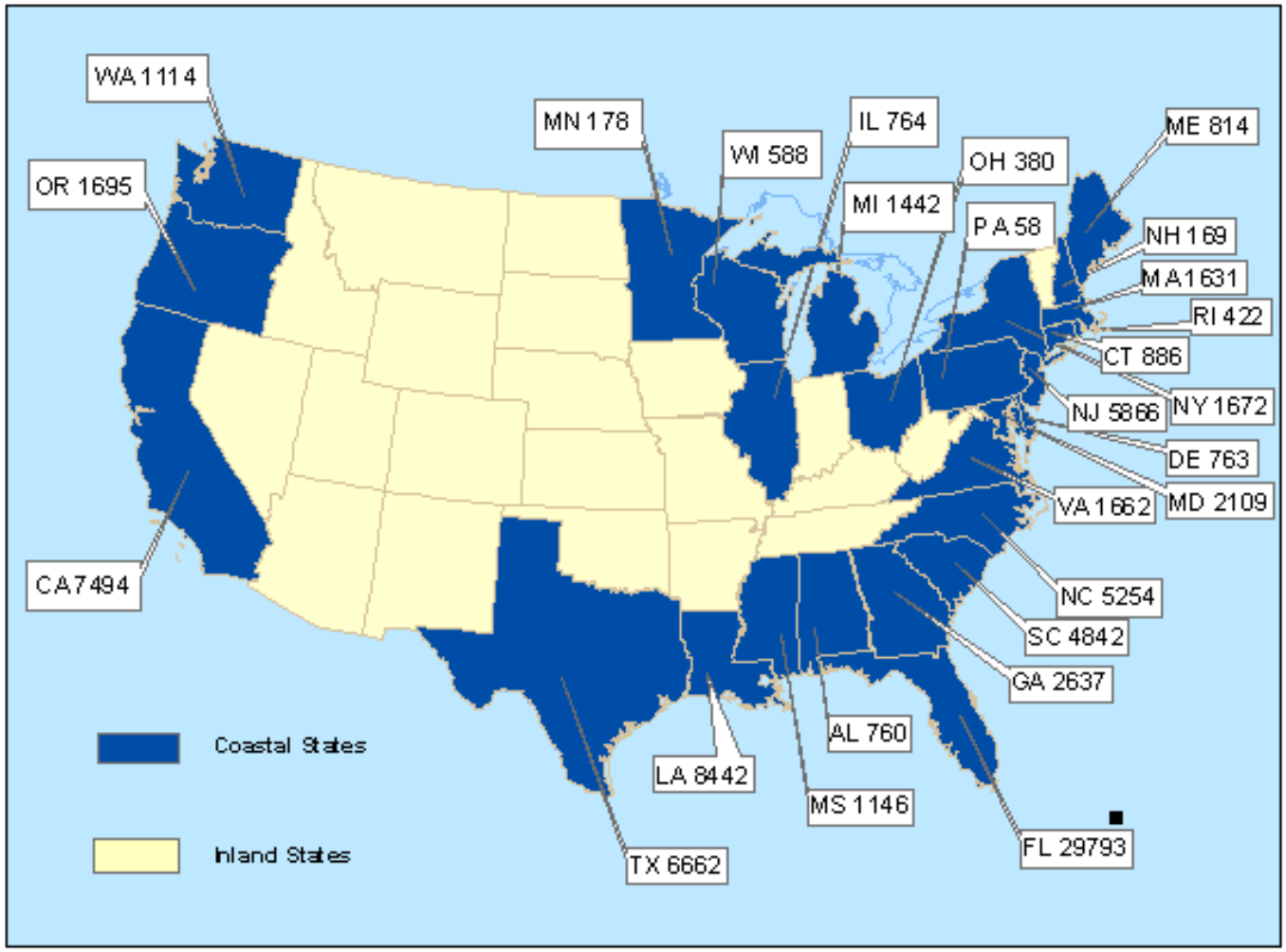
Transit (directional miles)
- 165,854 bus miles
- 4,407 commuter rail
- 1,596 heavy rail
- 1,097 light rail

Transit stations
- 1,153 commuter rail
- 1,023 heavy rail
- 723 light rail

Navigable channels
- 26,000 miles

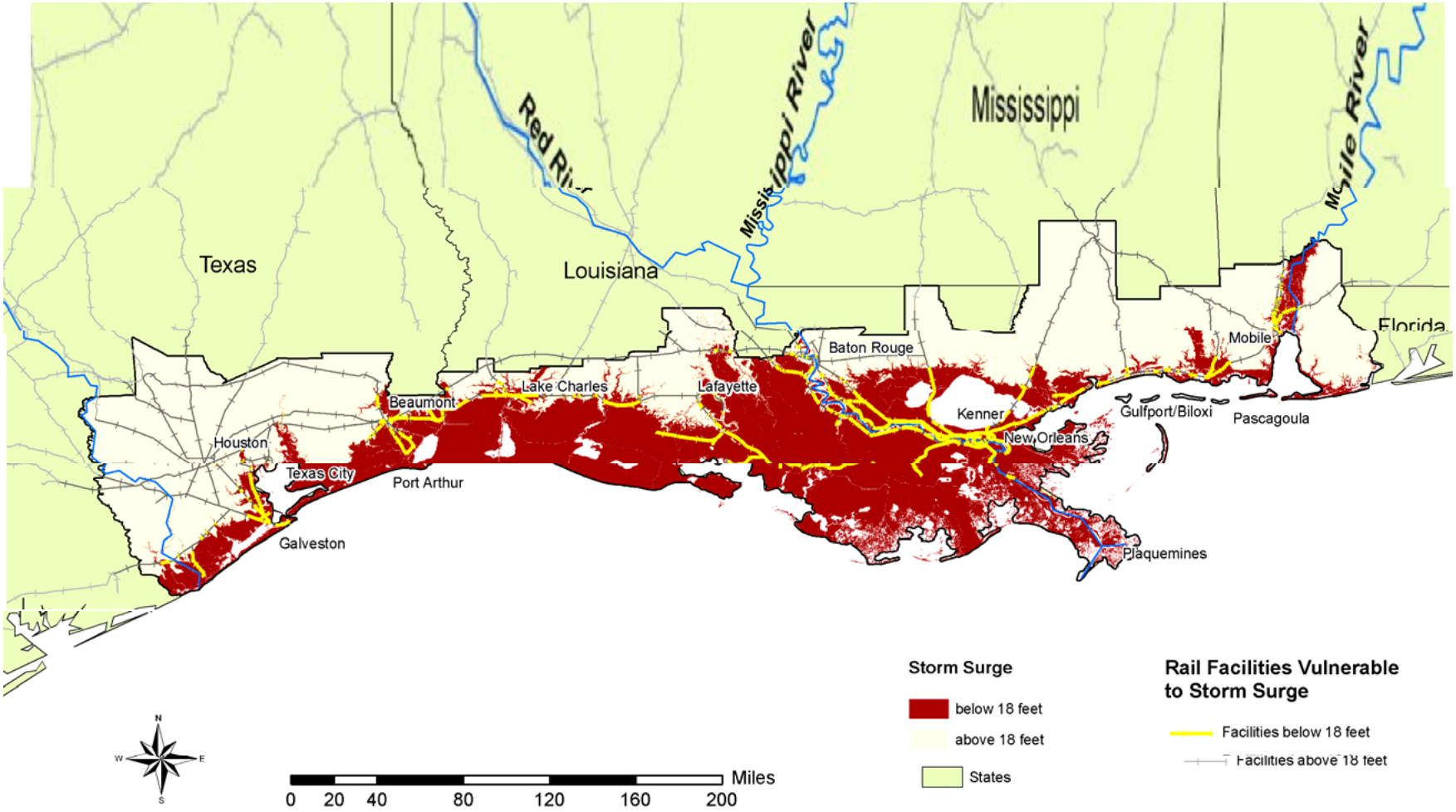
Commercial waterway facilities
- Great Lakes (600 deep/150 shallow draft)
- 2,320 Inland shallow draft
- 4,298 ocean deep/1,761 shallow draft
- 257 locks

Pipeline
- 60,043 miles crude
- 71,310 miles product
- 298,000 miles transmission
- 1,139,800 miles distribution



60,000 miles in FEMA coastal flood zone; 36,000 bridges within 15 nautical miles of coasts

Gulf Coast Study
Freight Rail Lines Vulnerable to Storm Surge of 18 feet



Transportation infrastructure that is vulnerable to 18 feet of storm surge includes:

- 51% of interstate miles, 56% of arterial miles, and most transit authorities
- 98% of port facilities vulnerable to surge and 100% to wind
- 33% of rail miles operated, 43% of freight facilities,
- 22 airports in the study area at or below 18 feet MSL
- Potentially significant damage to offshore facilities

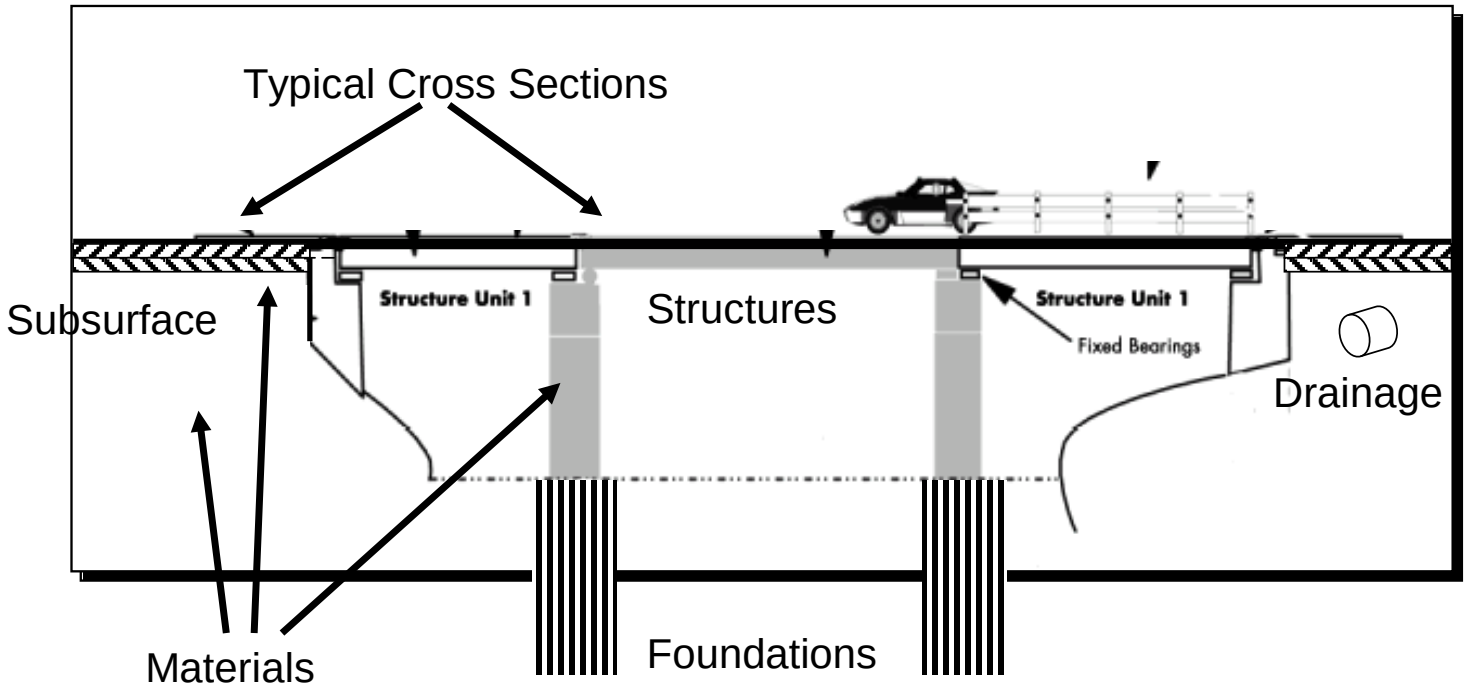
Environmental Factor	Facility	Possible Effect	Cause	Formula #
Rainfall intensity /frequency increase	Roadway foundation	Foundation weakening	Saturation	300, 301
			Erosion	
			Groundwater elevation increase	
		Foundation and roadway loss	Flooded culvert or bridge failure	
	Roadway pavement	Surface deterioration	Base and sub-base saturation	403, 404, 405, 406
		Surface loss	Flooded culvert failure	100-106
	Roadside slopes	Slope failure	Erosion	302
			Soil saturation	302
	Roadside planting	Species growth	Hydration	
	Bridge- water crossing	Structural damage	Scour	100-106
			Water load	202
			Soils pressure change	

Keller, Jake A.; Armstrong, Amit; Flood, Michael; Meyer, Michael D., AN APPROACH TO ADDRESSING THE IMPACTS OF CLIMATE VARIABILITY ON ROADWAY AND BRIDGE DESIGN, Paper presented at the Annual Meeting of the Transportation Research Board, Jan. 2011.

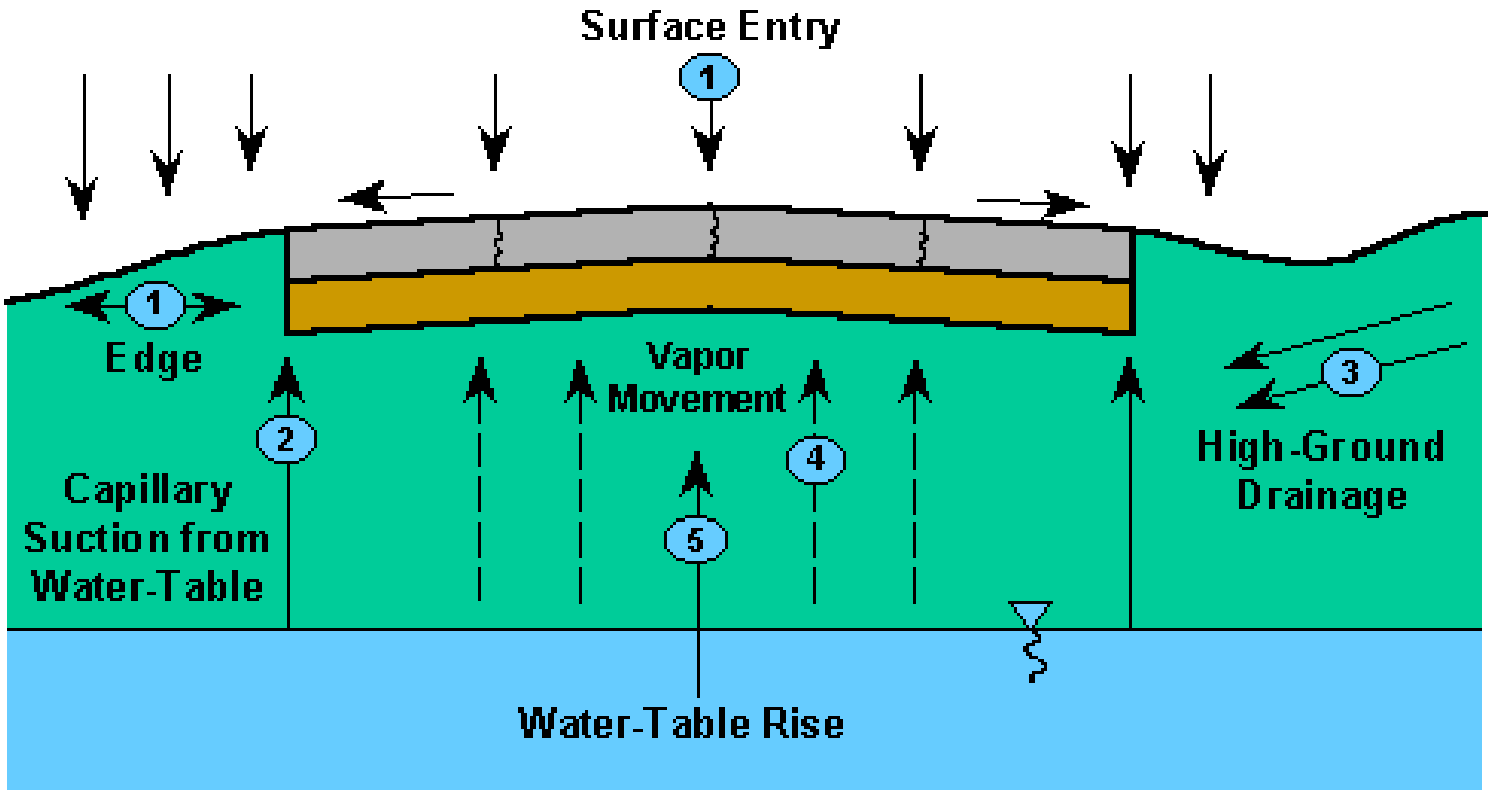
Environmental Factor	Facility	Possible Effect	Cause	Formula #
Rainfall intensity /frequency increase	Bridge—Roadway crossing	Structural damage	Soils pressure change	
			Erosion	
	Culvert	Structural damage	Erosion	
		Failure	Floodwater erosion	
			Buoyancy	
	Storm sewer	Surcharge	High runoff rate	100
	Open channel	Flooding	High runoff rate	100-108
			Soil saturation	302
		Failure	Erosion from high runoff rate and/or volume	101-108
		Stream mitigation	Erosion from high runoff rate and/or volume	100-108

Similar information for rainfall decrease…..

A Typical Infrastructure Segment

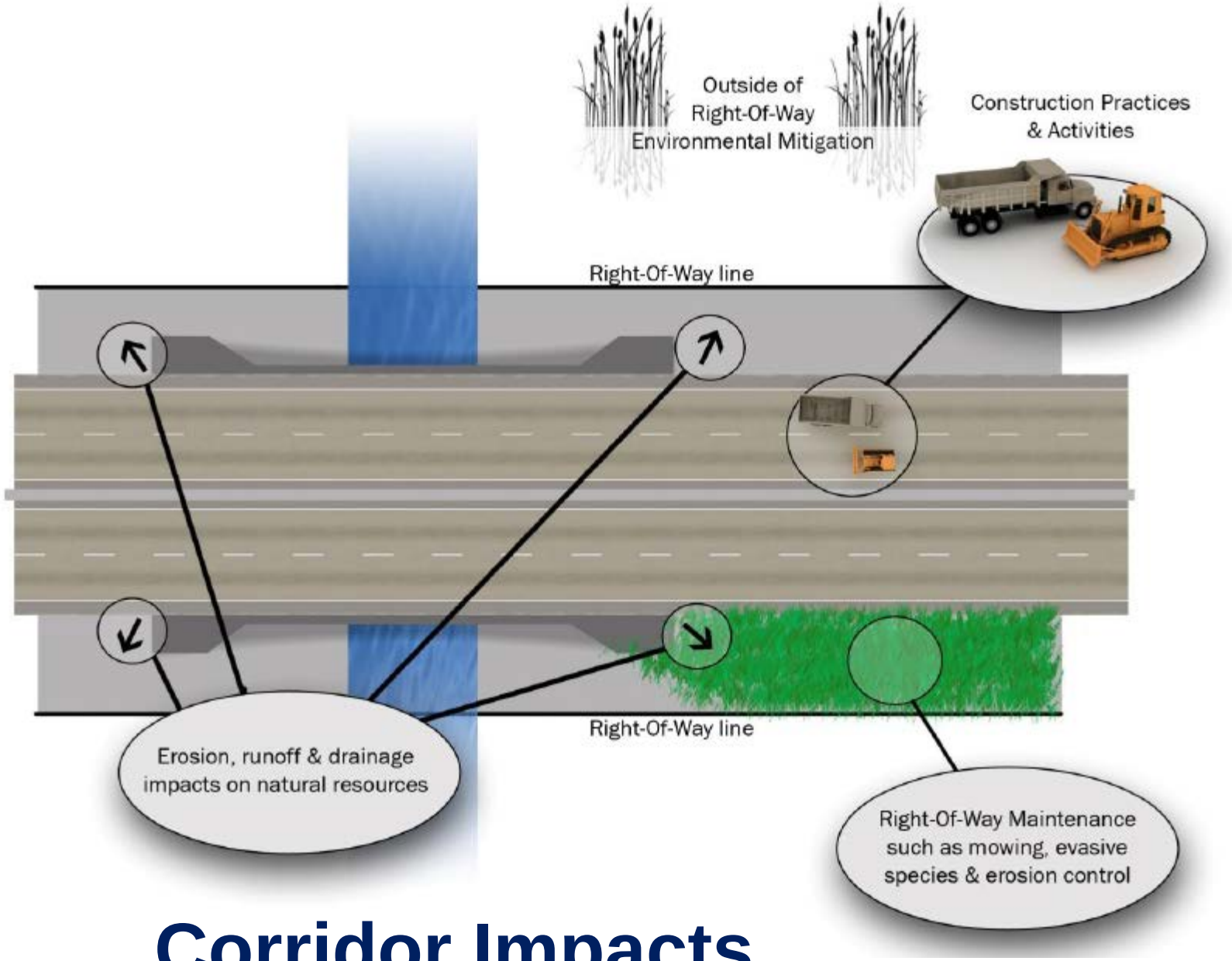


Water, for example, ……..

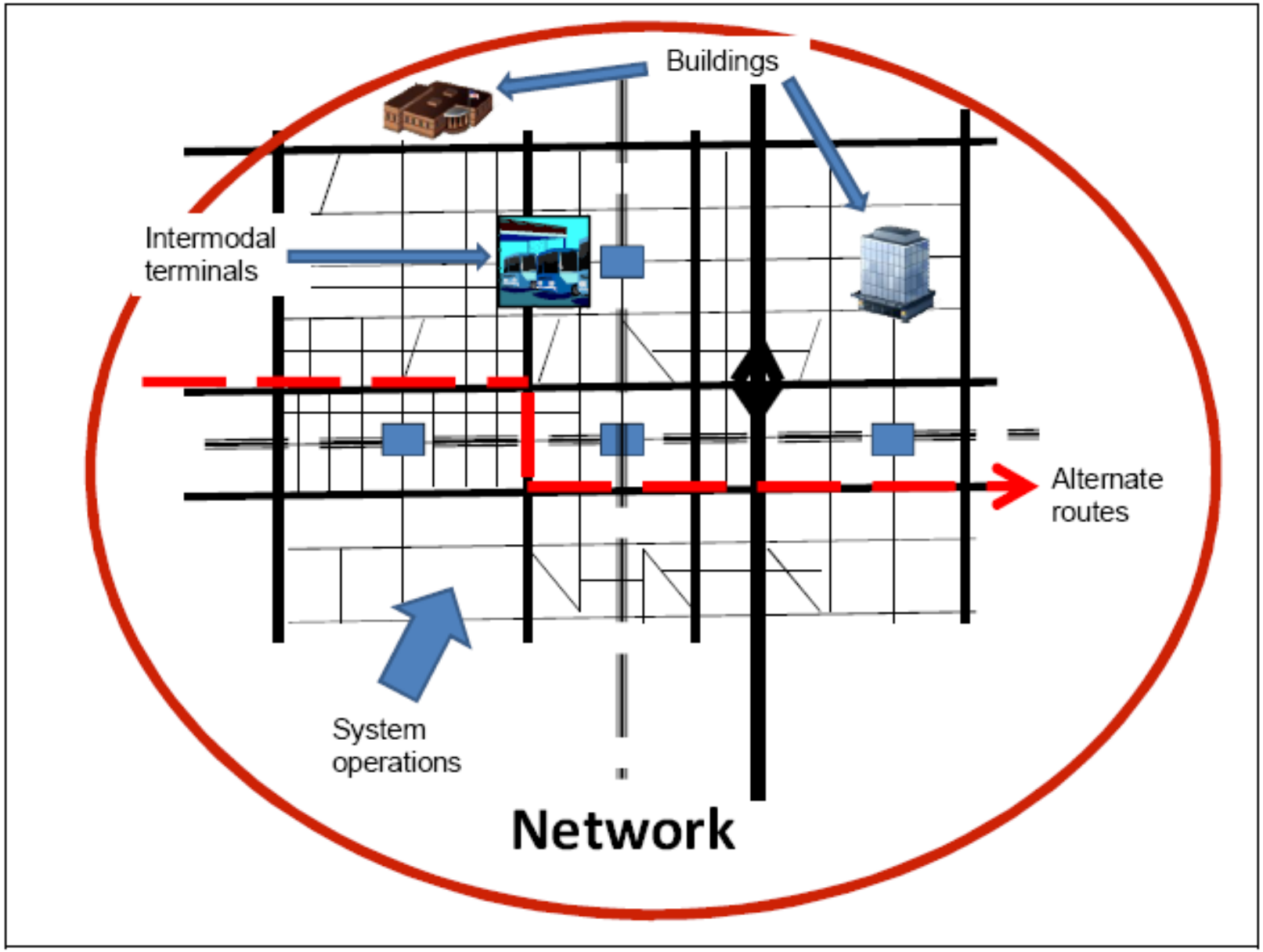


Critical Components of Infrastructure Design

1. Subsurface conditions
2. Materials specifications
3. Cross sections/standard dimensions
4. Drainage and erosion
5. Structures
6. Location engineering

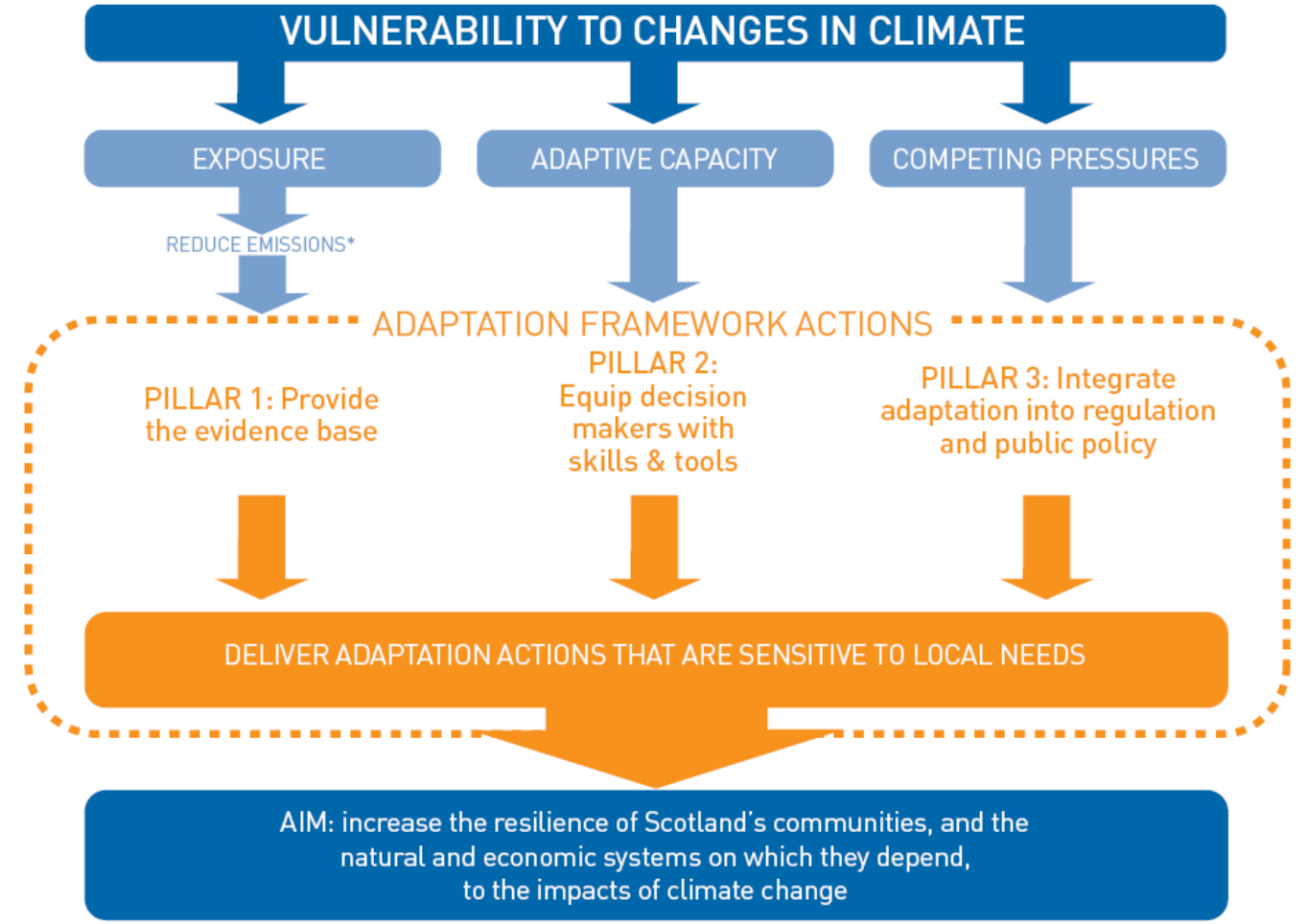


Corridor Impacts


Buildings
Intermodal terminals
Alternate routes
System operations
Network

Scotland's Climate Adaptation Planning Framework

DIAGRAM 3: MODEL FOR ADAPTING TO CLIMATE CHANGE IN SCOTLAND

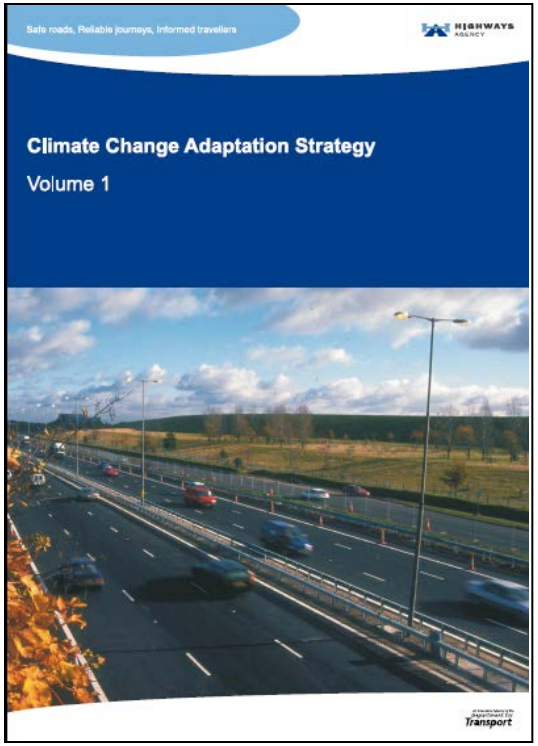


* Scotland's Climate Change Adaptation Framework will focus on achieving climate change adaptation but opportunities to reduce emissions will also be sought.

Work Program for Climate Adaptation Strategy in Scotland

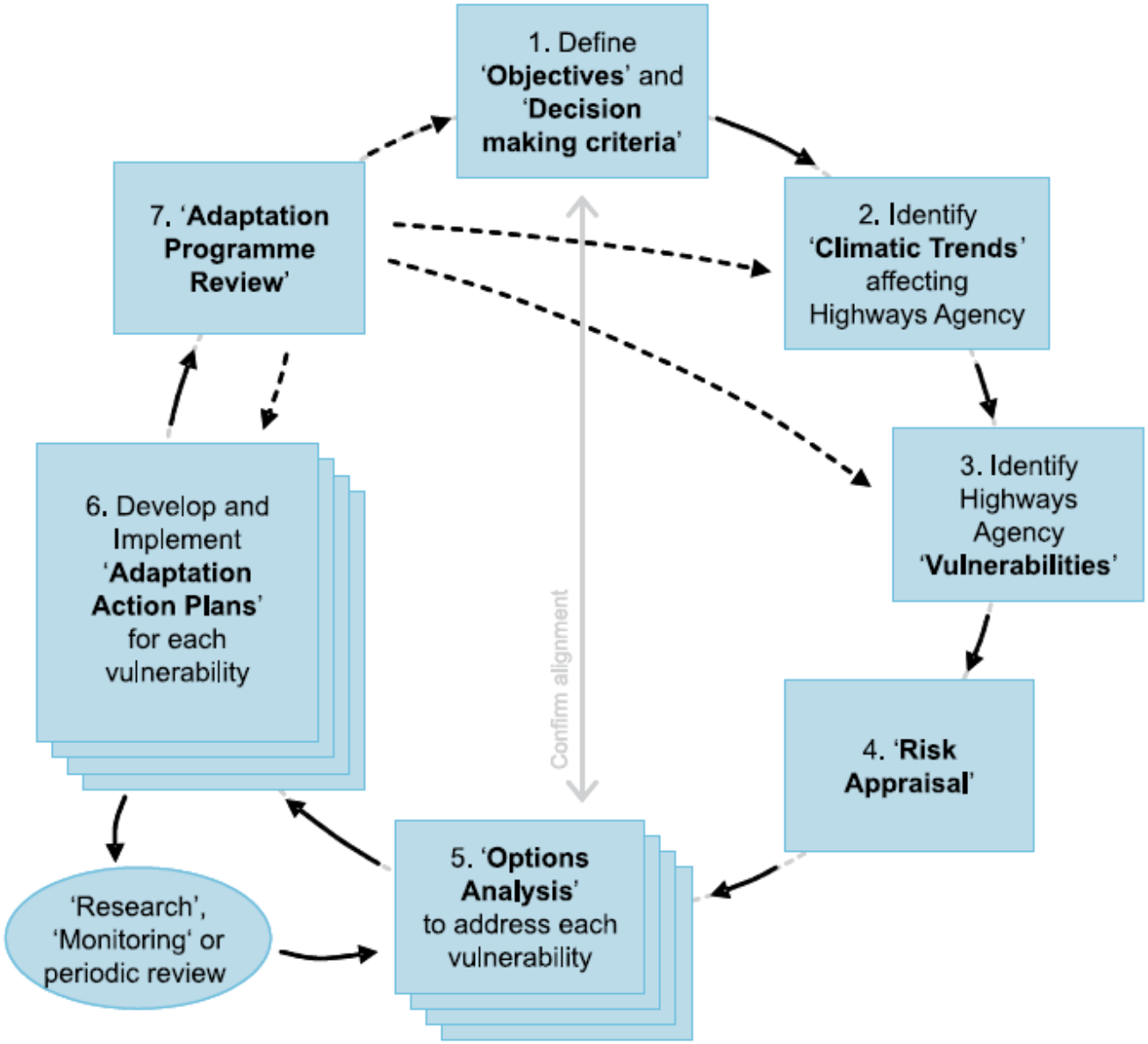
Source: http://www.scotland.gov.uk/Publications/2009/12/08131211/1

Understand the consequences of a changing climate			
1	Gather more detailed information on the susceptibility of transport networks to the effects of climate change and impact of severe weather. This will guide contingency planning for the types of incidents which cause significant widespread disruption.	Transport Scotland (TS)	Ongoing
2	Assess future adaptation requirements for road and rail networks in light of the UK Climate Projections 2009.	TS	2010 and then ongoing
Equip decision makers with skills and tools			
3	Develop the role of Transport Emergency Planning and Consequence Management.	TS	Ongoing
4	Scottish Road Network Climate Change Study: Take forward the program of design, research and policy initiatives that were identified in the study.	TS	2010 and then ongoing
5	Landslides Study: Implement recommendations from the Study.	TS and key stakeholders	2010 - 2012
6	2007 TRL Rockslope Risk Assessment: Implement recommendations of this Assessment.	TS	Ongoing
Integrate adaptation into public policy and regulation			
7	Scotland's National Transport Strategy: Review the Strategy, including the consideration of strategic climate change adaptation issues.	Scotland Government (SG)	2010
8	Scottish Ferries Review: This Review will inform the Scottish Government's long term strategy for lifeline ferry services and influence the next round of procurement of ferry services and supporting infrastructure.	SG	Public consultation on Review in 2010
9	High Wind Strategy: Implement the Strategy for the management of the impact of high winds on road networks	TS	Ongoing

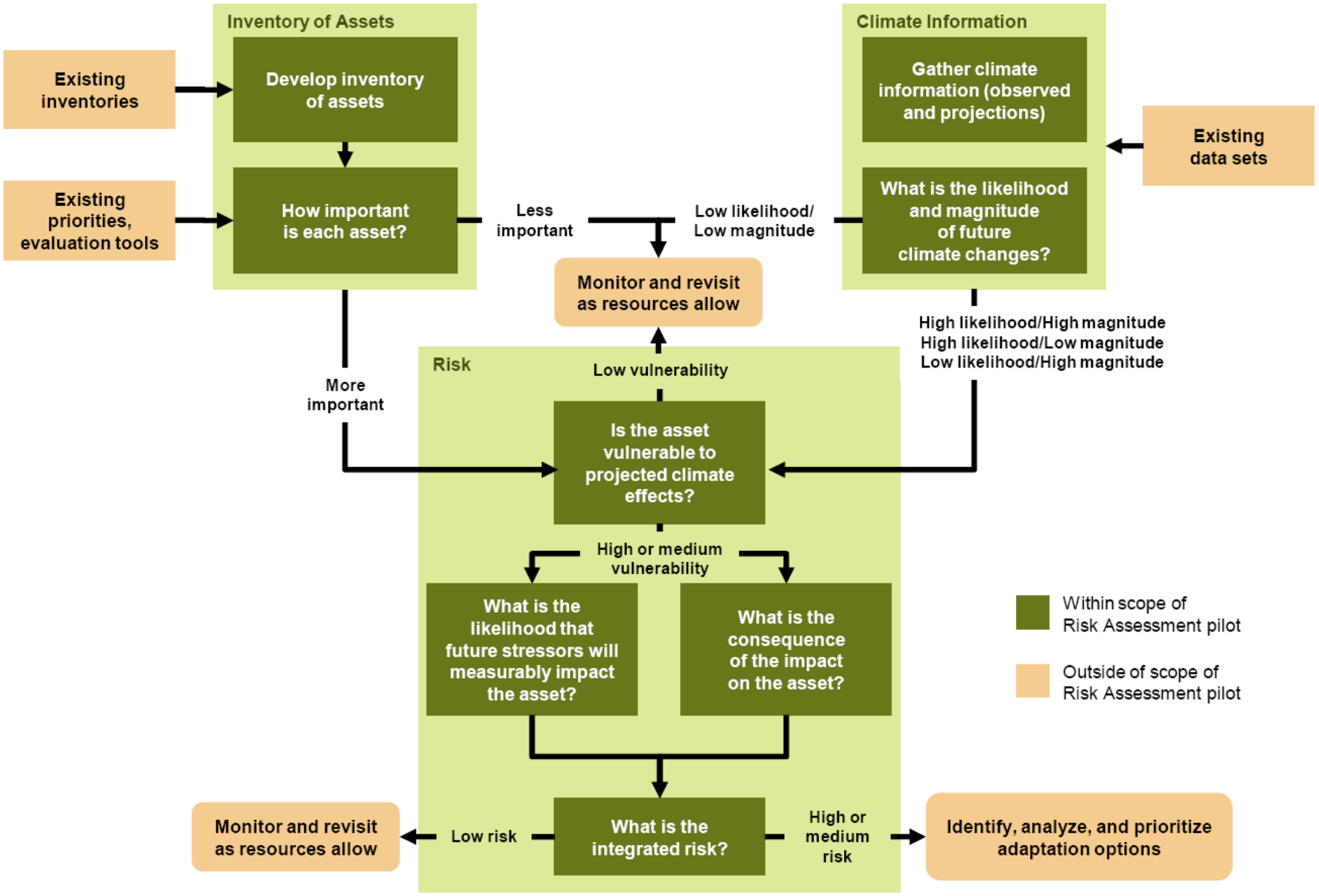


Primary Climatic Changes
Increase in average temperatures
Increase in maximum temperatures
Increase in winter rainfall
Reduction in summer rainfall
More extreme rainfall events
Reduction in snowfall
Increased wind speed for worst gales
Sea level rise

Highways Agency Adaptation Planning Process

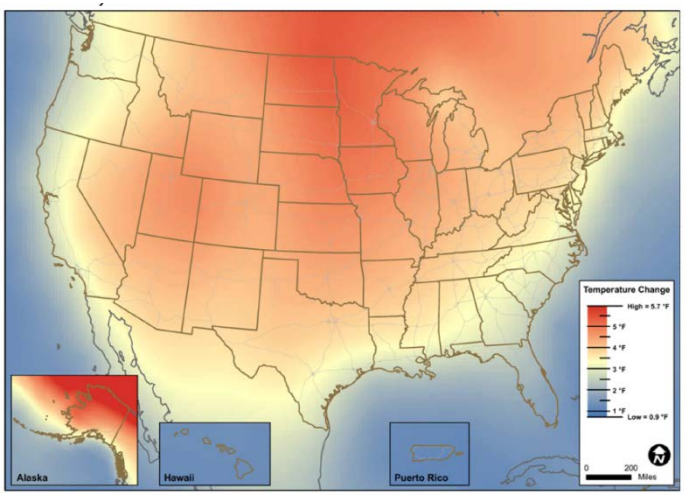


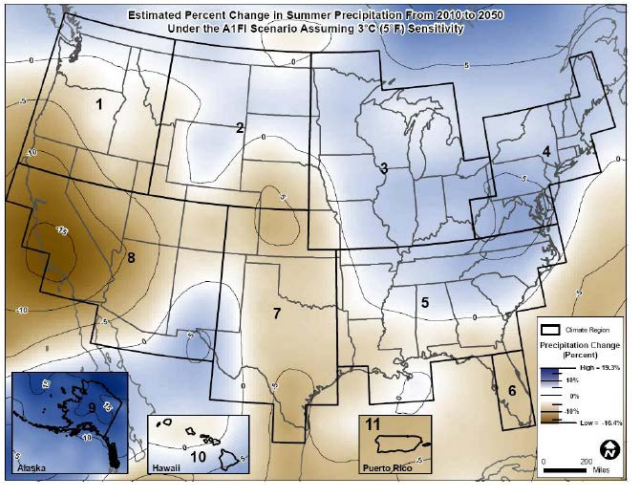
FHWA's Climate Adaptation Model



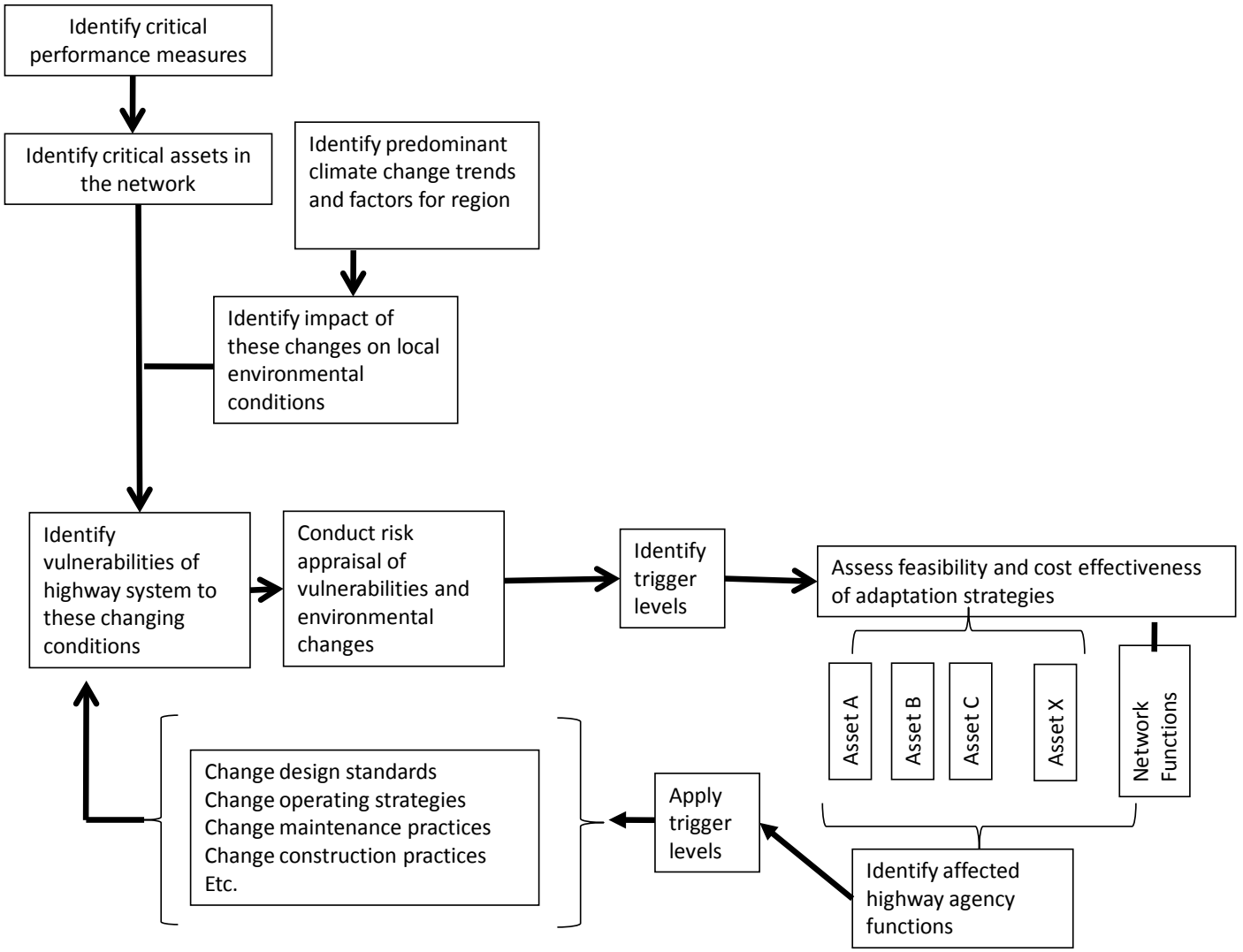
NCHRP 20-83(5)

Climate Change and the Highway System: Impacts and Adaptation Approaches





Proposed Diagnostic Framework for Climate Adaptation Planning – NCHRP 20-83(5)



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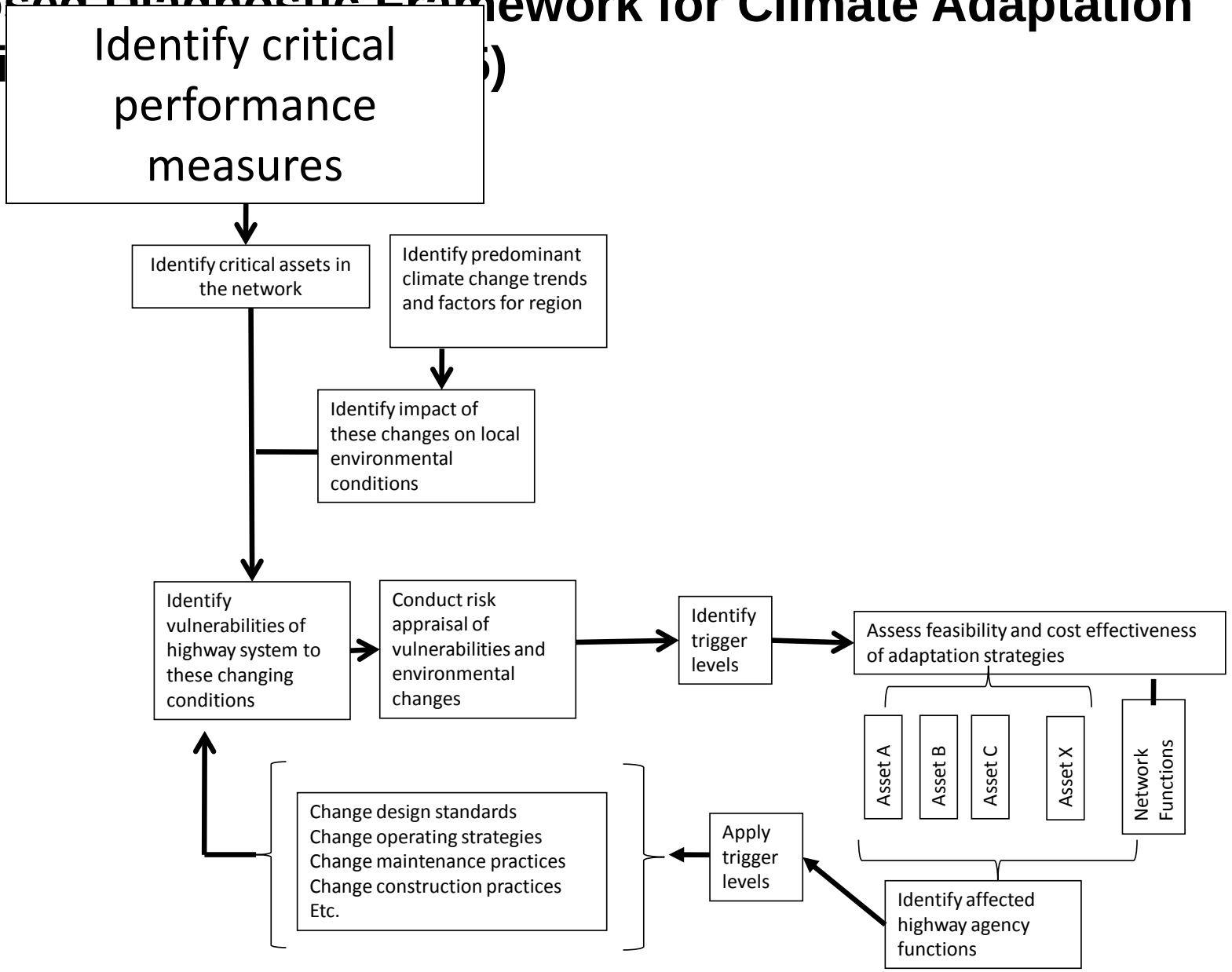

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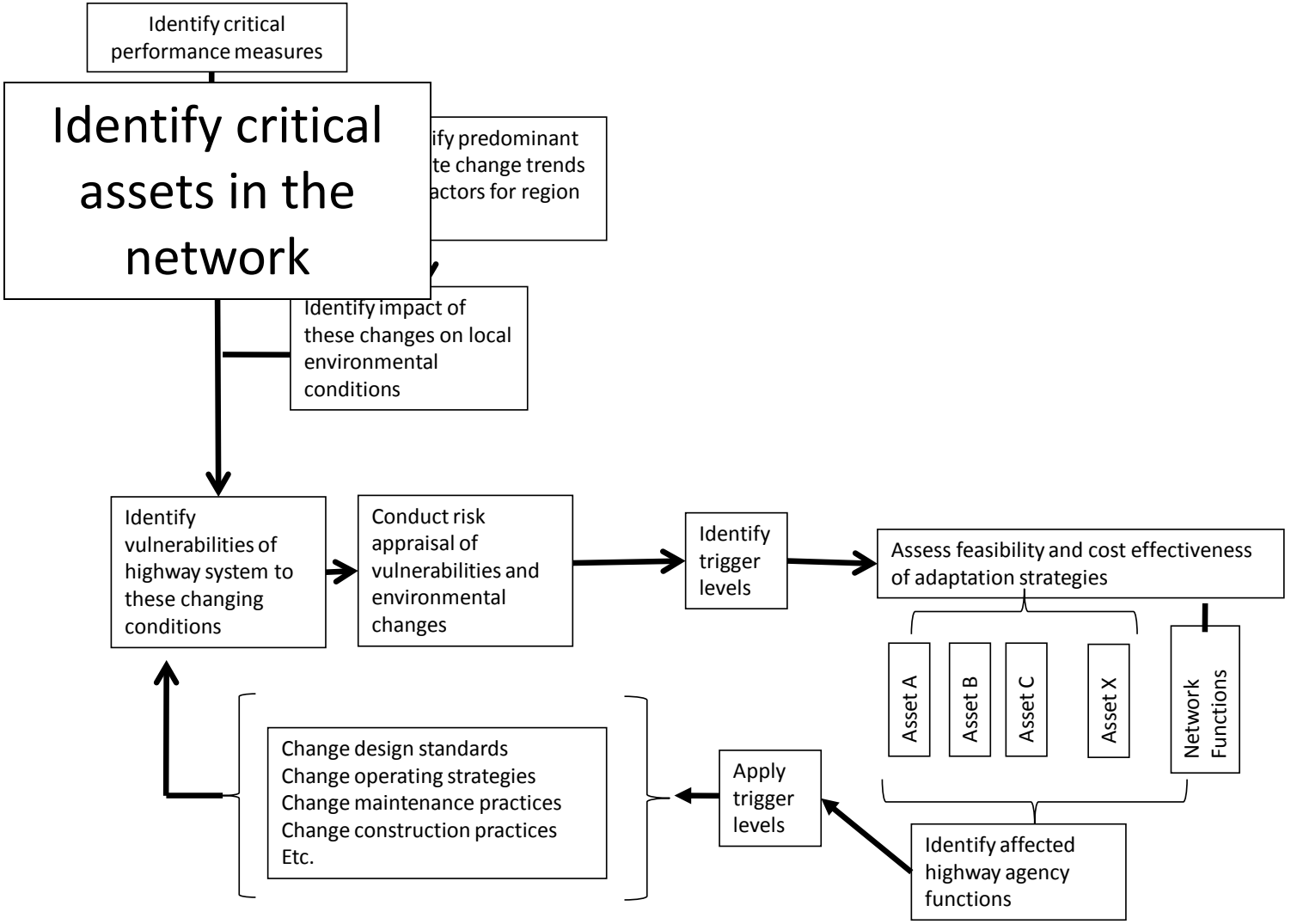

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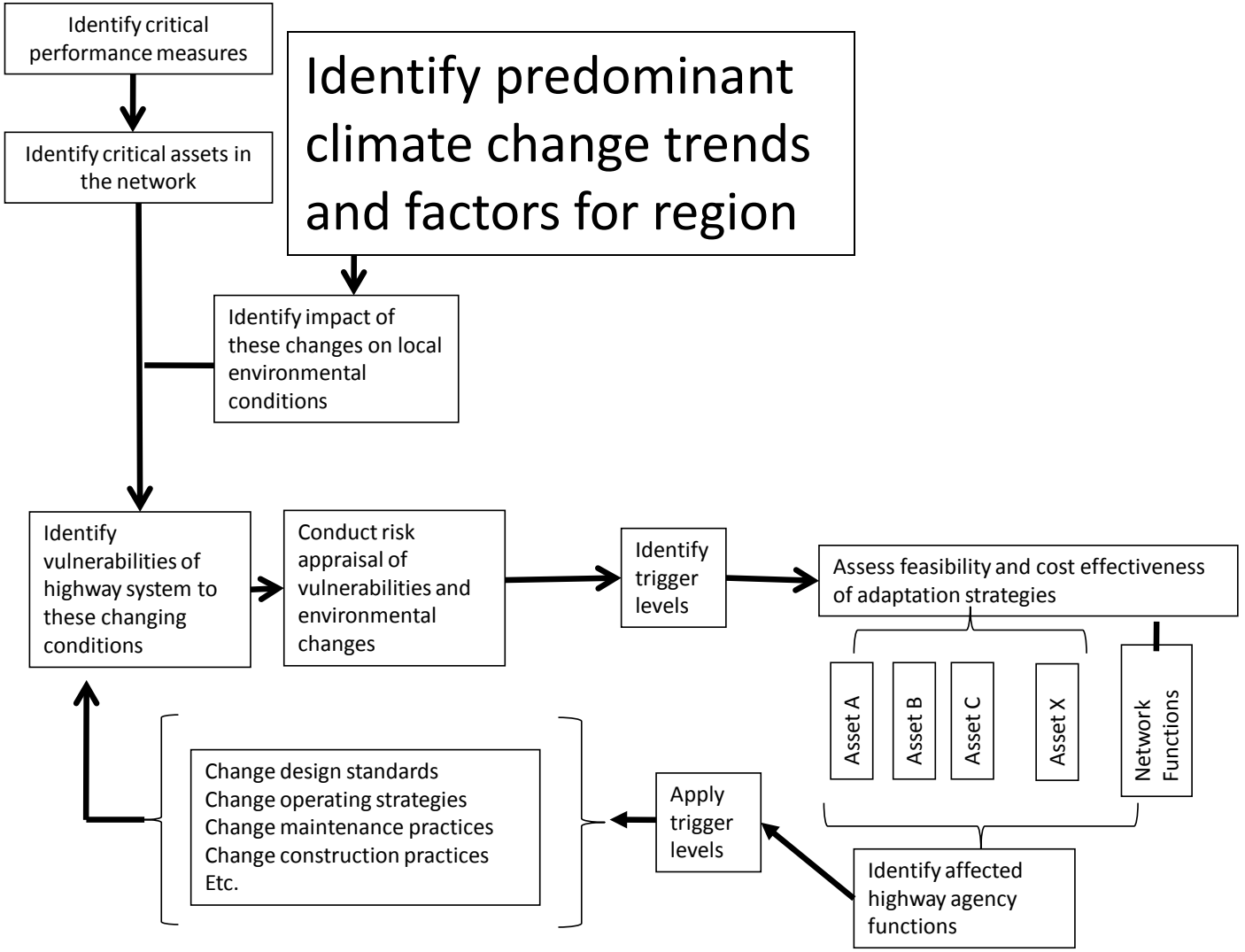

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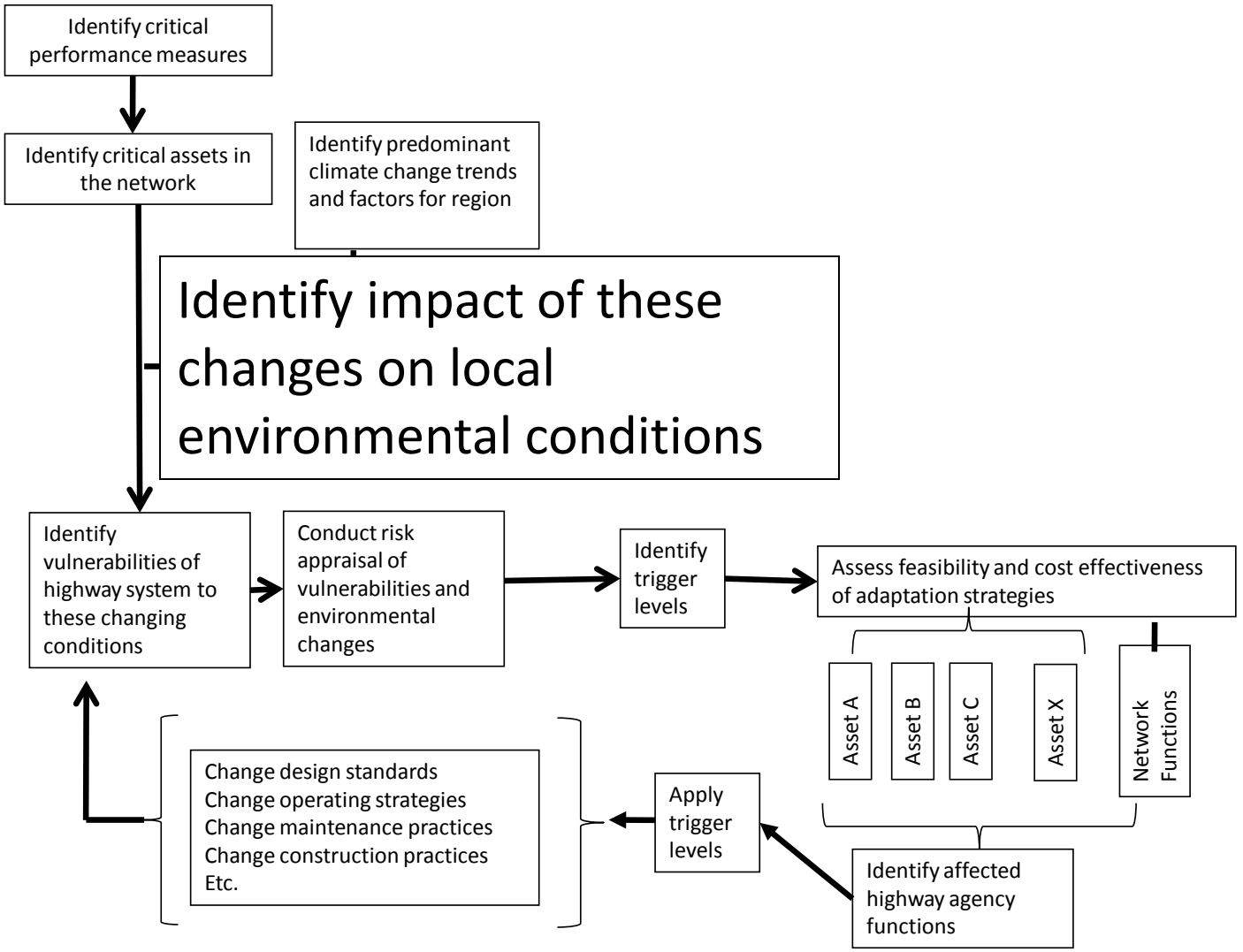

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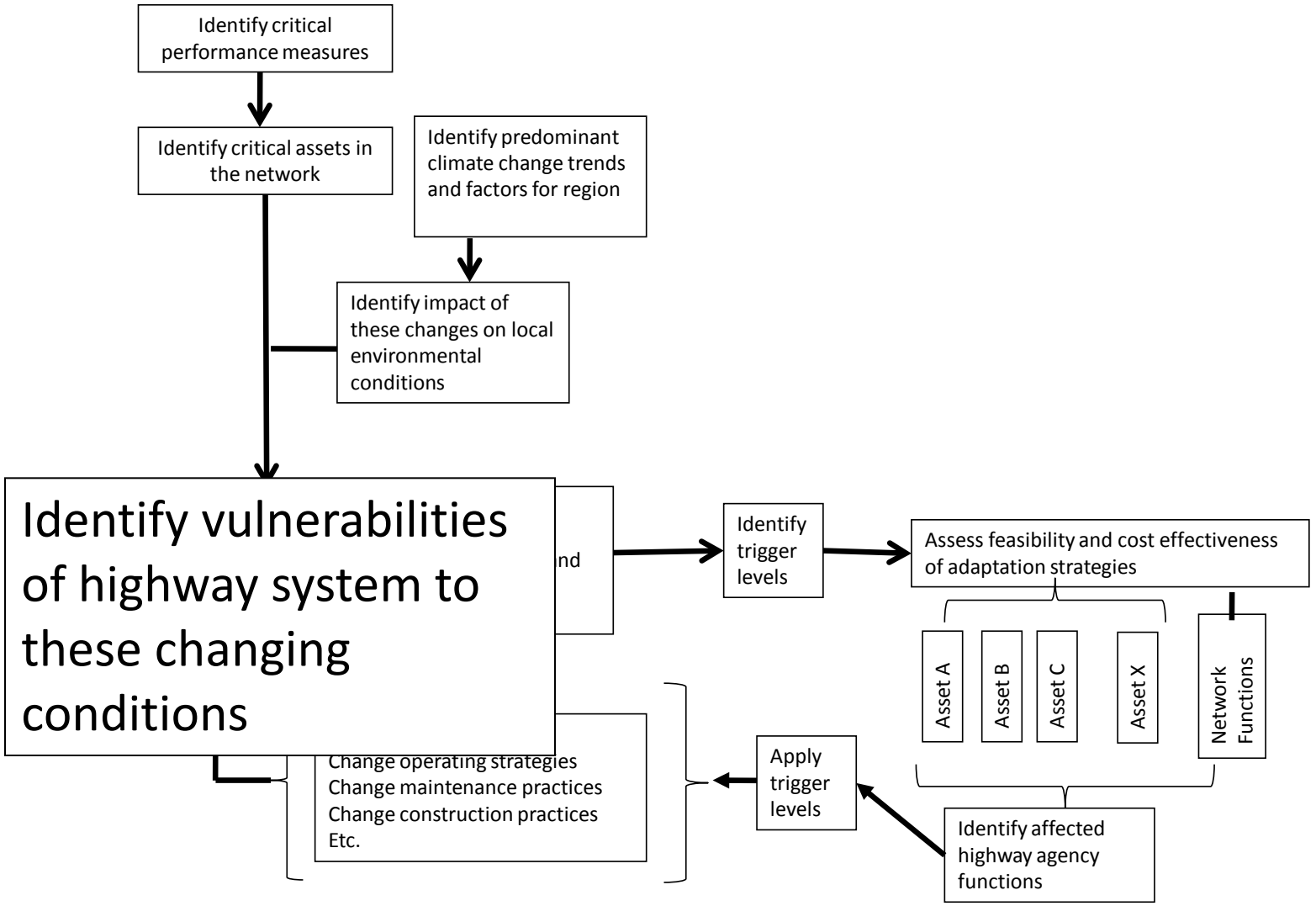

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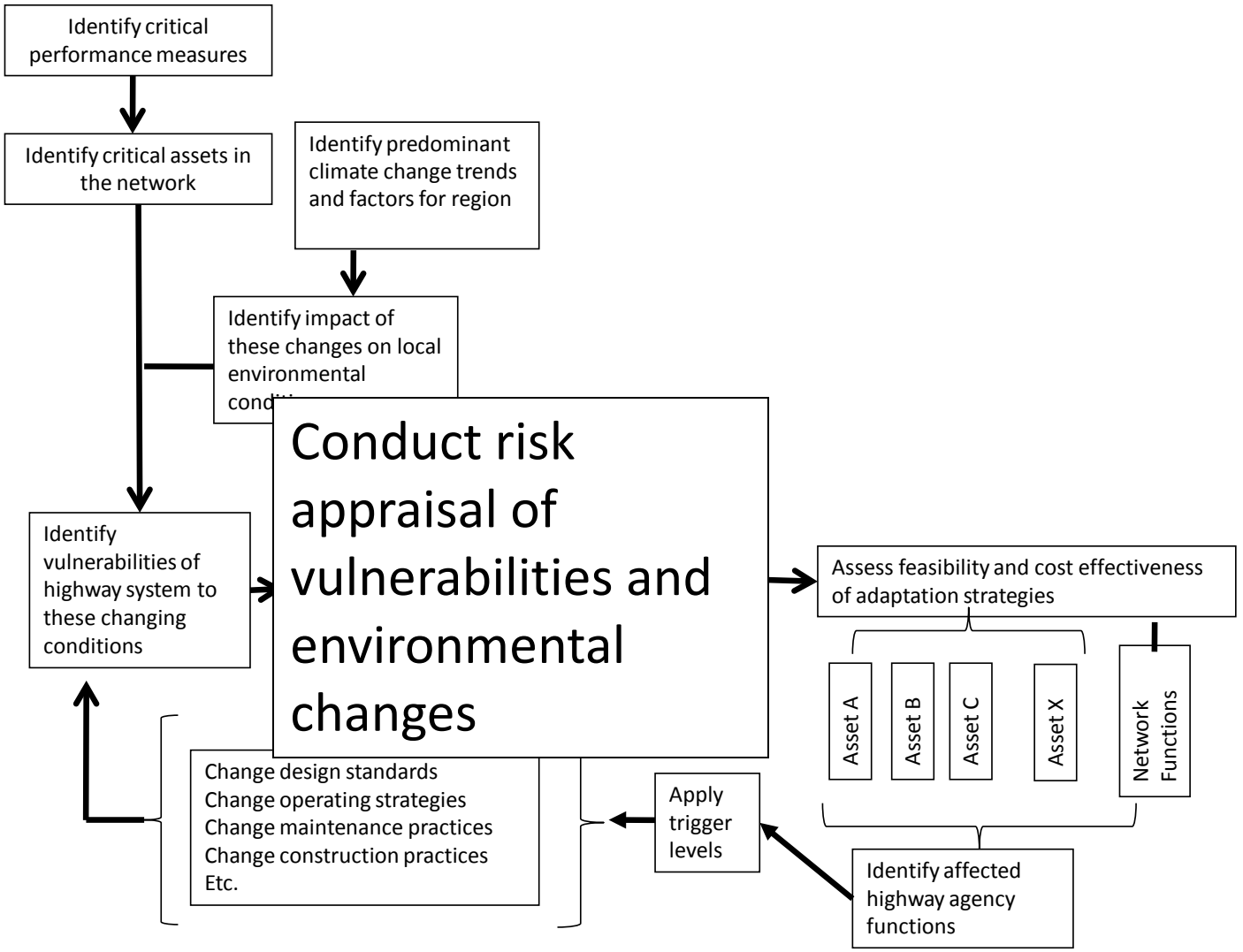

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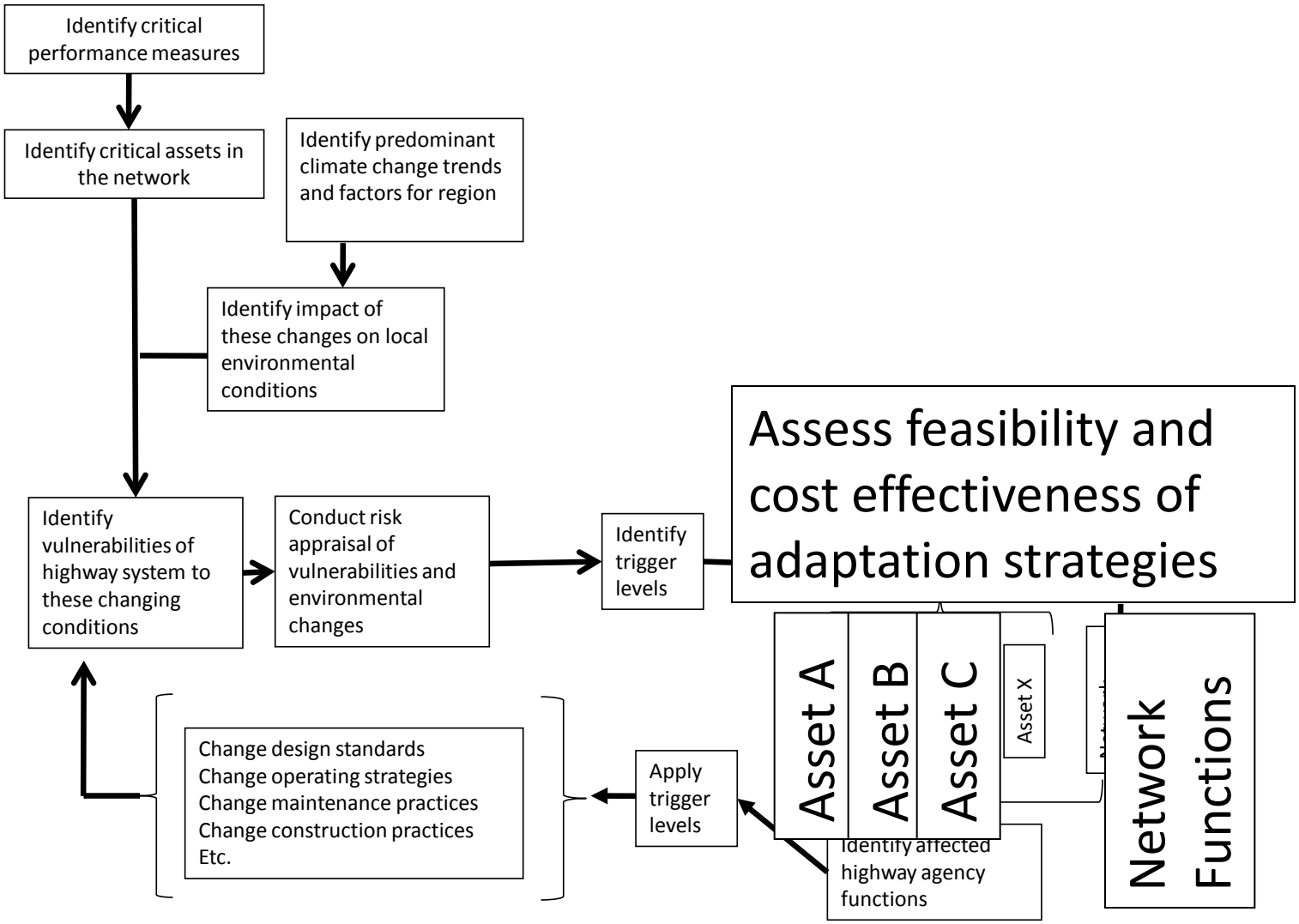

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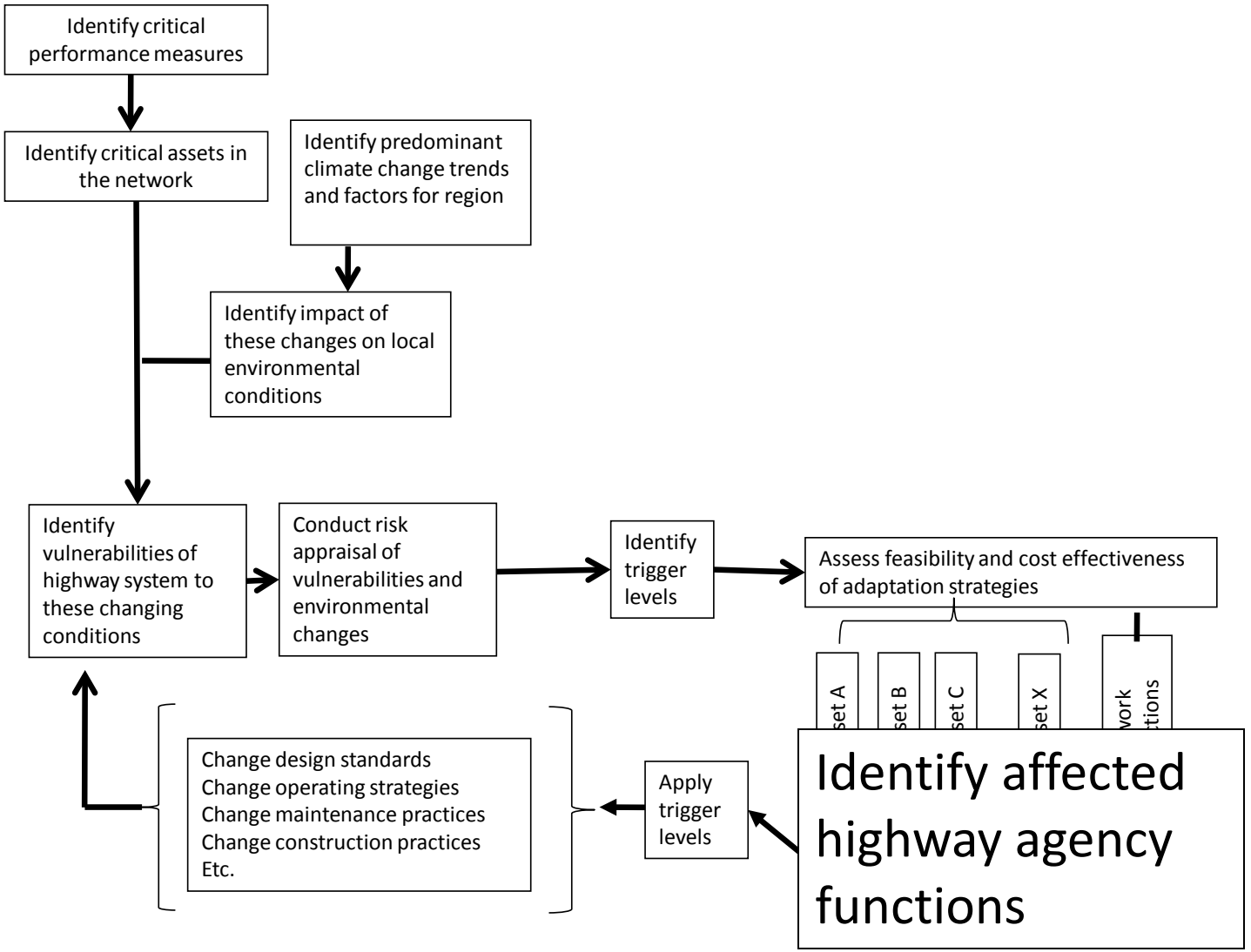

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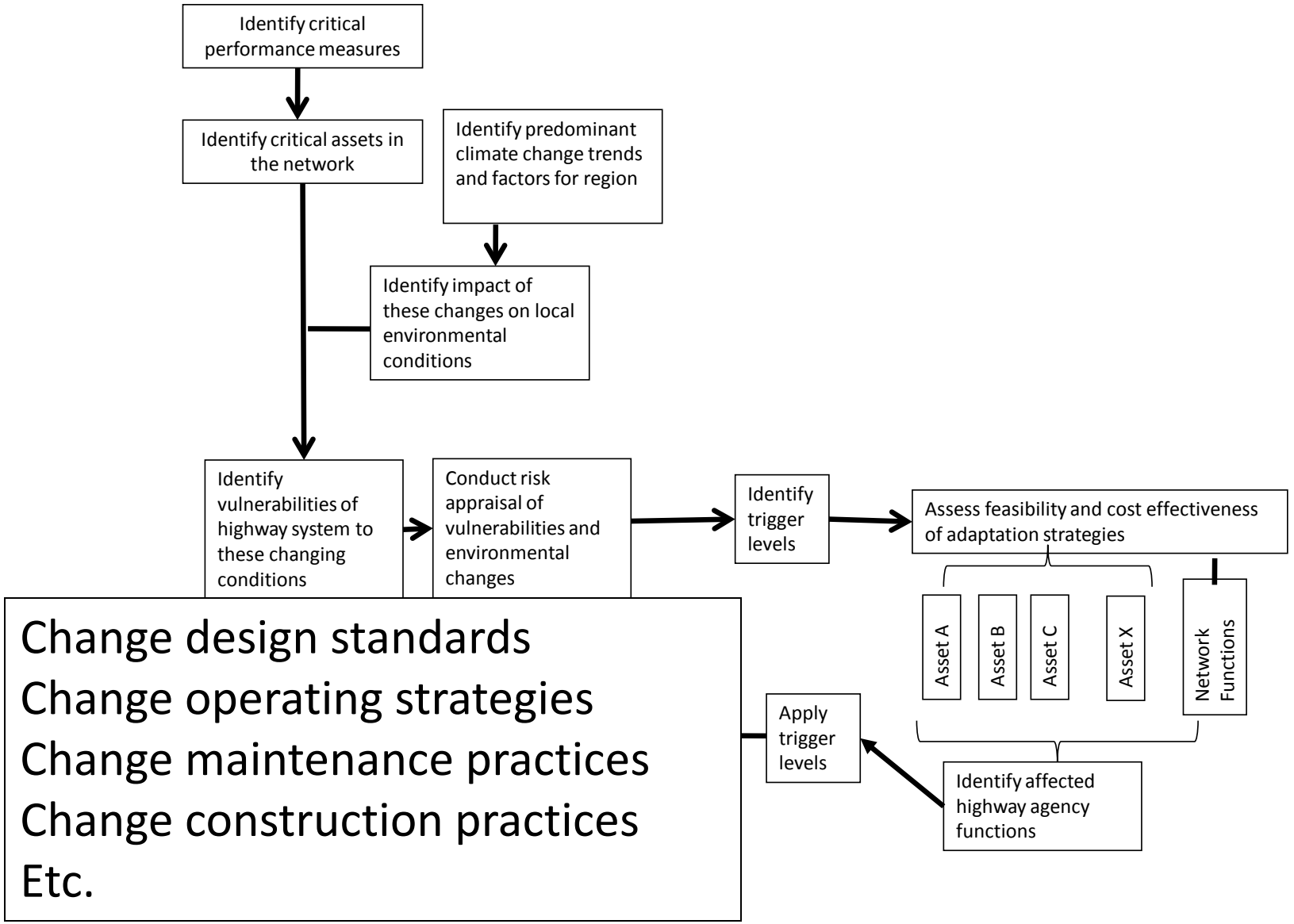

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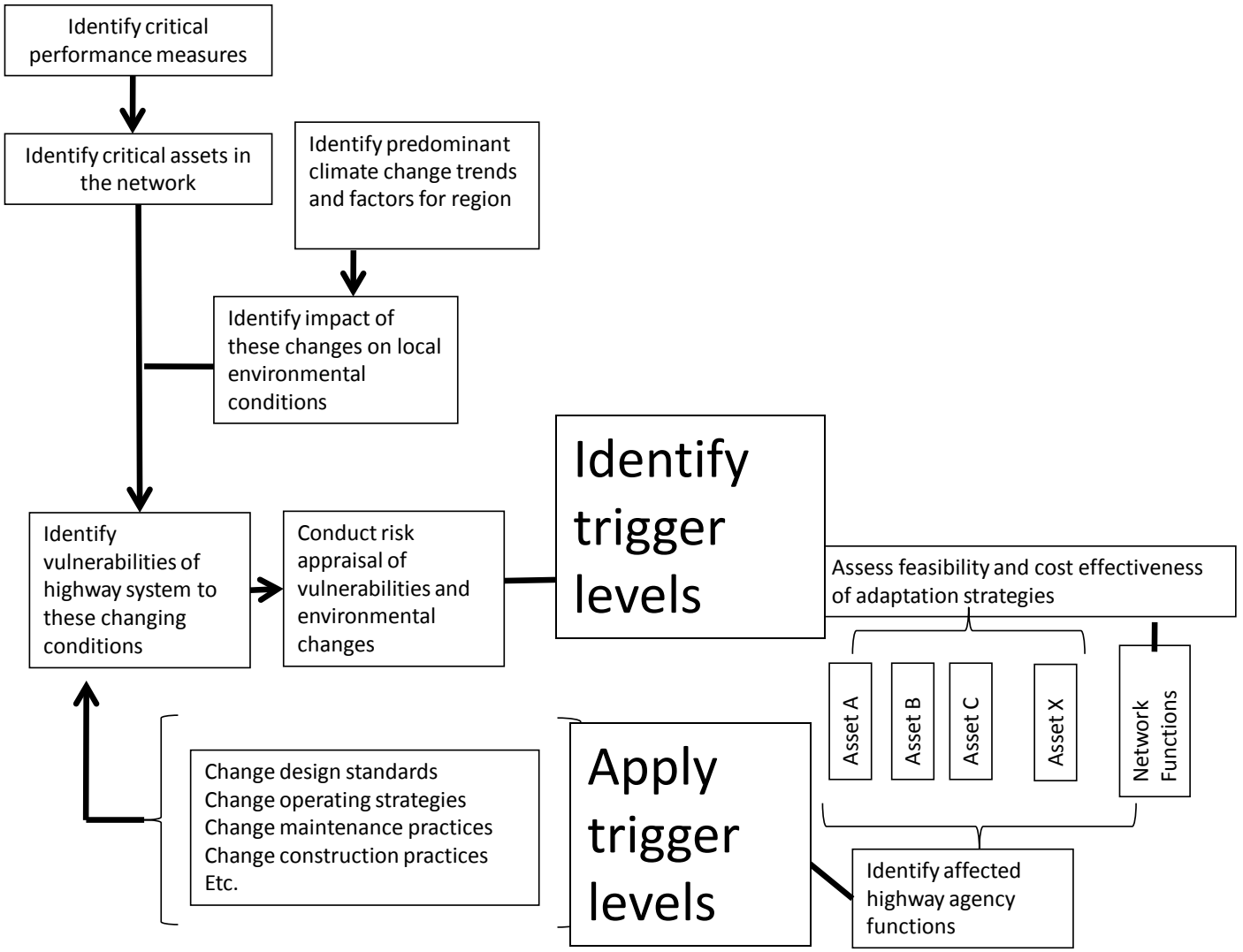

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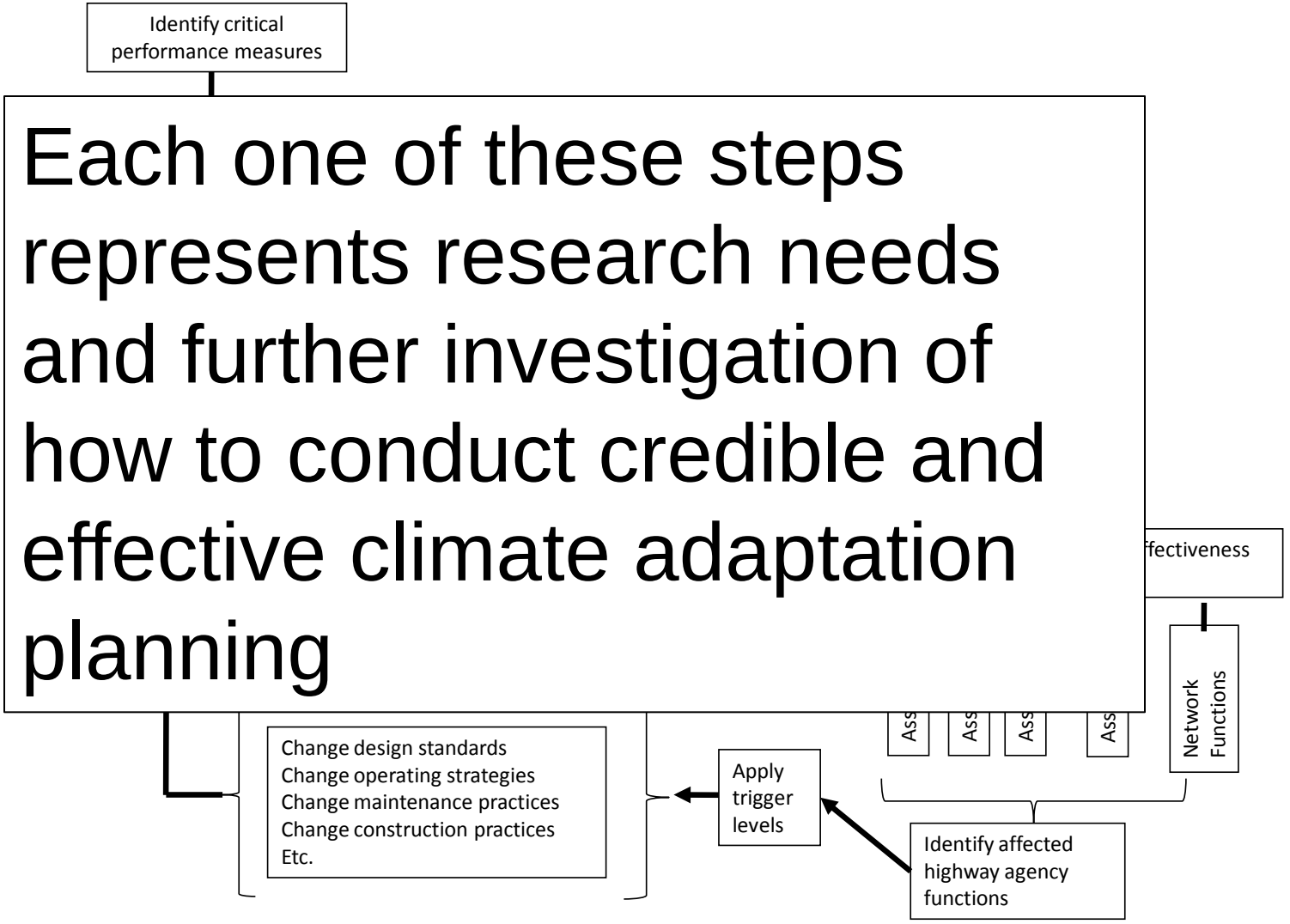

Importantly, climate adaptation is not just design oriented….it also includes operations, maintenance, construction, location engineering, land use and public policy (just to name a few).

How urgent is climate adaptation, and what is involved in adaptation?

How difficult and expensive will adaptation be for the transport sector? Can adaptation in this case be handled through normal transportation engineering and finance mechanisms, or does this need broader and higher attention?

Does the ability to adapt to a changing climate preclude the need to mitigate GHG emissions?