Imperial College London

Adaptation of Transportaiton Infrastructure to Climate Change from a Risk Based Policy Perspective

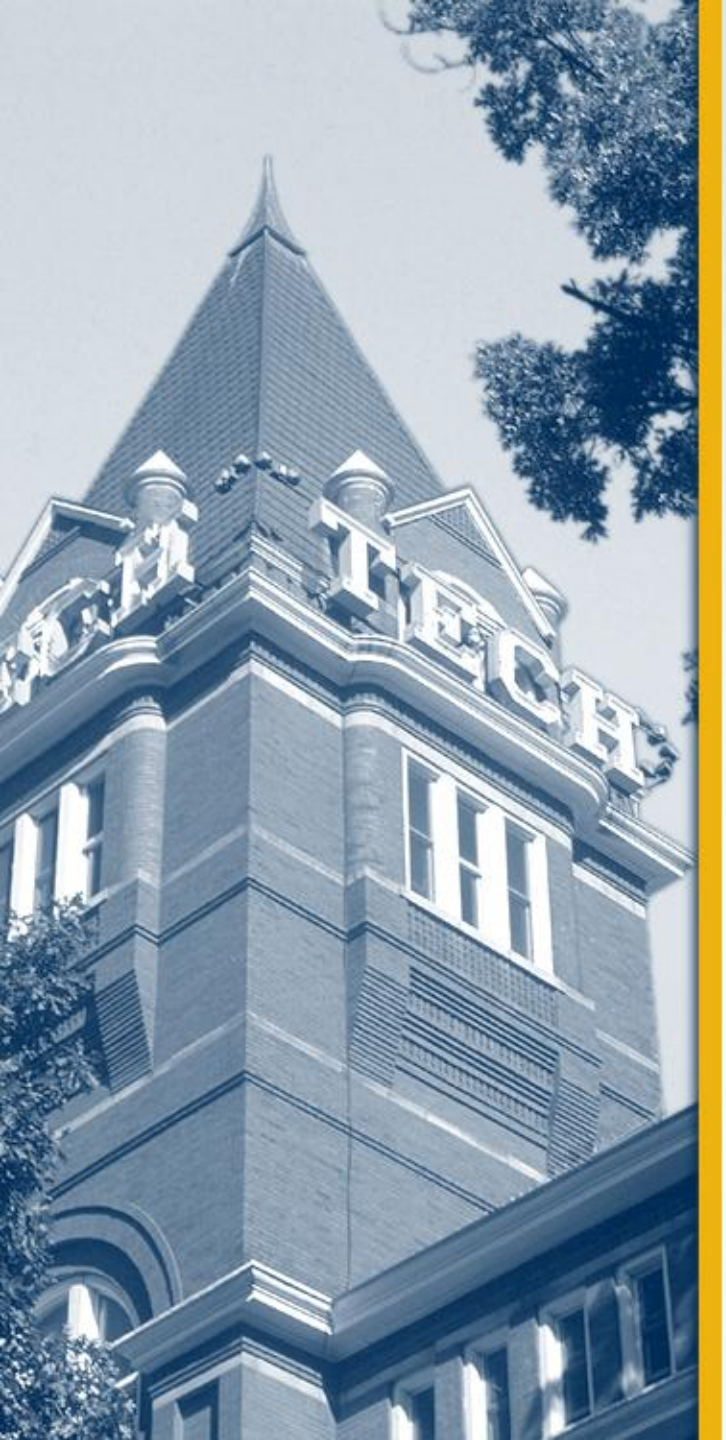
Mr. Tom Wall, Georgia Institute of Technology

Wednesday, 19 January 2011 - 16:00

Location: Room 610, Skempton (Civil Eng.) Bldg, Imperial College London

Abstract
Thomas Wall will discuss the need to adapt transportation infrastructure to meet the potential threats of climate change. This seminar will focus on the background motivation for adaptation, as well as general strategies to adapt to the potential impacts of climate change in light of current infrastructure management practices. Exemplary strategies discussed will include those developed in the UK, as well as those currently under development in the US.

Biography
Thomas Wall is a doctoral student in civil engineering at the Georgia Institute of Technology studying climate change adaptation as applied to transportation planning and infrastructure management. He holds an M.S. in civil engineering from Georgia Tech, as well as a B.S. in civil engineering from Oregon State University. Recently, Mr. Wall was awarded a Fulbright Scholarship to conduct climate change adaptation research at Imperial College London and the University of Amsterdam during the 2010-2011 academic year.



Climate Change and Risk: Adapting Transport Infrastructure to Future Climate Conditions

Thomas Wall

(Advisor: Dr. Michael D. Meyer)

Georgia Institute of Technology

January 19, 2011

Georgia Institute of Technology

Overview

- Climate change impacts to transport infrastructure
- Response options
- General guidance for adaptation and decision frameworks – the case for risk management
  - IPCC
  - United Kingdom - UKCIP & Highways Agency
  - Australia/NZ
- Work in development at Georgia Tech
  - Adaptation framework
  - Prioritization of adaptations
- Key questions/moving forward

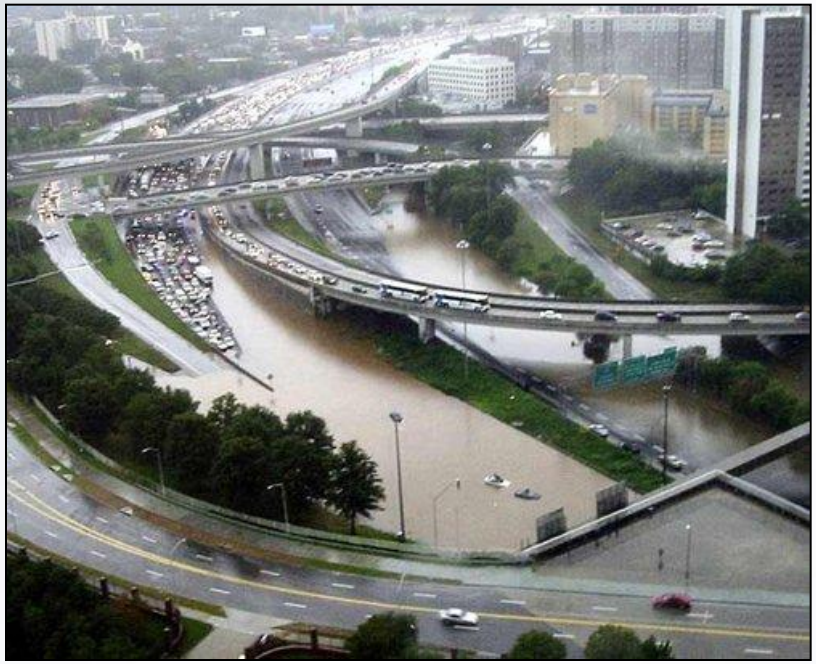
Climate Change Types and Magnitude

- Observed *changes* in climate:
  - Increased average surface temperature
  - Increased average sea level
  - Decreased Arctic/polar ice

- Observed *effects* of climate change:
  - Increase in frequency of hot days
  - Decrease in frequency of cold days
  - Increase in frequency of heat waves over most land areas
  - Increased frequency of high intensity storms/rainfall

Impacts on transportation infrastructure, 1

- Inland flooding and increased storm water runoff
  - Atlanta flodding, USGS: greater intensity than 500 year storm



Source: AJC, 2009

Source: AJC, 2009

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Impacts on transportation infrastructure, 2

- Coastal flooding and extreme high sea-level
  - Hurricane Katrina (2005)
- Increased average surface temperatures
  - Permafrost melt in Alaska

Source: SUNY-Buffalo (MCEER), 2010

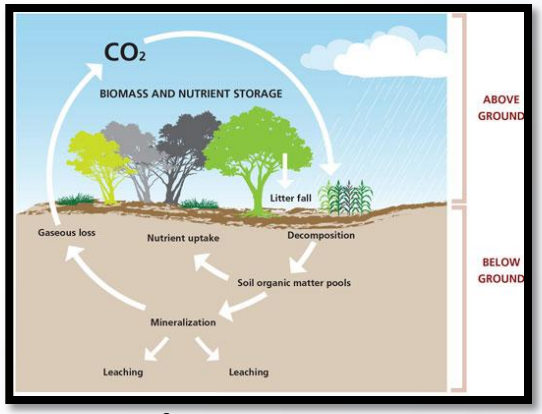
Source: University of Idaho, 2009

Responses to Climate Change Impacts

- Mitigation

Source: ClimateCrisis, 2011

Source: Low Carbon Economy, 2008



Source: fao.org, 2011

- Adaptation

"Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected *climate change effects.*" (IPCC, 2007)

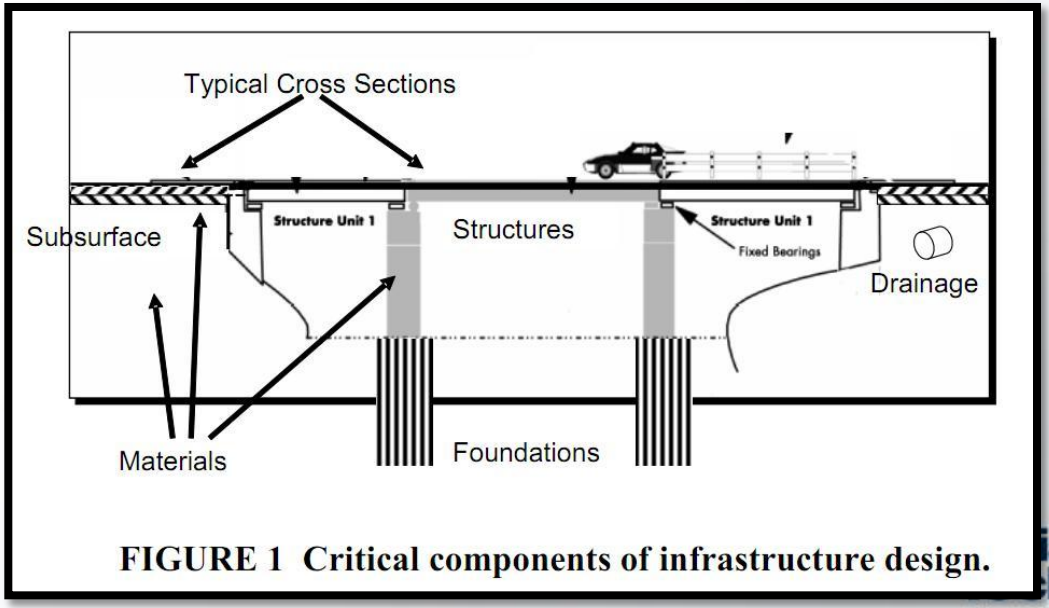


FIGURE 1 Critical components of infrastructure design.

Source: Meyer, 2006

General Guidance for Adaptation, 1

- Intergovernmental Panel on Climate Change (IPCC)
  - 1992 (IPCC, supplement to AR1) – Scenario-driven impact assessment, “adaptive policies”
  - 1994 (IPCC, supplement to AR1) – Scenario-drive impact assessment, evaluation of “adaptation strategies”
    - Defining goals and objectives
    - Specifying important climate impacts
    - Identifying adaptation options
    - Examine constraints of identified options
    - Quantify measures and formulate alternative strategies
    - Weight objectives and evaluate trade-offs
    - Recommend adaptation measures
  - 1995 (IPCC, AR2) - Introduces risk analysis for socio-economic and biophysical impact analysis

General Guidance for Adaptation, 2

- Intergovernmental Panel on Climate Change (IPCC)
  - 2001 (IPCC, AR3) – Introduces risk management in response to:
    - Attitude of risk aversion and loss-mitigation in infrastructure management community – top down vs. bottom up approaches.
    - Uncertainty associated with climate change
      - Climate change projections
      - Actual effects of climate change
      - System vulnerabilities
      - Adaptive capacity of systems
      - Ability to implement adaptation
      - Adaptation costs
    - Offers no formal framework for risk management approach

General Guidance for Adaptation, 3

- UK Climate Impacts Programme
  - 2000 (UKCIP) – Impacts assessment, stakeholder involvement

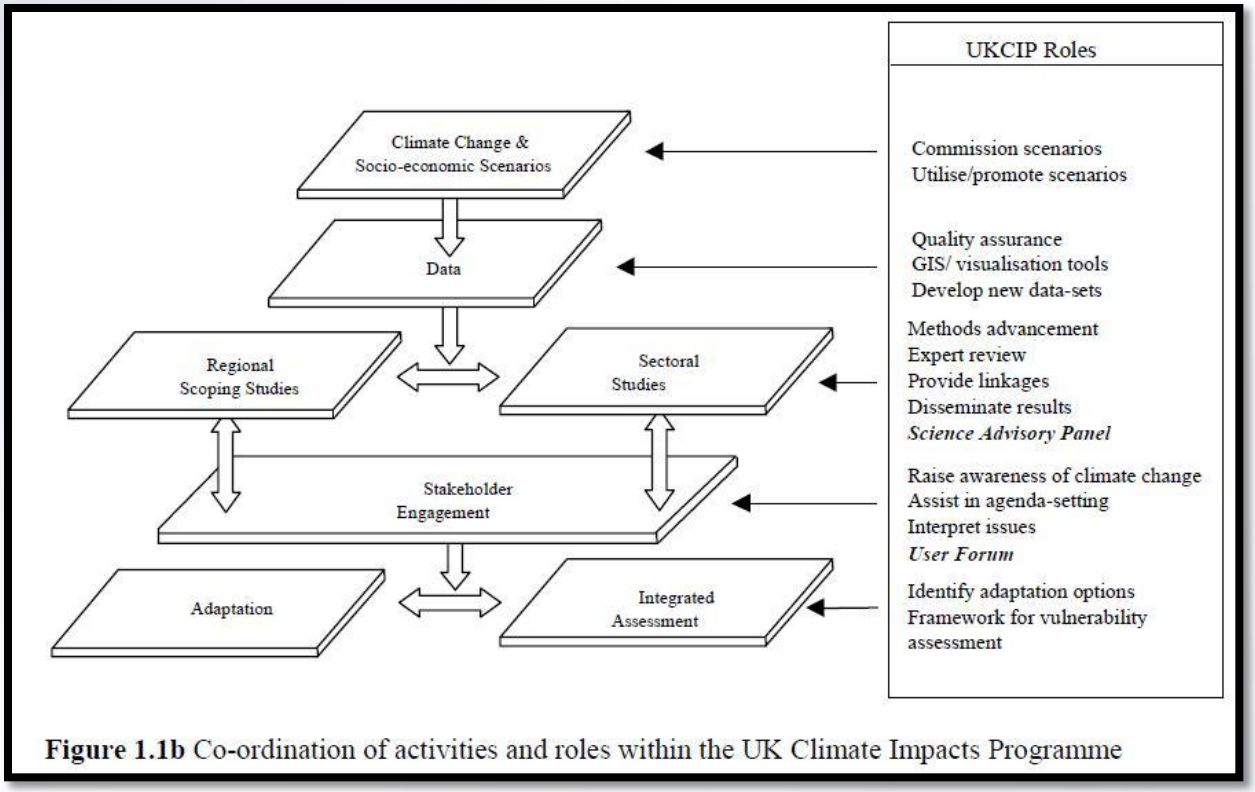


Figure 1.1b Co-ordination of activities and roles within the UK Climate Impacts Programme

Source: UKCIP, 2000

General Guidance for Adaptation, 4

- UK Climate Impacts Programme (UKCIP)
  - 2003 technical report – Adaptation framework to address *risk* and *uncertainty**

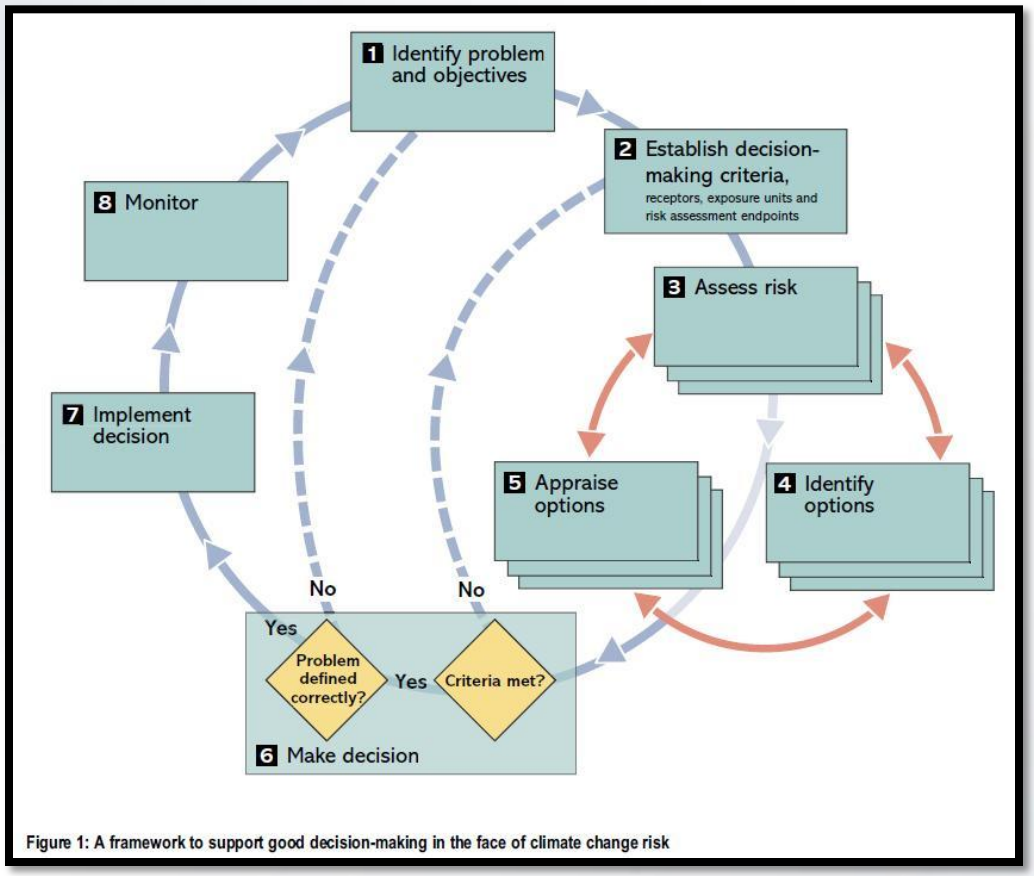
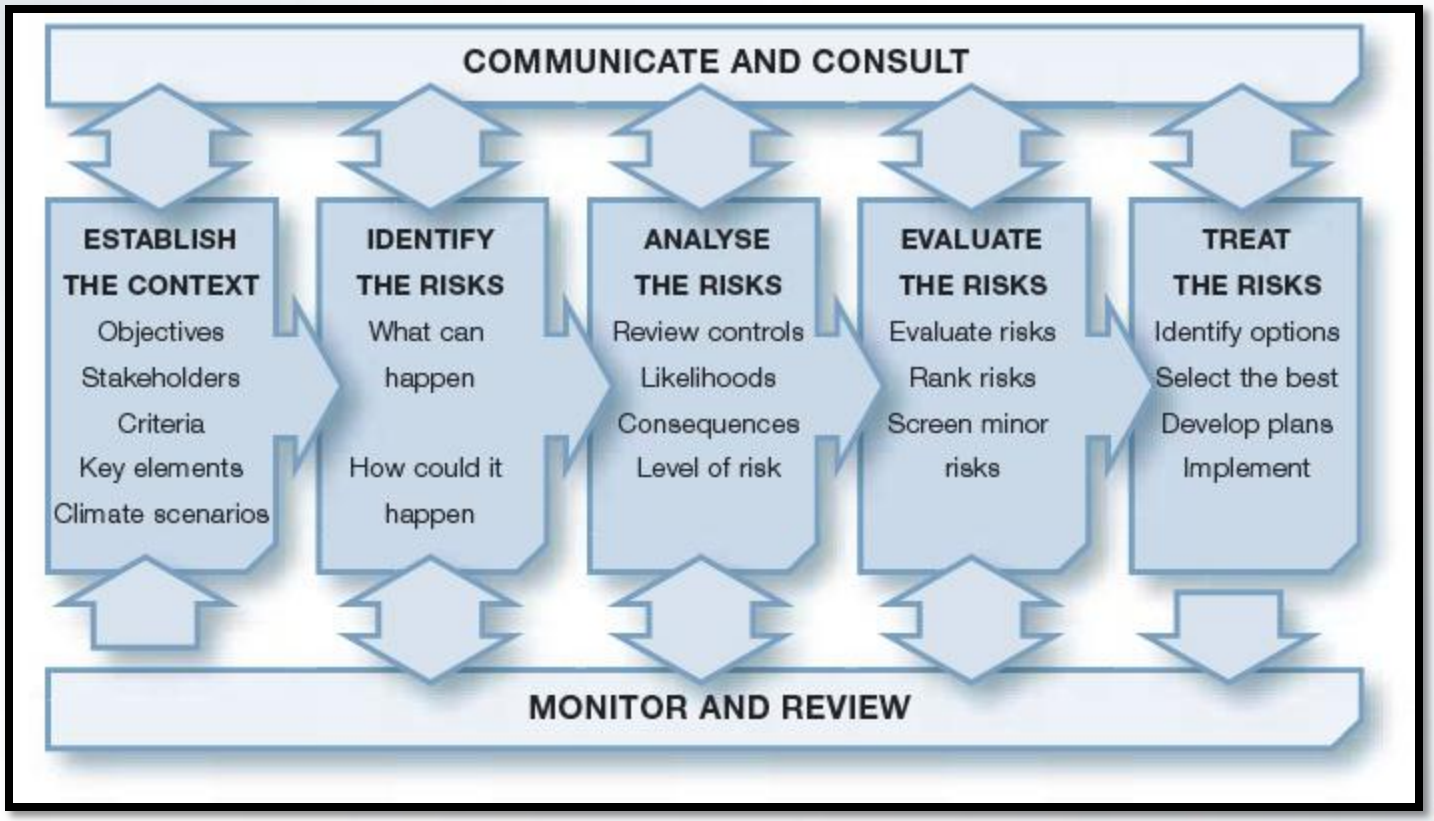


Figure 1: A framework to support good decision-making in the face of climate change risk

Source: UKCIP, 2003

General Guidance for Adaptation, 4

- Australia & New Zealand introduce joint standard for risk management,
  - 2004 - AS/NZS 4360



Source: Standards Australia and Standards New Zealand, 2004

General Guidance for Adaptation, 5

- Intergovernmental Panel on Climate Change (IPCC)
  - 2007 (AR4) – *"the certainty that some climate change will occur is driving adaptation assessment beyond the limits of what scenario-driven methods can provide."* (IPCC, 2007)
  - Introduces a generalized risk management framework:
    - A scoping exercise, Establish context of overall assessment is approach to be used.
    - Risk identification, climate and non-climate sources of risk, acceptable risk levels.
    - Risk analysis, Determines and analyzes impact likelihood and consequences.
    - Risk evaluation, Prioritization of adaptation and/or mitigation measures.
    - Risk treatment, Application and monitoring of selected adaptation and/or mitigation

UK Highways Agency: Transportation Specific Adaptation Frameworks

- UK Highways Agency
  - 2008 - *Climate Change Adaptation Strategy*

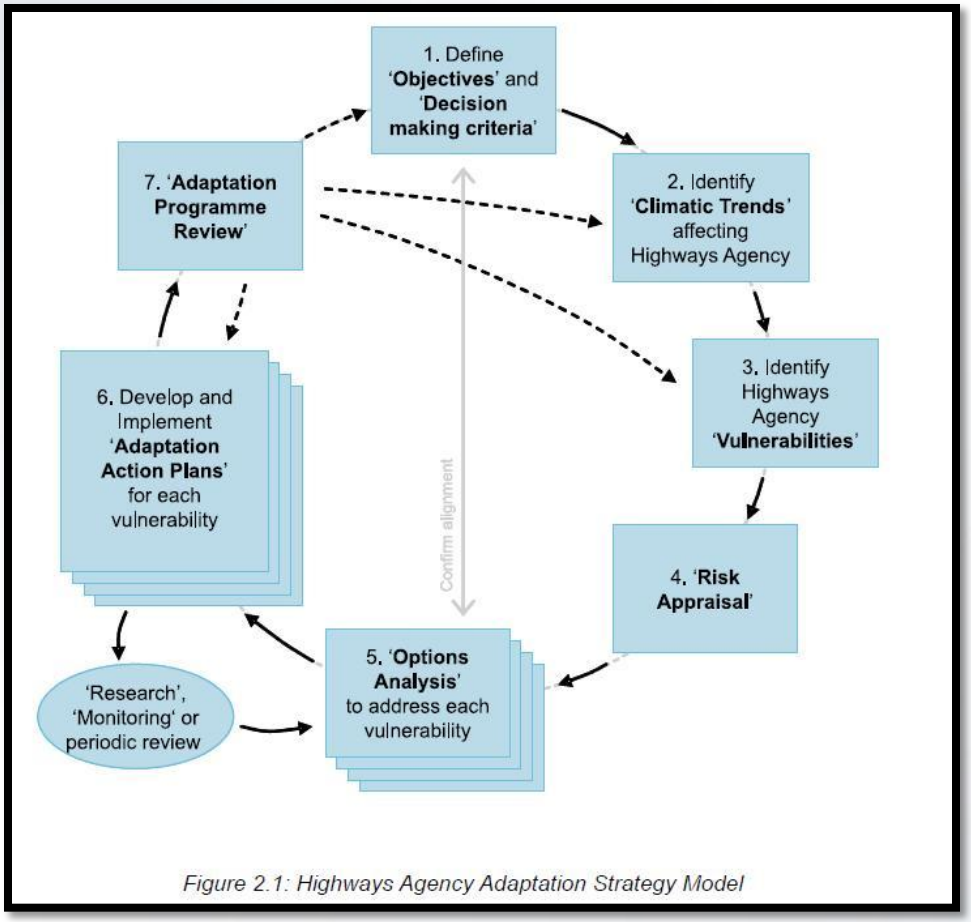


Figure 2.1: Highways Agency Adaptation Strategy Model

Source:

UK Highways Agency: Transportation Specific Adaptation Frameworks

Primary criteria for risk appraisal and prioritization (Highways Agency, 2008)

- Uncertainty
  - Climate change predictions
  - Effects of impacts
- Rate of climate change
  - Time horizon of climate change vs. expected life of asset/activity
- Extent of disruption
  - Number of network disruptions
  - Extent to which users are affected by disruptions
- Severity of disruption
  - Recovery time/recoverability

UK Highways Agency: Transportation Specific Adaptation Frameworks

Primary criteria for risk appraisal

- Uncertainty
  - Climate change predictions
  - Effects of impacts

		Uncertainty level - effects of climate change on asset/ activity		
		High	Medium	Low
Uncertainty level – climate change predictions	High	H	H	M
	Medium	H	M	L
	Low	M	L	L

Table 4.4: Uncertainty matrix

Source: Highways Agency, 2008

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UK Highways Agency: Transportation Specific Adaptation Frameworks

Primary criteria for risk appraisal

- Rate of climate change
  - Time horizon of climate change vs. expected life of asset/activity

		Asset life / activity time horizon	
		High	Medium
Time horizon for climate change effects to become material	Short-term (up to 2020)	H	H
	Mid-to-longer term (between 2020 and 2080)	M	H
	Longer-term (beyond 2080)	L	M

Table 4.5: Rate of climate change matrix

Source: Highways Agency, 2008

UK Highways Agency: Transportation Specific Adaptation Frameworks

Primary criteria for risk appraisal

- Extent of disruption
  - Number of network disruptions
  - Extent to which users are affected by disruptions

Score	Criterion: Extent of Network Affected
High	>80% of network / users affected, or any specific highly strategic routes/ locations
Medium	20-80% of network / users affected
Low	<20% of network / users affected

Table 4.6: Extent of disruption matrix

Source: Highways Agency, 2008

UK Highways Agency: Transportation Specific Adaptation Frameworks

Primary criteria for risk appraisal

- Severity of disruption
  - Recovery time/recoverability

	Criterion: Severity of Disruption
High	Disruption time > 1 week
Medium	Disruption time 1 day-1 week
Low	Disruption time <1 day

Table 4.7: Severity of disruption matrix

Source: Highways Agency, 2008

UK Highways Agency: Transportation Specific Adaptation Frameworks

Prioritization:

- Highly disruptive, time-critical with high confidence

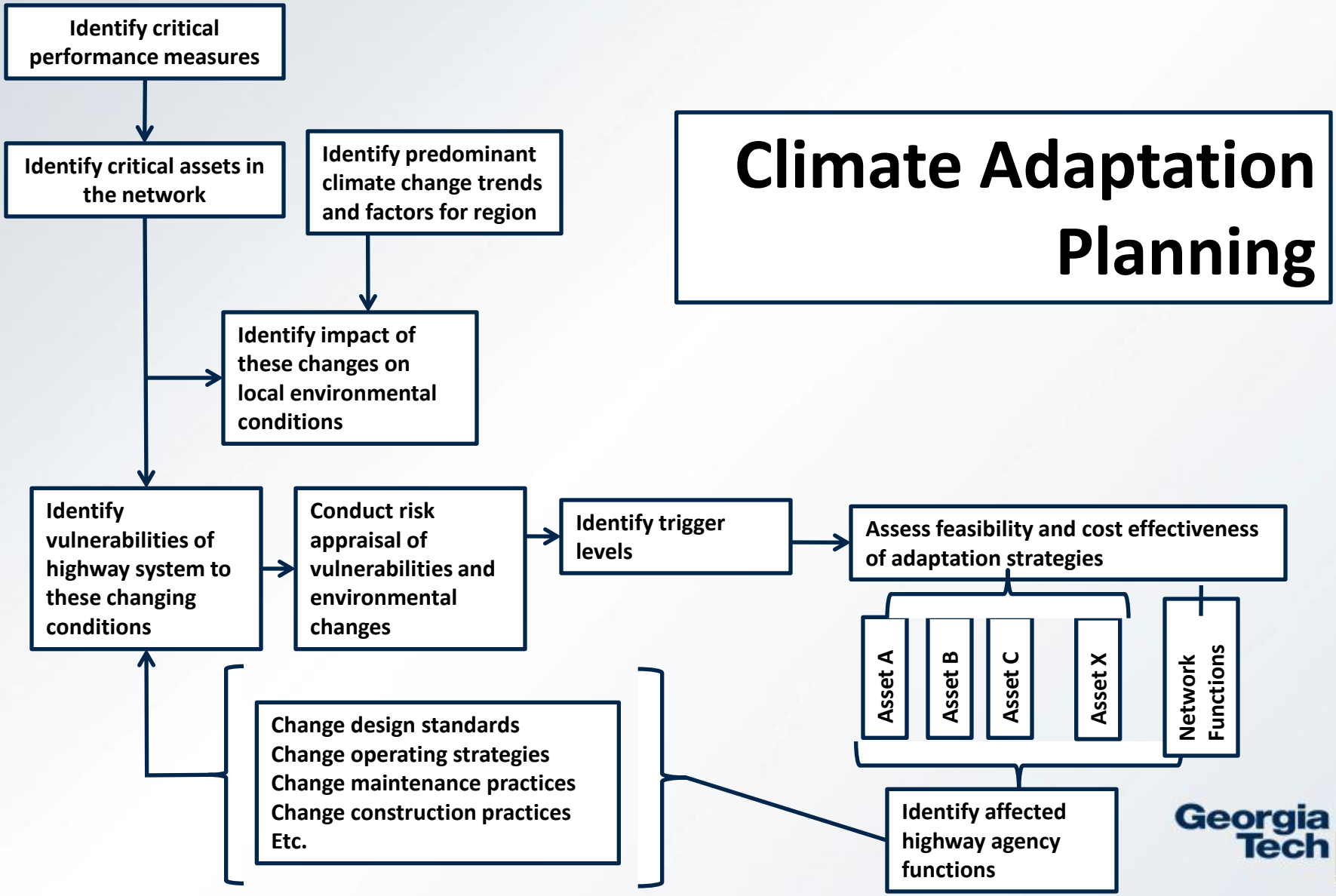
[Rate of climate change] x [Extent of disruption] x [Severity of disruption] x (4 - [Uncertainty]) divided by 81

Qualitative Score	Numerical Score
High	3
Medium	2
Low	1

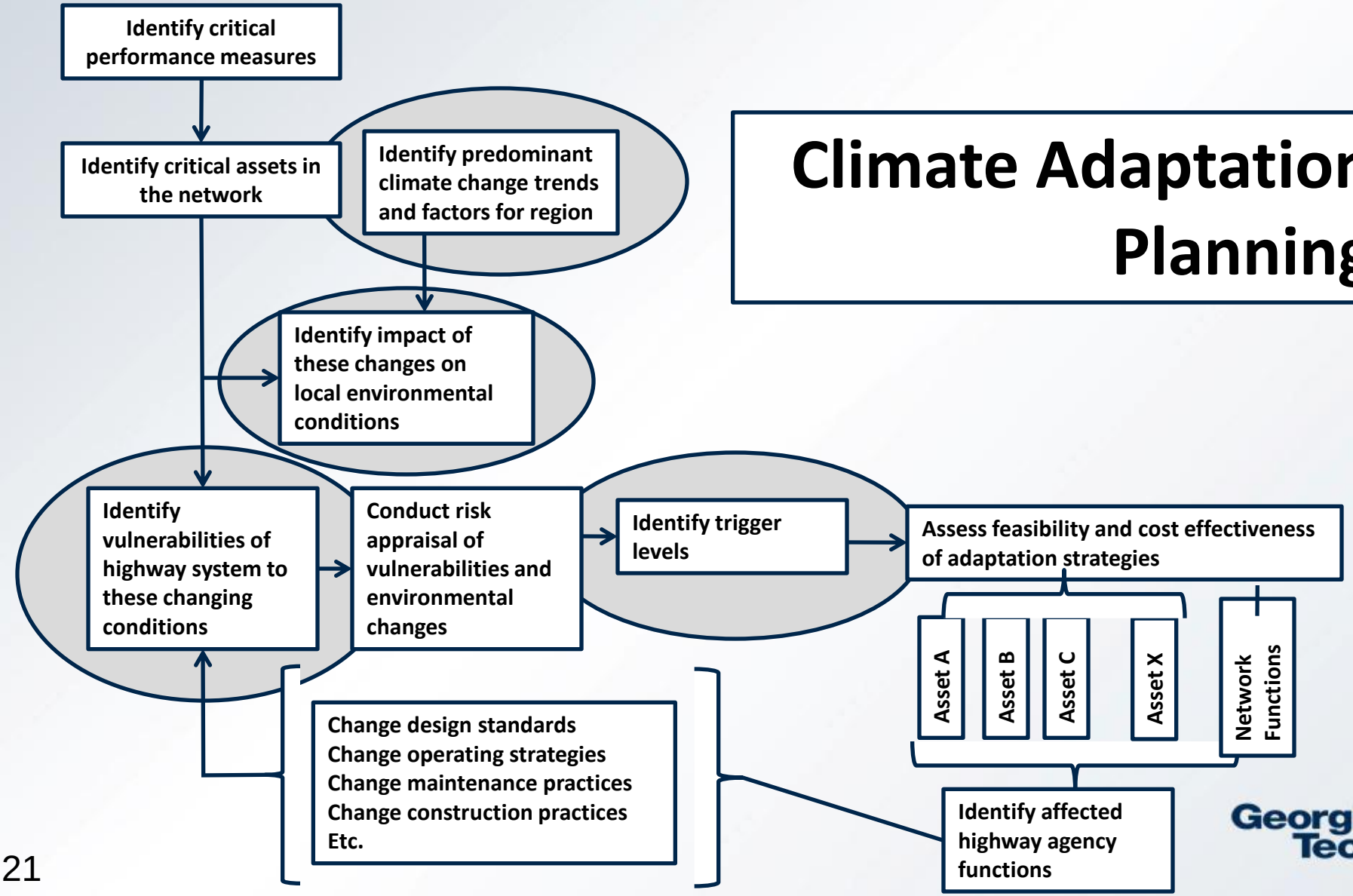
Table 4.8: Scoring conversion

Source: Highways Agency, 2008

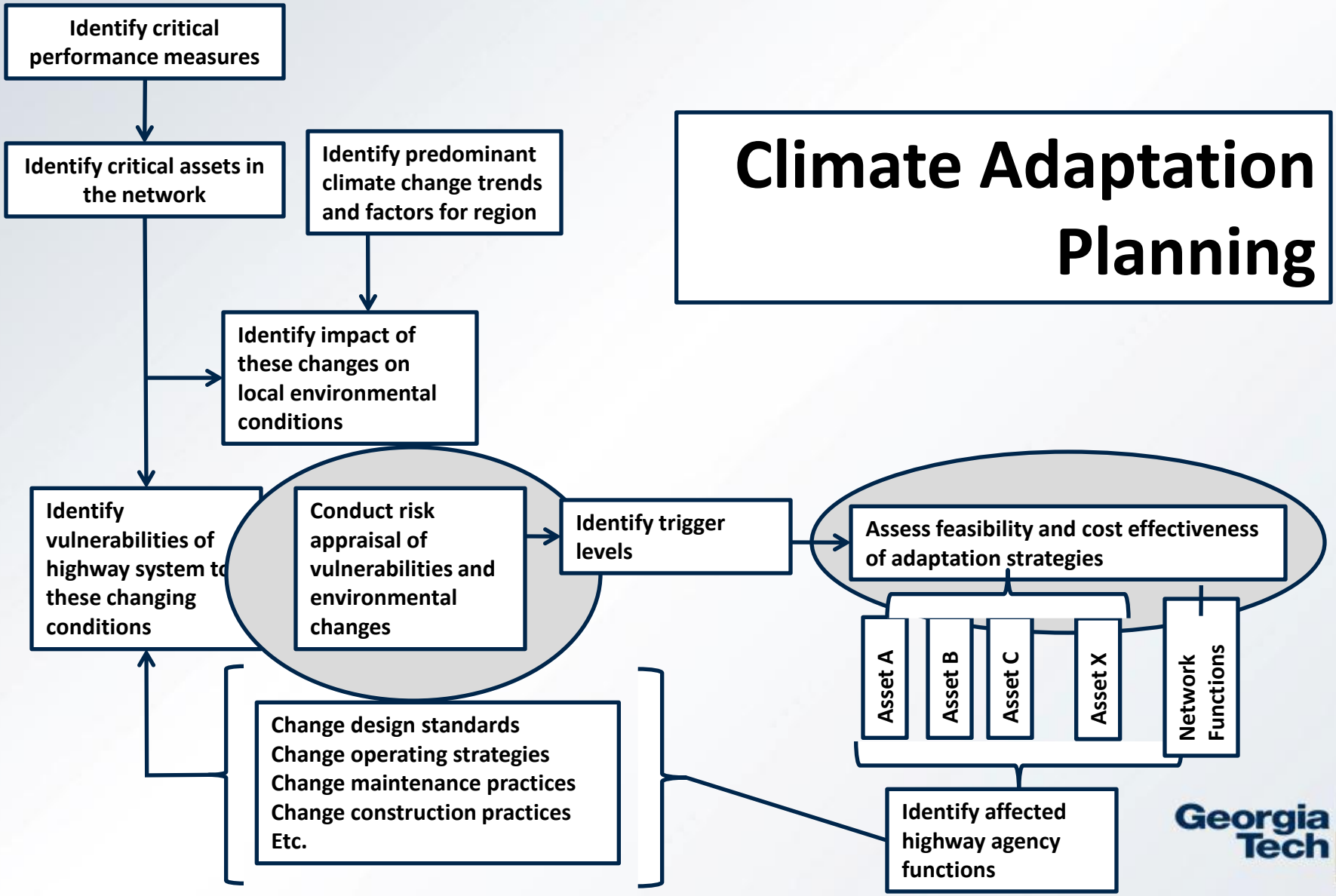
Transportation Specific Adaptation Frameworks - Work at Georgia Tech, 1



Transportation Specific Adaptation Frameworks - Work at Georgia Tech, 2



Transportation Specific Adaptation Frameworks - Work at Georgia Tech, 2



Prioritization Schemes

National Research Council (NRC, 2010)

- Methods for comparing and ranking adaptations
  - Cost-effectiveness analysis
  - Benefit-cost analysis
  - Risk management
  - Decision analysis
  - Multi-criteria analysis
- Issue of uncertainty
  - Risk management “gaining traction as complementary analytic tool”
  - Several general strategies available
  - Alternate approaches

Risk-Based Prioritization, 1

Probability of critical event

- Probability of regional climate variation
- Probability of critical event
- Probability of asset adversely impacted by critical event
  - f(x) of vulnerability (asset age, condition, type, location, adaptive capacity, etc.)

Examples of probability models

- Earthquake engineering
- FHWA's HYRISK – bridge scour model using NBI
- Dr. Laurie Garrow, Dr. Matt Higgins (Georgia Tech) – NBI-based simulation model, trigger points

Risk-Based Prioritization, 2

Consequences

- Cost/feasibility of asset repair/replacement
- System/network disruption –
  - User disruption (e.g., HYRISK – bypass length, ADT, ADT-truck)
  - Impacts to local economies
  - National defense
  - Emergency evacuation
- Strata of consequence – Primary, Secondary, Tertiary…

Integration into decision-making framework

- Benefit-cost analysis
- Multi-criteria analysis
- Cost-effectiveness analysis

Key questions moving forward

- How to better integrate *uncertainty* into prioritization and analysis framework?
  - Hallegatte, 2008
    - No-regrets strategies
    - Reversible strategies
    - Safety margin
    - Soft strategies
    - Strategies that reduce decision-making time horizons
  - Potential others
    - Risk management
    - Iterative/periodic analysis
- Which decision-making analysis method(s) are most appropriate?
- What socio-economic variables to include?
- Where do you draw the line with consequences?
- Threshold of actionability?

Questions & References, 1

Questions?

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Questions & References, 2

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