Priority-Setting for the Future Interstate System with Emergent and Future Conditions

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Acknowledgements

- Hampton Roads Planning District Commission
- Hampton Roads Transportation Planning Organization
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- John Carlock, AICP, Deputy Executive Director, HRPDC
- US Federal Highway Administration
Risk and Resilience Analytics

**Risk analysis** …

An influence of *scenarios* to *priorities*.

The effect of uncertainty on objectives.
ISO 31000 (2009)

What can be done in what time frames, what are the tradeoffs, and what are the impacts of current decisions on future options
Haimes (1991)

What can go wrong, what are the likelihoods, what are the consequences
Kaplan and Garrick (1981)

Measure of the probability and severity of adverse effects.
Risk, Safety, and Security

Programs

What risks are addressed
What are the resources
What is monitored and evaluated

Sources: Teng, Thekdi, and Lambert 2012a, 2012b
**Scenarios are:**
- Projected from **stakeholders**
- Related to **aspirations** or **advocacy positions**

**Scenarios not necessarily:**
- Mutually exclusive or complete
- An event space
- Objective or primitive mathematical constructs
- Repeatable across experts and elicitations

Emergent & Future Conditions

• **Regulatory**
  – New guidelines or increasingly stringent national or international trade policies.

• **Technological**
  – Immediate, unforeseen shifts in the directions of energy technologies (such as nuclear technologies, coal technologies, or promising renewable energy technologies).

• **Cyber**
  – Known and unknown conditions of data/information and control systems

• **Geopolitical**
  – Shifts in the geopolitical power relating to fossil fuels and natural gas that influence availability and costs of these energies.

• **Behavioral**
  – Changes in societal viewpoints or lack of acceptance of energy legislation.

• **Climate and others**
  – Disruption of infrastructure services, commercial energy grid failures, destruction of energy systems, and deterioration of energy and other infrastructure systems.

Sources: Thorisson, Lambert et al. 2016;
Opportunities, threats, and the influential scenarios

Hazard scenarios to be filtered

Foundations in decision and behavioral sciences

scenario-based preferences & risk analysis

resilience analytics in multiple time frames

scenario-based preferences

Mise-en-scene
Adjust weights based on baseline scenario

Transitional object
Preference aggregation across scenarios

scenario analysis and multicriteria

Evaluate alternative-scenario pairs

Dynamic mcda

Multicriteria analysis

Dynamic mcda

Goodwin and Wright (2001)
Belton and Stewart (2002)
Corner et al (2001)
Montibeller and France (2010)

Separate additive model for each scenario
Robustness based on regret

Montibeller et al. (2006)
Ram et al (2009)

Iteration and evolution
Hamilton Dissertation
Hamilton and Lambert (2016)
Hamilton et al. (2013a and b)
Parlak et al. (2012)
Karvetski and Lambert (2012)
You et al. (2013)
Karvetski et al. (2011a and b)
Schroeder and Lambert (2011)
Karvetski et al. (2009)

Foundations in decision and behavioral sciences
Recent Hampton Roads efforts address climate
  – HRPDC studies and reports
  – Cooperative efforts with Univ. VA, Old Dominion Univ., Va. Institute of Marine Science

Transportation planning
  – Newly developed Project Prioritization Process for Long-Range Transportation Plans
  – Other plans (VTRANS2035, Transit Vision, etc.)
Motivation (cont.)

• Adaptations were identified, though had not been integrated to regional planning, with a few exceptions

• Primary focus had been rise of sea level

• Methods and tools were needed for climate impacts to be considered in long-range plans
Motivation (cont.)

• Tools for informing adaptation decisions
  – Where to protect, accommodate, retreat

• Must describe how climate impacts can affect investment priorities
  – Where to invest in new infrastructure or maintenance

• Moving forward
  – Incorporating climate change and adaptive management into local and regional plans, including LRTP
  – Utilizing scenario analysis across economic and other infrastructure sectors
Address the influences of climate scenarios to long-range transportation planning.

- Climate combines with other factors: Economy, regulation, maintenance/repair, technology, ecology, demographics, etc.

- Which scenarios are an advantage to strategic plans? Which are disruptive to strategic plans?

- Where should investigative resources be focused to avoid regret and belated action?
Agenda

Motivation / Purpose

Foundation

Technical Approach

Results

Conclusions
Virginia and Hampton Roads efforts on climate and transportation planning

Recent work with US Army Corps of Engineers, VTrans2035 Office of Intermodal Planning and Investment, FHWA
Foundations (cont.)

- Virginia Governor's Commission on Climate Change, 2008.
- Chesapeake Bay Land Subsidence and Sea Level Change, 2010 (VIMS)
- Sea Coast and Sea Level Trends, 2009 (VIMS)
- The Chesapeake Bay and Global Warming, 2007 (NWF)
- Hampton Roads 2030 Long-Range Transportation Plan, 2007 (HRTPO)
- Prioritization of Transportation Projects for Hampton Roads 2035 Long-Range Transportation Plan: Project Evaluation and Scoring-Final Report, 2010 (HRTPO)
- Climate Change in Hampton Roads Phase I: Impacts and Stakeholder Involvement, 2010 (HRPDC)
- Climate Change in Hampton Roads Phase II: Storm Surge Vulnerability and Public Outreach, 2011 (HRPDC)
- Critical Infrastructure Protection and Resiliency Strategic Plan, 2008 (Commonwealth of Virginia)
Priority-setting for Alaska coastal villages vulnerable to erosion and climate change

Karvetski, Lambert, et al. 2011, pp. 258-273

Copy available by email to lambert@virginia.edu
Integration of Decision Analysis and Scenario Planning for Coastal Engineering and Climate Change

Climate change and other scenario impacts to infrastructure systems


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Scenario-based multiple criteria analysis for infrastructure policy impacts and planning

Multimodal transportation policies influenced by climate change and other scenarios

Alaska USA Coastal Erosion

200 communities with erosion concerns and accelerating climate change

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Technical Approach

Emphasis of the current effort

- Existing inventories
- Existing priorities, evaluation tools

Inventory of Assets
- Develop inventory of assets
- How important is each asset?

Climate Information
- Gather climate information (observed and projections)
- What is the likelihood and magnitude of future climate changes?

Assets Vulnerabilities
- High or medium vulnerability
- What is the likelihood that future stressors will measurably impact the asset?
- What is the consequence of the impact on the asset?

Monitor and revisit as resources allow
- Low risk
- What is the integrated risk?
- High or medium risk

Identify, analyze, and prioritize adaptation options

Existing data sets
- High likelihood/High magnitude
- High likelihood/Low magnitude
- Low likelihood/High magnitude
- Low likelihood/Low magnitude
- High likelihood/High magnitude

Withinscope of Risk Assessment pilot
Outside of scope of Risk Assessment pilot
Step 1. Understand the Hampton Roads regional long-range transportation plan
Multicriteria analysis of 155 strategic project priorities

Step 2. Identify climate conditions
Based on survey of Hampton Roads climate change and transportation technical reports

Step 3. Build climate scenarios
Mixing conditions of climate, maintenance, technology, economy, regulation, etc.

Step 4. Assess which are the influential scenarios
Focus *modeling/analysis* on the influential scenarios

**Additional perspectives. Repeat the Steps 1-5, substituting transportation projects by**

- **Existing transportation assets**
  Highway sections, bridges, tunnels, operations systems
- **Traffic analysis zones (TAZs) vulnerable to climate**
  2011 Hampton Roads climate study and others
- **Multimodal transportation policies**
  2009 VTrans twenty-year horizon multimodal policies
• Three categories of criteria for project priority-setting
  – Project utility
  – Economic vitality
  – Project viability

• Dozens of subcriteria specific to the project types
  – Highway
  – Interchange
  – Bridge/tunnel
  – Intermodal
  – Transit
Performance Criteria (cont.)

- Score ranges represent **significance** among the criteria
- Importance was assessed by **TPO/MPO public-involvement activities**
- Assessment has not yet considered climate or other worst- and best-case scenarios
Projects of the Long-Range Plan

- Total of 155 projects with thirty-year horizon
- Project are rated on each of the criteria
- Projects are ranked within types (highway, interchange, bridge/tunnel, intermodal, and transit)
- Particular of the projects could be robust to climate scenarios
  - With respect to (i) project scores and (ii) project rankings
Scenarios that Include Climate

• **Up to five scenarios**
  – Sea-level, seasons, storms, ecosystem, etc.

• **Scenarios reflect evidence and experience of diverse stakeholders**

• **Scenarios mix climate-change with other factors** (economic, regulatory, ecological, technological, etc.)

• **Scenarios are updated** with new available information

• **Question:** Do the scenarios influence or disrupt strategic project priorities of the long-range transportation plan
### Scenarios that Include Climate

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Scenarios</th>
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</thead>
<tbody>
<tr>
<td>Climate Conditions</td>
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<tr>
<td>Increase in sea level rise</td>
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<td>Increase in storm surge</td>
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<td>Increase in precipitation</td>
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<td>Increase in stormwater</td>
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<td>Increase in storm frequency</td>
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<td>Increase in days below freezing</td>
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<td>Increase in extreme heat days</td>
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<td>Increased occurrence of drought</td>
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<tr>
<td>Non-Climate Conditions</td>
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<tr>
<td>Economic recession</td>
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<td>No further increase on federal government debt cap</td>
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<tr>
<td>Increased wear and ear on public infrastructure</td>
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<td>New technology for maintenance / inspection</td>
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<td>Increase in traffic demand</td>
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<td>Increase in area tourism</td>
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<td>Population growth</td>
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<td>Energy shortage</td>
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<td>Changes in land use regulation</td>
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<td>Increased infectious disease occurrence</td>
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<td>Increased loss of forest and plant life</td>
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<td>Increased mortality of native animal species</td>
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</table>
### Scenarios that Include Climate

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<tbody>
<tr>
<td>[PU-Highway] Congestion Level</td>
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<td>MAJOR INCREASE</td>
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<tr>
<td>[PU-Highway] Continuity and Connectivity</td>
<td></td>
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<td></td>
<td>MAJOR INCREASE</td>
<td>minor decrease</td>
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<tr>
<td>[PU-Highway] Cost Effectiveness</td>
<td></td>
<td></td>
<td>MAJOR INCREASE</td>
<td>minor decrease</td>
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<tr>
<td>[PU-Highway] Land Use Pattern Compatibility</td>
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<td>MAJOR INCREASE</td>
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<tr>
<td>[PU-Highway] Safety and Security</td>
<td></td>
<td>minor increase</td>
<td>minor increase</td>
<td>major increase</td>
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<tr>
<td>[PU-Highway] Infrastructure Condition</td>
<td>MAJOR INCREASE</td>
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<tr>
<td>[PU-Highway] Modal Enhancements</td>
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<td>[PV-All] Additional Funding</td>
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<td>[PV-All] Prior Commitment</td>
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<td>[PV-All] Federal Mandates</td>
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<td>minor decrease</td>
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<tr>
<td>[PV-All] Project Readiness</td>
<td></td>
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<tr>
<td>[EV-Highway and Bridges/Tunnels] Travel Time Reduction</td>
<td></td>
<td></td>
<td></td>
<td>MAJOR INCREASE</td>
<td></td>
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<tr>
<td>[EV-Highway and Bridges/Tunnels] Labor Market Access</td>
<td></td>
<td></td>
<td>minor decrease</td>
<td></td>
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<tr>
<td>[EV-Highway and Bridges/Tunnels] Sector Industries Satisfaction</td>
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</tbody>
</table>

**Adjustments of the criteria importance for each of the five scenarios**
Several Perspectives of Prioritization

• Priority-setting for
  (a) Projects, (b) Assets, (c) TAZs, (d) Multimodal policies

• Scenarios may disrupt priority-setting
  in any/all of (a) to (d)

• Adopt existing multi-criteria priority-setting tools and find what is the influence of climate change

• Do climate scenarios influence priority-setting in (a) to (d)

• Does climate combine with other emergent conditions to influence priority-setting in (a) to (d)
  –Economic, regulatory, maintenance/repair, demographic, environmental, others
Agenda

- Motivation / Purpose
- Foundation
- Technical Approach
- Results
- Conclusions
### Sample of Results

**Projects Scores and Prioritization under Climate-Change Scenarios**

#### Projects Scores

Below are the scores (out of 100, with 100 being the best) that each project received under the baseline and each scenario.

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Project Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>207 202 201 190 187 178 171 160</td>
</tr>
<tr>
<td>S1. Scenario 1</td>
<td>207 202 201 190 187 178 171 160</td>
</tr>
<tr>
<td>S4. Scenario 4</td>
<td>207 202 201 190 187 178 171 160</td>
</tr>
<tr>
<td>S5. Scenario 5</td>
<td>211 202 201 173 170 167 174 147</td>
</tr>
<tr>
<td>Base Score</td>
<td>211 202 201 190 187 178 174 160</td>
</tr>
</tbody>
</table>
Sample of Results (cont.)

Project Rankings

The project rankings table below provides the ranking of each design for each scenario. The first project ranking within each scenario is considered to be the best performing.

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Project Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>1 2 3 4 5 6 7 8</td>
</tr>
<tr>
<td>S1. Scenario 1</td>
<td>1 2 3 4 5 6 7 8 1 2 3</td>
</tr>
<tr>
<td>S4. Scenario 4</td>
<td>1 2 3 4 5 6 7 8 1 2 3</td>
</tr>
<tr>
<td>S5. Scenario 5</td>
<td>1 2 3 5 6 7 4 8 1 2 3</td>
</tr>
<tr>
<td>Base Ranking</td>
<td>1 2 3 4 5 6 7 8 1 2 3</td>
</tr>
</tbody>
</table>
Each vertical bar indicates sensitivity of project ranking to climate scenarios.

Project rankings:

155 Strategic Transportation Projects
Sample of Results (cont.)

Project: Route 17 (G.W. Memorial Hwy)

Highest ranking

Base scenarios ranking

Lowest ranking
Sample of Results (cont.)

**Dam Neck Road**

- **Baseline Ranking**: 18
- **Highest Ranking**: 3 (S5. Traffic Scenario)
- **Lowest Ranking**: 20 (S4. Ecology Scenario)
- **Influential Criterion**: PU-HW.C1 Congestion Level

**Laskin Road**

- **Baseline Ranking**: 20
- **Highest Ranking**: 15 (S1. Climate Scenario)
- **Lowest Ranking**: 42 (S2. Economy Scenario)
- **Influential Criterion**: PU-HW.C3 Cost Effectiveness
Sample of Results (cont.)

Perspective: Priority-Setting of Transportation Assets

Asset rankings

37 Assets
Sample of Results (cont.)

Perspective: Priority-Setting of Multimodal Policies

Policy rankings

25 Policies
Sample of Results (cont.)

Perspective: Priority-Setting for Vulnerability of Traffic Analysis Zones

50 TAZs

TAZ rankings
Sample of Results (cont.)

- S0. Base Scenario
- S1. Climate Change
- S2. Climate + Economy
- S3. Climate + Wear / Tear
- S4. Climate + Ecology
- S5. Climate + Traffic Demand
### Influenal Scenarios

<table>
<thead>
<tr>
<th>Projects</th>
<th>Assets</th>
<th>TAZs</th>
<th>Policies</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1. Climate Change</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S2. + Economy</td>
<td></td>
<td>*</td>
<td></td>
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<tr>
<td>S3. + Wear and tear</td>
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<tr>
<td>S4. + Ecology</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>S5. + Traffic demand</td>
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<td>*</td>
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</tbody>
</table>

* = most influential scenario(s)
• Implementation and impact to decision making
  – Results influenced priority-setting in the Long Range Transportation Plans
  – Methods are transferred to other states via a website

• Workshops and trainings
  – Hampton Roads Planning District Commission
  – Hampton Roads Transportation Planning Organization
  – Virginia Department of Transportation
  – Others
Publication #1. “Climate change influence on priority setting for transportation infrastructure assets”

Focuses on Hampton Roads transportation assets


Copy available by email to lambert@virginia.edu
Publication #2. “Quantifying the influence of climate change to priorities for infrastructure projects”

Focuses on projects of the 2034 Hampton Roads Long-Range Transportation Plan


Copy available by email to lambert@virginia.edu
Publication #3. “Climate and other scenarios disrupt priorities in several management perspectives.”

Focuses on climate impacts to priorities for policies, projects, assets, geographic locations, etc.


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Agenda

Motivation / Purpose

Foundation

Technical Approach

Results

Conclusions
Addressed priority-setting for projects, policies, TAZs, and assets

Studied the influence of climate scenarios to long-range transportation plans

Performed a case study in the region of Hampton Roads, VA

Provided the Excel workbook tools for use by TPOs/MPOs in regions across the nation
• The Virginia pilot has supported the FHWA conceptual model, in three layers:
  
  – Layer 1: Multicriteria priorities of the regional Long-Range Transportation Plan
  
  – Layer 2: Climate scenarios influence priorities for transportation projects
  
  – Layer 3: Climate scenarios influence four types of priorities (projects, assets, locations-TAZs, and policies)
Climate scenarios influence priority-setting in several perspectives of the long-range transportation plan.
Summary (cont.)

• A final report describes the significance, methods, and results of the Virginia pilot

• Appendices
  – User guide for software workbook tool
  – Mathematical statement of the Virginia framework
Workbooks made available for technology transfer at:
http://www.virginia.edu/crmes/fhwa_climate/
Lesson 1. Ample scientific work including models of climate impacts was available at the initiation of the studies.
Lesson 2. The *long-range transportation plan* is an appropriate venue for addressing the impacts of climate change in decision making.
Lesson 3. The transportation planners (MPO) used existing scientific and engineering results on climate change for the long-range plan, with effective use of the staff and available resources.
Lesson 5. Climate combined with other factors, including economics, ecology, travel demands, wear and tear, land use, regulation, energy policies, technology, etc., to influence priority-setting.
Lesson 6. The results identified the most influential scenarios for priority-setting. With each update of the long-range plan, our results helped in the allocation of resources.

Most influential scenario for priority-setting: Sea-level rise and storm surge combined with increase in traffic demand
Lesson 7. The framework has been effective in education and training of agency officials et al.
Lesson 8. The approach is transferable to the nation. The software workbook tools are provided via a website:
Lessons Learned and Needs (cont.)

• Asset vulnerability is insufficient to address climate change -- must address several planning elements
  Assets, projects, policies, locations (TAZs), other elements...

• Climate change intersects actual decision making in a region’s Long Range Transportation Plan
  Time horizon of thirty years or more, updated every four to five years mandated by federal and state laws

• Climate change influences priority-setting both alone and in combination with other factors
  Travel demand, economic, wear and tear, ecology, technology, others
Mobile Grid

Resilience of Energy, Transportation, and Communications Infrastructures

Best Paper Award, 2015 IEEE Systems and Information Engineering Design Symposium
Afghanistan Sustainable Infrastructure Plan

Disruptions inform resilience, an evolution of priorities in time.
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www.virginia.edu/crmes/fhwa_climate