ASSESSING THE VULNERABILITY OF TRANSPORTATION INFRASTRUCTURE TO CLIMATE STRESSORS, SAN DIEGO, CALIFORNIA

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moffatt & nichol
DUDEK
SANDAG
Caltrans
INTRO TO SAN DIEGO

• 70+ miles of Coast
• San Diego County Population: 3.4 million (2017) – 5th most populous County in the US
• Transportation Corridors along the Coast

Source: https://maps-san-diego.com/north-county-san-diego-map
CLIMATE STRESSORS IN SAN DIEGO—TEMPERATURE

• Temperature Projected to Increase 4-6°F by 2100
  • Wildfires expected to increase in occurrence and intensity (Santa Ana winds likely to become hotter and more frequent)

Source: California’s Fourth Climate Change Assessment, San Diego Regional Report
CLIMATE STRESSORS IN SAN DIEGO—PRECIPITATION

- California’s 4th Climate Change Assessment (2018):
  - Precipitation (more intense precipitation events, more frequent and intense droughts)

Source: California’s Fourth Climate Change Assessment, San Diego Regional Report
CLIMATE STRESSORS IN SAN DIEGO—SEA LEVEL RISE

- Sea Level Rise
  (0.1 to 8.0 feet depending on the climate scenario)
  - 6.6 feet of sea level rise leads to annual losses of $400 million in industrial and commercial property

Source: California’s Fourth Climate Change Assessment, San Diego Regional Report

Sea level rise (SLR) estimates for La Jolla from three different publications and two different greenhouse gas scenarios. These include SLR projections made for the Fourth Climate Change Assessment (Pierce et al., 2018) for RCP 4.5 (light blue) and RCP 8.5 (dark blue) for each decade over the 21st century. The California Ocean Protection Council Rising Seas projections are shown for RCP 2.6 (pink), RCP 8.5 (red), and the extreme scenario H++ (green dot). The National Research Council (NRC, 2012) sea level estimates for all of California are shown by the black dots and grey lines. Each decade’s estimate is shown as a range from the 5th to 95th percentile with the circle representing the 50th percentile and the x representing the 99.9th percentile. Inset shows projections carried out to 2200.
HAZARDS IN SAN DIEGO

• Tidal Inundation
• Storm Surge and Flooding

• Shoreline Retreat
• Bluff Erosion

Photo credit Kenneth and Gabriella Adelman, California Coastal Records Project
Three Risk Aversion Curves for SLR from OPC Guidance 2018 for Los Angeles, CA

- **H++ Scenario - Extreme Risk Aversion**
- **0.5% Probability, Medium-High Risk Aversion**
- **Top range of 66% Probability - Low Risk Aversion**

**Sea Level Rise (ft)**

**PROJECTIONS AND GUIDANCE**

- 2010
- 2030
- 2050
- 2070
- 2100
- 2150
### Probabilistic Projections (in feet) (based on Kopp et al. 2014)

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<th>1-in-20 Chance</th>
<th>1-in-200 Chance</th>
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STUDY MOTIVATION

• SLR Planning Efforts Conducted at the Local Level

• SANDAG Initiative
  • Bring together local work
  • Analyze transportation through a regional lens

• Moffatt & Nichol Scope
  • Analysis of SLR hazards
  • Assess risk of select assets
STUDY METHODS

• Flood hazard modeling: USGS CoSMoS
• Need to translate model results into vulnerability for each asset
• DOT Vulnerability Assessment Scoring Tool (VAST)
DEFINING VULNERABILITY

- Exposure
- Sensitivity
- Adaptive Capacity
- Damage
- Vulnerability
VAST: STRESSORS AND ASSETS

Use the yellow cells below to enter the climate stressor(s) you want to include in your vulnerability screen. Use buttons to add or remove stressors. These stressors will be used to structure the vulnerability analysis and provide suggestions of indicators to use. You may select up to 5 stressors.

Enter the number of stressors you plan to include: 

Enter the number of asset types you plan to include: 

Click the "Update Stressors and Asset Types" button at the top of the sheet once you have entered your stressors and asset types.
**VAST: EXPOSURE INDICATORS**

Legend
- 6.6 ft (2.0 m) of Sea Level Rise
  - Daily Inundation
  - Flooding (100-yr Storm)

Roadways
- I-5
- N Coast Highway
- SR-75

Coastal Bikeways & Trails
- Active Transportation Pathway

Coastal Transit
- Railroad
- Public Transit Route

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**Indicators of Exposure to Sea Level Rise**

1. Elevation of Asset
2. Length of Impacted Asset
3. [Pull an Indicator from]
VAST: SENSITIVITY AND ADAPTIVE CAPACITY INDICATORS

**Indicators of Regional Transportation Assets Sensitivity to Sea Level Rise**

*Write in indicator names or click the " ‣ " button.*

1. Degree of Historical Flooding
2. Presence of Coastal Flood Protection
3. Impaired Access to Critical Facilities
4. Disruption Duration

**Indicators of Regional Transportation Assets Adaptive Capacity**

*Write in indicator names or click the " ‣ " button.*

1. Feasibility of Adaptation
2. Detour Length
3. Annual Average Daily Traffic (AADT)
## VAST: EXPOSURE INDICATOR SCORING

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Asset ID</th>
<th>Asset Name</th>
<th>Elevation of Asset</th>
<th>Length of Impacted Asset</th>
<th>Exposure Scores</th>
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### Exposure Scoring Approach for Sea Level Rise

How much should each indicator contribute to the overall exposure score?

- Elevation of Asset: 20%
- Length of Impacted Asset: 80%

**Total Weight:** 100%
### VAST: SENSITIVITY INDICATOR SCORING

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<th>Sensitivity</th>
<th>Degree of Historical Flooding</th>
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<td>1.0 1</td>
<td>4.0 4</td>
<td>0.0 1</td>
<td>4.0 1</td>
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</table>

**Sensitivity Scoring Approach**

How much should each indicator contribute to the overall sensitivity score?

- Degree of Historical Flooding: 25%
- Presence of Coastal Flood Protection: 10%
- Impaired Access to Critical Facilities: 40%
- Disruption Duration: 25%

**Total Weight:** 100%

*How are scores calculated?*
## VAST: Adaptive Capacity Indicator Scoring

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<tr>
<th>Adaptive Capacity</th>
<th>Feasibility of Adaptation</th>
<th>Detour Length</th>
<th>Annual Average Daily Traffic (AADT)</th>
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<tbody>
<tr>
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<td>People per Day</td>
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### Adaptive Capacity Scoring Approach

How much should each indicator contribute to the overall adaptive capacity score?

- Feasibility of Adaptation: 60%
- Detour Length: 20%
- Annual Average Daily Traffic (AADT): 20%

**Total Weight:** 100%
# VAST: FINAL VULNERABILITY SCORES

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**Adjust Vulnerability Component Weights:**
- Exposure: 33%
- Sensitivity: 33%
- Adaptive Capacity: 33%

**Damage Component Weights:**
- 50%

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moffatt & nichol
VAST: VISUALIZATION

Regional Transportation Assets Vulnerability to Sea Level Rise - Damage vs. Adaptive Capacity

- Low
- Adaptive Capacity
- High

Damage

1. 1
2. 2
3. 3
4. 4
5. 5
6. 6
## STUDY RESULTS

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VAST TAKEAWAYS

Strengths:
- Flexible
  - Able to incorporate own indicators
  - Weighting scores
  - Multiple stressors
  - Easily updated
  - Scale up/down
- Transparent
  - Individual scores easily tracible

Weaknesses
- Most effective for large datasets of similar asset types
- Scores can be difficult to translate across asset types
NEXT STEPS

Additional VAST Capabilities

- Additional stressors
  - Precipitation—changes in riverine flow, roadway flooding, impassability
  - Temperature—increased temperatures beyond design thresholds or reduction in service life.
APPLICATIONS OF RESULTS

- Mitigation Planning
- Prioritizing Capital Improvement Projects
- Quantifiable Vulnerability Changes
- Securing Grant Funding