Simulated Climate Adaptation in Stormwater Conveyance Structures

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Outline

- Climate change adaptation in distributed stormwater systems
- Research questions
- Modeling and analysis methods
- Results and conclusions

Adaptation in Distributed Systems

- Decision-makers struggle with two almost universal adaptation questions
  - When to adapt?
  - How to adapt?
- Often relatively lower consequence per unit failure
- Made at many governmental levels but often guided by state or federal regulations
- Smaller agencies do not have the resources for specialized decision making process (Kraybill & Lobao, 2001)
Risk in Adaptation

- Climate model predictions of intense precipitation in Colorado range from no significant change to a 12-25% increase (Mahoney et al., 2013; Wubbles et al., 2014)

Nuisance flooding in Miami, possible under adaptation

- Under Adaptation
  - Unacceptable exposure to extreme events
  - Increased monetary and service loss from failing infrastructure

- Over Adaptation
  - Adaptation spending is greater than the benefit gained
  - Decreases adaptive capacity and reduces resources for other adaptation

60 Million dollar pumping facility for the great salt lake that has never been used, an example of over adaptation

Culverts
Culvert Failure

Culvert Failure
Culvert Failure

Culverts Failure
Research Questions

1. How do adaptation strategies with different timing qualities perform with varying climate change trends and crossing characteristics?

2. Can crossing characteristics be used to predict the preferred strategy based on cost, and if so, how much better are predictions when climate change is known?

3. Do individual crossings with unique characteristics respond to climate change in ways that warrant individual-level adaptation strategies, or is system performance best served by monolithic adaptation strategies?
Monolithic Adaptation

Vertically Flexible Adaptation
Modeling Methods

- Exploratory Modeling for Policy Analysis (Bankes, 1993)
  - Computational experiments to explore hypothesis and assumptions
  - Uses a scenario based approach to determine
- Simulate virtual culvert testbed through 100 years of normal replacements, extreme events, climate change, and adaptation strategies.
- Examine the interaction of climate and adaptation strategies with crossing characteristics.

Simulation Model

Repeat for 100 yrs.
Crossing Characteristics

- **Upgrade Cost**: The cost of increasing the capacity of a crossing
- **Upgrade Amount**: How much a crossing can be upgraded
- **Emergency Cost**: The increase cost to replace a crossing after a failure
- **Resilience Factor**: The degree to which a crossing’s capacity can be exceeded before it fails

Adaptation Strategies

- **Nominal**: Replacement as necessary with same sized crossings. Typically at end of useful life.
- **Concurrent**: Crossing capacity is increased at replacement, assuming climate is changing and damaging events are indicators of that change
- **Anticipatory**: Crossing capacity is increased prior to normal replacement in anticipation of future increase in flood events
- **Reactive**: Switch from the Nominal Strategy to the Concurrent Strategy when a crossing is destroyed by and extreme event, used as a pacemaker for adaptation
Adaptation Strategies

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Model Assumptions

• Future cost are proportional to construction cost.

• There is variability in the climate sensitivity and adaptability across individual elements.

• Climate change is only realized in the shifting location of the extreme events distribution.

• Decision evaluation is limited to cost from flood damage and construction.

• Damage is assumed to linearly increase with increases in exceedance.
Analysis and Results

Research Question
• Do individual crossings with unique characteristics respond to climate change in ways that warrant individual-level adaptation strategies, or is system performance best served by blanket adaptation strategies?

Analysis and Simulation Methods
• Global sensitivity analysis with all crossing characteristics continually varied
• Compare using the same adaptation strategy for a test bed of eight culverts (monolithic approach) with a variable adaptation strategy based on crossing characteristics and selected using a multinomial model.

Cost vs. Climate Change
Cost vs. Climate Change

Vertically Flexible vs. Monolithic
Vertically Flexible vs. Monolithic

Conclusions

• Allowing for vertical flexibility in decision making can increase the efficiency of adaptation under moderate levels of climate change.
• Rather than waiting for better climate projections decision-makers can use adaptability and sensitivity to climate change as a method of efficient adaptation decision making.
• Flexible policies that inform adaptation choices by using the adaptability and climate sensitivity of individual infrastructure offer a method of decision making that leverages managers existing competencies rather than requiring a specialized knowledge of climate projections.
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Thank You

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