Integrated Modeling and Optimization of Engineering Decisions for Enhancing Civil Infrastructure Systems Resilience

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Problem: Natural hazards threaten civil infrastructure systems, which can disrupt critical lifeline services when civil infrastructure is not resilient.

Goal: Create an integrated systems model with a systematic search among possible civil infrastructure engineering improvement decisions to determine the best and most cost-effective choices to improve system resilience.
Civil Infrastructure Representation

- **Nodes** = components
- **Arcs** = relationships
  - Intersections
  - Roads
  - Possible levee breach locations

Physical Network

- **Arcs** represent physical and logical interdependency

Interdependency Network
System Performance Metrics

Goal: Increase system resilience to hazards

How can resilience be quantified?

What is a non-resilient infrastructure system?

Assess the lifeline services provided by components

Design so that components can fail, but the system still provides services
Metrics Example – Recovery Time

System resilience measured as the time until services restored

Inputs

Civil Infrastructure System
Component States
Interdependencies

Potential Recovery Actions

Calculate Service at each time period

Time Since Hazard

3 weeks

Time Until Services Restored
Scenario Analysis

Multiple Hazard Scenarios

Multiple Failure Scenarios

Calculate system performance in each scenario

Aggregate System Performance
Optimization Model

Systematic Optimization for Cost-Effective Engineering Improvements

Scenario | Recovery Time
---|---
Cat. 2 Storm 1 Breach | 1.5 weeks
Cat. 3 Storm 1 Breach | 2 weeks
Cat. 5 Storm 3 Breaches | 2.5 weeks
Average | 2 weeks

Check for better combinations of engineering improvements

Apply decisions

Modify Scenarios

Calculate system performance in each scenario

Aggregate System Performance

Multiple Hazard Scenarios

Multiple Failure Scenarios