Risk Analysis for Electricity Infrastructure Hardening

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## Related Research Areas

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How can we use available data to estimate outage and damage risk?

Current & recent projects:

1. Estimating number & location of outages in Southern Company service area
2. Estimating effectiveness of tree trimming at reducing outages
3. Estimating damage to water distribution systems in San Antonio & Philadelphia
Statistical Approaches Used

1. Poisson GLM, Negative Binomial GLM, and Poisson GLMM

2. Zero-inflated models
   - Like (1) but account for extra zero counts

3. Bayesian hierarchical models
   - Similar to (1) and (2) except more flexible distributions, can capture additional variability and spatial correlation.
   - Yields more complete characterization of uncertainty
   - Computationally challenging!
PRA and Bayesian Modeling

- How can we estimate outage and damage risk when we do not have much data?
- Current & recent projects:
  1. Estimating pole damage in hurricanes without damage data (Gulf Coast)
  2. Estimating damage to water systems without complete knowledge of the system (Philadelphia)
  3. Estimating failure probability of current Mars Rover missions with almost no data (NASA – JPL)
1. PRA (Probabilistic Risk Analysis)
   - Systems engineering approach for estimating and managing risk

2. Bayesian influence diagrams
   - Probabilistic representation of uncertainty and decision-making on the basis of both data and expert knowledge

3. Bayesian structural reliability models
   - Method for estimating likelihood of structural failure given external loads
   - Collaborative work with others at Texas A&M
What should we do to harden systems given our best available risk estimates?

Current & recent projects:
1. Optimizing power restoration process in Los Angeles after earthquakes
2. Efficiently allocating resources for construction and maintenance of transportation assets in Texas
3. Developing general methods for allocating reinforcement resources among many possible alternatives in complex systems
1. Decision analysis
   - Captures preferences & values of decision maker

2. Genetic algorithms, branch-and-bound, and other optimization techniques
   - Efficiently selects good hardening options from among a large set of alternatives

3. Simulation
   - Allows experimentation with “virtual” system to examine impacts of decisions

4. Game theory
   - Useful if intelligent threats are involved
Electricity Infrastructure Hardening: Some Key Questions

1. What can we do to harden the system?
   - Reinforce physical system? Improve maintenance practices? Improve management practices? Improve restoration plan/process?

2. How effective and costly are these different options?
   - Do we have data to estimate this? How do we measure effectiveness?

3. How do we choose which options to use in different portions of the system when hurricane impacts are highly uncertain?
Possible Future Research

- Develop Bayesian outage models to better capture uncertainty
- Focus on damage rather than outage estimation
  - A combination of statistical, physical/structural, and PRA models
- Develop better tree trimming effectiveness models
- Develop a long-term hurricane risk model that accounts for possible global warming influences
- Tie this together in a system-wide optimization model to suggest good hardening options
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  - National Science Foundation (CU, SU)
  - Texas Department of Transportation
  - U.S. Air Force
Selected Publications (1)

- **Publication List:** [http://ceprofs.tamu.edu/sguikema/pubs.htm](http://ceprofs.tamu.edu/sguikema/pubs.htm)
Selected Publications (2)