A Dynamic Simulation Model of the Effects of Interdependent Infrastructures on Emergency Service Response

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Abstract

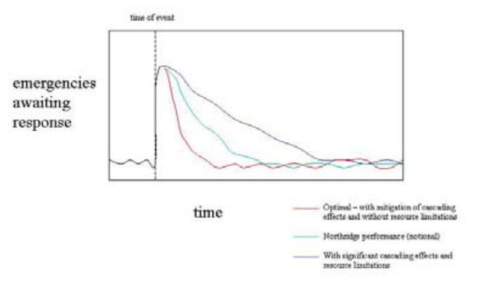
Infrastructure Interdependency Modeling

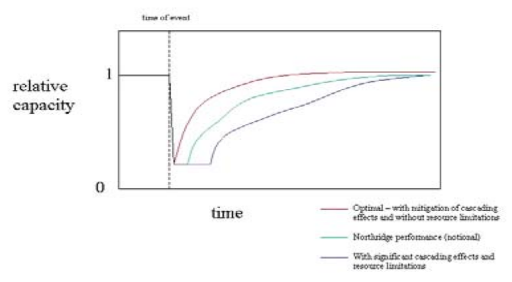
Models of telecommunications and emergency services were added to an existing infrastructure interdependencies model. The interdependency model tracks the flow of materials between infrastructures and other services.

The resulting model was used to evaluate alternative service restoration sequences for catastrophic disruptions caused by an earthquake, and to evaluate whether or not service restoration priorities and sequences will significantly alter the potential death toll, the extent of physical damage, or utility service restoration times.

The model can be used to investigate a wide range of ideas for potentially improving emergency response and disaster recovery. We want to find the leverage points in a particular system that will allow for overall improvement of emergency responses.

We utilized a California earthquake as a test case because it entails widespread and severe disruption to many infrastructures. Since the mid-1980's, LA has worked hard to improve disaster (earthquake) recovery. All the obvious improvements have already been made. The remaining needs are less obvious and likely can be identified through a better understanding of the interplay between interacting infrastructures. Building and exercising the model helps us develop this understanding.

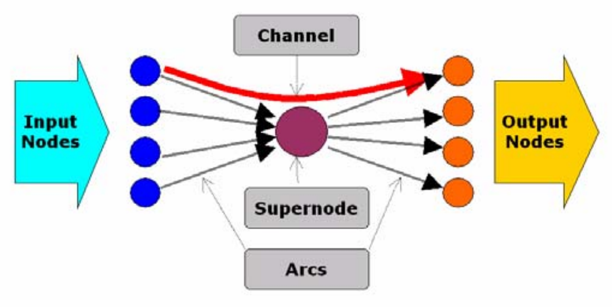




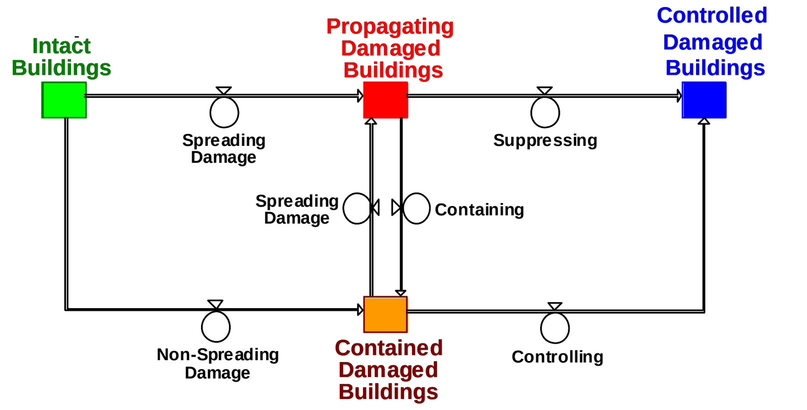
Model Structure

California Interdependency Model Components

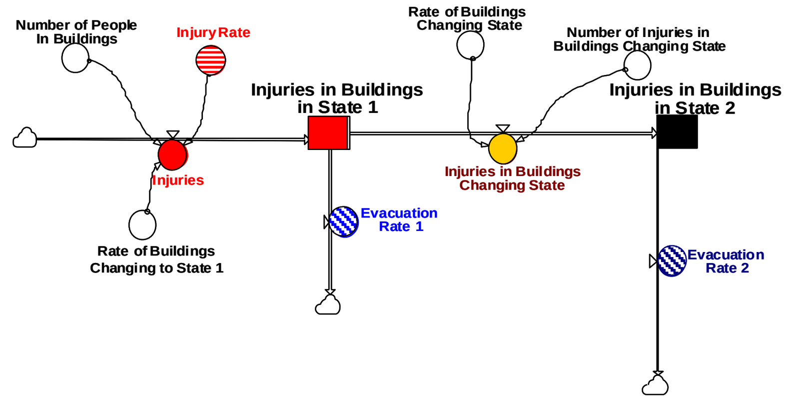
- *Commodity Production, Transportation, Storage, Sales and Consumption*
  - ***Electric Power***
    - *environmental conditions influence demand and supply*
  - ***Water***
    - *demand and supply a function of environmental conditions*
  - ***Agriculture***
  - ***Fossil Fuels*** *(natural gas, oil and refined petroleum products)*
    - *storage behavior a function of price*
    - *prices a function of supply relative to demand*
  - ***Communications***
    - *bandwidth (estimated capacity at time of Northridge earthquake)*
  - ***Emergency Services***
    - *demand modeled as a function of damage*
- *Commercial, Industrial and Residential Consumers*
- *Highly Simplified Representations of Networks (Communication, Transportation and Pipeline)*



States and State Transitions for Model Elements Subject to Physical Damage

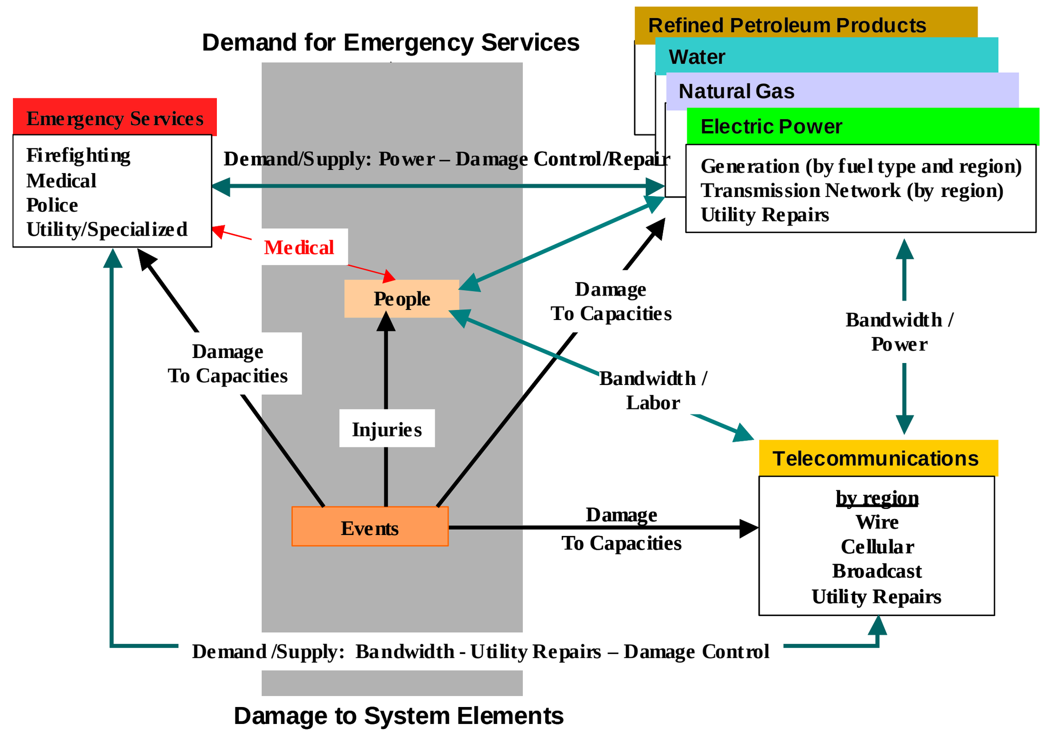


Stock and Flow Diagram of Model Injury Tracking



Model Application

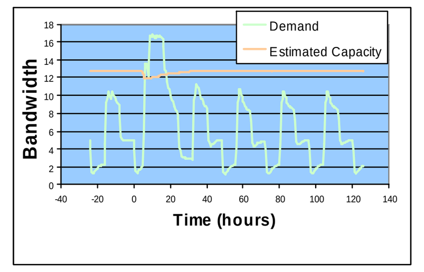
Emergency Services / Telecommunications Interdependency Models



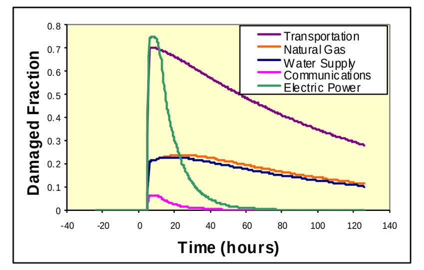
How the Model Was Used

The model was used to:

- *evaluate the potential benefit of prioritizing telecommunications service to the emergency responders*
- *evaluate a strategy of placing highest priority on restoring infrastructure services to emergency service providers*
- *evaluate how the time of day, hence the differences in people's location and behaviors, influence the effectiveness of emergency services and the sensitivity of the model results to infrastructure service prioritization*



Calling Event < 20 hours

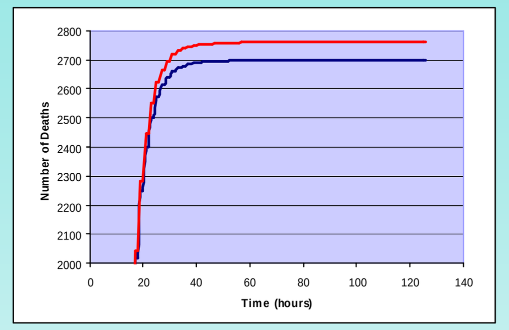


Repair Time for Networks 35 hours (communications) – months (transportation)

Results

For the input used in this analysis, we found that prioritizing telecommunications made a small but significant difference in the ultimate number of fatalities.

60 Fewer Deaths without Disruptions in Emergency Service Communication



Emergency Services Simulation and Analysis Earthquake During Rush Hour

We also found that the effectiveness of emergency services was not significantly hindered by infrastructure damage. Although the delivery systems for power, natural gas, and water, along with the transportation system, suffered large capacity losses, the emergency services were not constrained by interruptions in the availability of key materials. They were able to provide services faster than the rates at which structural damage could spread or human injury worsen. As a result, restoring infrastructures to emergency services provided little response benefit, and slightly increased restoration times to other infrastructure users. However, we believe that improvements in modeling the transportation infrastructure could disclose other constraints on delivery of emergency services and suggest policies that could help relieve those constraints.

The results indicate that the model can be used to evaluate emergency response priorities and potentially improve emergency response through a better understanding of the interdependencies. This type of analysis can be used to identify areas where more detailed modeling and data analysis would be of benefit.

National Infrastructure Simulation & Analysis Center (NISAC)

The National Infrastructure Simulation and Analysis Center (NISAC) is being established as the first comprehensive capability to assess the system of infrastructures and their interdependencies. NISAC's core partners are Sandia National Laboratories and Los Alamos National Laboratory.

Mission: Provide fundamentally new modeling and simulation capabilities for the analysis of critical infrastructures, their interdependencies, vulnerabilities, and complexities. These advanced capabilities will help improve the robustness of our Nation's critical infrastructures by aiding decision makers in the areas of policy analysis, investment and mitigation planning, education and training, and near real-time assistance to crisis response organizations.

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