Resilience of Socio-Technical Systems in Disasters

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Research Overview

- **Risk Assessment** – how to monitor in real time?
- **Impact** – what are the short-term and long-term impacts?
- **Hazard Mitigation** – how to minimize negative consequences?
- Invest less in physical infrastructure
- Identify the governing solutions
- Assess the system-wide impact
- How to retrofit? In what order?
- How to avoid complete disruption?
Research Questions

- **Resilience**: human-centric perspective
- **Interdependence**: people and physical infrastructure
- Create the notion of adaption in people
- Make people more proactive instead of being reactive
- How to leverage social and information networks?
- How people are making decisions?
- How decisions are being changed?
- How to disseminate information?
- Large-scale modeling of real-world networks
Post-Tornado Recovery

- March 2-3, 2012 tornado outbreak
- Small towns in southern Indiana
- The recovery effort is ongoing

Household-level Recovery Time (N=294)

<table>
<thead>
<tr>
<th>Recovery Time</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 12 hours</td>
<td>15</td>
</tr>
<tr>
<td>12 hours to less than 1 day</td>
<td>2</td>
</tr>
<tr>
<td>1 day or more</td>
<td>3</td>
</tr>
<tr>
<td>2 days or more</td>
<td>10</td>
</tr>
<tr>
<td>1 week or more</td>
<td>12</td>
</tr>
<tr>
<td>2 weeks or more</td>
<td>15</td>
</tr>
<tr>
<td>1 month or more</td>
<td>85</td>
</tr>
<tr>
<td>6 months or more</td>
<td>90</td>
</tr>
<tr>
<td>12 months or more</td>
<td>62</td>
</tr>
</tbody>
</table>

World Bank’s Global Facility of Disaster Risk Reduction (GFDRR)

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Post-Tornado Recovery

“Denser Networks, Faster Recovery”
“Geographic Proximity, Faster Recovery”

Hurricane Sandy Evacuation

- Individuals are **more likely to evacuate**:
  - (+) Larger network size  
  - (+) Higher Heterogeneity (gender)  
  - (+) Longer length of relationship

Hurricane Sandy Crisis Communications

- ~ 52 M tweets
- ~ 13 M users
- Oct 14 - Nov 12, 2012
- Disaster Communication Networks

Giant Component

Largest Hub
Information Spreading Capacity

Information Spreading Capacity ~ power law

“Fewer Nodes with Higher Capacity, Many Nodes with Less Capacity”
Information Spreading Capacity

Centrality (↑) → Spreading Capacity (↑)
Crisis Communication Patterns

- **Warning** phase:
  - storm prediction
  - storm watch and advisory
  - storm preparedness
  - user concerns about the storm
  - previous hurricane experience
  - climate change and global warming

- **Response** phase:
  - basic needs of people
  - major infrastructures
  - different transportation facilities
  - responses from local officials
  - evacuation order
  - first responders

- **Recovery** phase:
  - disaster relief efforts
  - fundraising efforts
  - possible aftermath

- **Locations** of impacted areas
- **Time**
- **Media** coverage
- **Political** leaders
- **Celebrity** activities

System-wide Impact Assessment

**Demand Side Input**
- Household Characteristics
- Environment inputs
- Evacuation Behavior Models
  - Evacuation vehicles
    - Location and time for:
      - Prep. Activities
      - Evacuation

**Supply Side Input**
- Network Data
- Data Modeling
  - Input network
    - Road shapefile
    - Lane shapefile
    - Zone shapefile

**Agent-based traffic simulator**
- Network Partitioning
- Paralleled Scheduling
- Traffic Flow Models
  - Car Following
  - Lane Changing
- Routing

**Output preference**
- Travel time
- Clearance time, etc

**Measures of Effectiveness**

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Thank you!