Cascading Failures in Catastrophic Earthquakes: A Risk Finance Perspective

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Overview

- Cascading Failures in Earthquakes
  - Examine why cascading failure risks matter to the Risk Finance System
  - Consider trends in business and technology that may increase cascading failures in earthquakes and look at the experience of Tohoku
  - Explore what risk management approaches can be improved to anticipate and control cascade-driven losses

(Photos: US Navy/Matthew M. Brady, Katorsi, and Ben Farone)
Infrastructure Interdependency

- Cascading failures: when individual failures are communicated to other infrastructures
- Cascading ability proportional to:
  - Compactness of inter and intra-network functions – density and immediacy
  - “Health” of the infrastructure – resiliency and adaptability

Simplified Risk Finance System

- (Re)Insurance
- Retrocession
- Risk Capital
- Regulation
- Rating

(Rinaldi, 2001)

(Tillman, 2012)
Trends Toward Cascading Failures?

**Physical Infrastructure**
- Systems operating near capacity limits
- Limited investment or maintenance
- Lack of “inter-system” design specification
- Small deficiencies stack up, quickly spread through network
- Intervention by government is ineffective
- Social unrest

**Business Environment**
- Globalized Production
- Supply chain optimization – just in time economics
- Low-cost versus high-flexibility
- Contingent business interruption
- Supplier fragility leads to recovery snags
- Market-share loss

**Risk Finance**
- Using models without stress-testing
- Diversification with unrecognized correlation
- Inter-action at the extreme tails
- Loss amplification beyond typical multipliers
- Very rare, but extreme events shock investors
- Industry-wide capacity shortages

Which Historical Events Had Cascading Failures?

<table>
<thead>
<tr>
<th>Event/Location</th>
<th>Year</th>
<th>Contributors to Cascade</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Francisco, CA</td>
<td>1906</td>
<td>Post-EQ fire caused by ruptured gas mains, loss of water supply system, excessive demolition during fire fight</td>
<td>25,000 buildings and 490 city blocks destroyed</td>
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<tr>
<td>Kanto, Japan</td>
<td>1923</td>
<td>Post-EQ Fire, loss of water supply, tsunami</td>
<td>&gt;100,000 deaths</td>
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<tr>
<td>Oakland, CA</td>
<td>1991</td>
<td>Fire damage to power lines feeding 17 water pumping stations (Oakland water) Lack of interoperability of communication systems and fire responder equipment. Access limitations on wildland-urban interface roadways</td>
<td>25 deaths, $1.5B in damage. Fundamental change in the way disasters are managed in CA.</td>
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<tr>
<td>Hurricane Katrina</td>
<td>2005</td>
<td>Failure of levees (80% of NO flooded), loss of power, roadway damage, incomplete evacuation, uncoordinated disaster response.</td>
<td>&gt;1,800 deaths, &gt;1 million people relocated, $81B in damage, including widespread unemployment, reduced tax revenue.</td>
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<tr>
<td>Tohoku, Japan</td>
<td>2011</td>
<td>Tsunami, nuclear crisis</td>
<td>&gt;200,000 evacuated, power shortage, future of nuclear power in question in Japan and elsewhere, serious interruptions in global supply chains for car parts and electronics</td>
</tr>
</tbody>
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Critical Impact on the “Excess of Loss Position”

- Un-modeled loss increase risk for the Excess of Loss position:
  - Model bias (hazard, vulnerability, loss amplification factors, etc.)
  - Correlation not captured; Underestimates in uncertainty
  - Cascading failures

Towards Quantifying Extreme Tail Impacts

- Some vendor models employ “non-linear factors” to capture interdependent cascading failures
  - Proportional to the size of the event
  - Compactness of exposure matters
- Deterministic safety tests
  - Set boundary conditions according to exposure spread
  - Correlate to other risk exposures
  - Stress-test loss components, especially the proportionality of consequential losses in extreme tails (e.g., fire-following loss as a percentage of overall ground-up shake loss)
Toward Quantifying Extreme Tail Events

- Recognize current modeling limitations for cascading failures in earthquakes
  - Parameter risk in models is poorly informed in models; events are the rarest of the rare
  - Complex infrastructure appears simple, so sensitivities may be underestimated (Carlson and Doyle, 1999)
  - Models for our evolving infrastructure may not anticipate the “sustainability challenge” (Chang, 2009)
- Identify where control and intervention points will limit cascading failures

Summary

- Cascading events in earthquakes can incite unanticipated losses to the risk finance industry
- We need to be able to anticipate the influence of cascading failures as trends intensify interconnections globally
- Quantifying this risk helps businesses and governments take proactive measures to control the worst consequences of cascading failures.

(Phillip Capper, 2005)