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# 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

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

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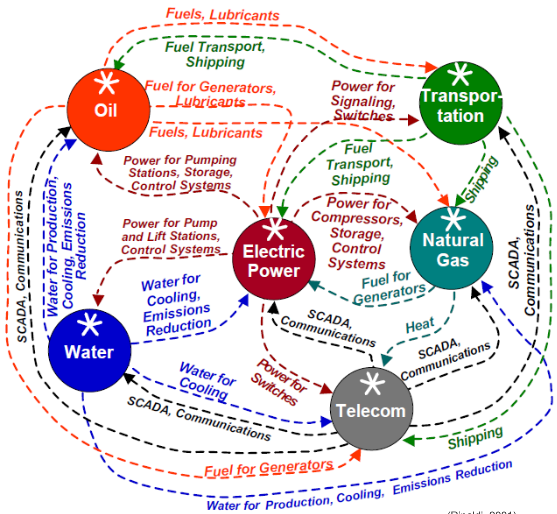
## Infrastructure Interdependency

- 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




(Rinaldi, 2001)

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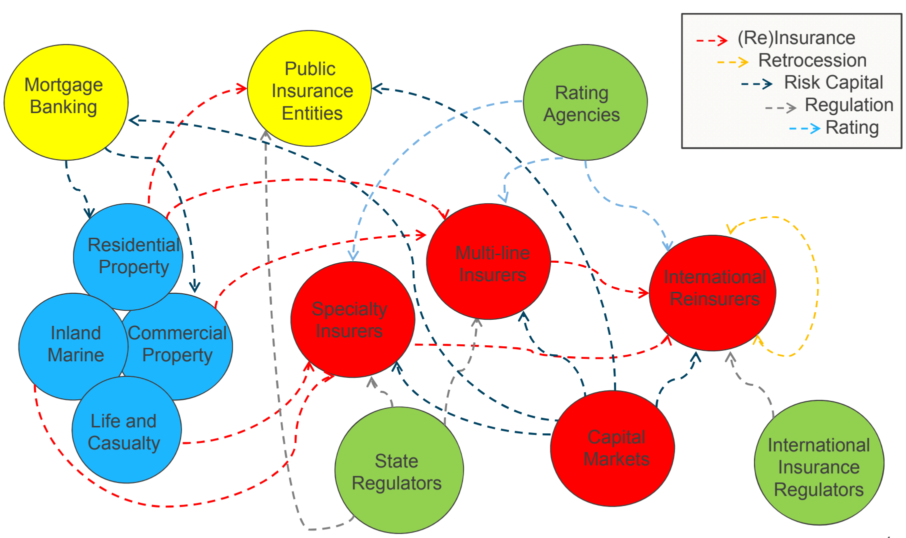
## Simplified Risk Finance System




(Tillman, 2012)

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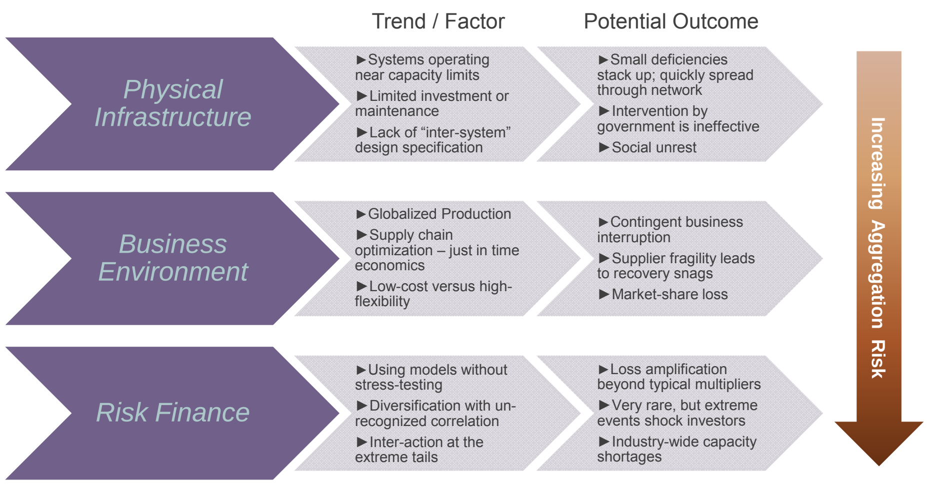
## Trends Toward Cascading Failures?

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## Which Historical Events Had Cascading Failures?

| Event/Location | Year | Contributors to Cascade | Effects |
|---|---|---|---|
| San Francisco, CA Earthquake | 1906 | Post-EQ fire caused by ruptured gas mains, loss of water supply system, excessive demolition during fire fight | 25,000 buildings and 490 city blocks destroyed |
| Kanto, Japan Earthquake | 1923 | Post-EQ Fire, loss of water supply, tsunami | >100,000 deaths |
| Oakland, CA Firestorm | 1991 | 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 | 25 deaths, $1.5B in damage. Fundamental change in the way disasters are managed in CA. |
| Hurricane Katrina, LA, MS, AL | 2005 | Failure of levees (80% of NO flooded), loss of power, roadway damage, incomplete evacuation, uncoordinated disaster response. | >1,800 deaths, >1 million people relocated, $81B in damage, including widespread unemployment, reduced tax revenue. |
| Tohoku, Japan | 2011 | Tsunami, nuclear crisis | >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 |

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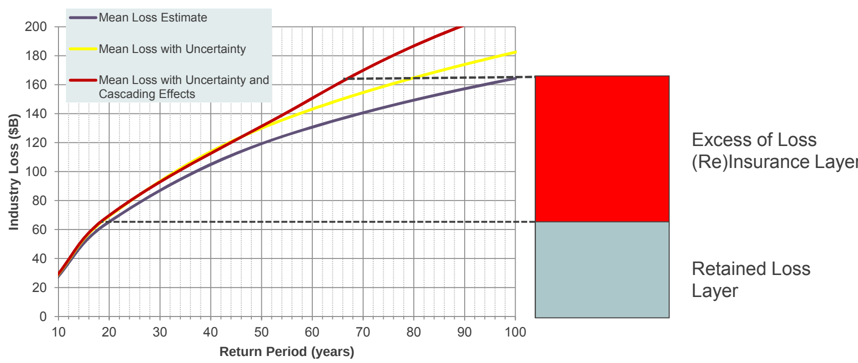
## Critical Impact on the "Excess of Loss Position"

- 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

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## 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)

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## 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

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## 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)

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