USING CATASTROPHE RISK MODELS TO OPTIMIZE SUPPLY CHAIN RESILIENCE

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CATASTROPHE RISK MODELLING FOR INSURANCE

Recent history

Earthquake +

Pandemic

Hurricane +

Toxic release

Flood

Cyber

Synthetic history
FRAMEWORK FOR EARTHQUAKE RISK MODELING

Define Events
Create a set of earthquake events that characterize long-term probabilities

Assess Ground Motion
Calculate the ground motion for all sites due to each stochastic event

Calculate Damage
Calculate the average damage and associated uncertainty. Determine the business downtime.

Quantify Risk
Calculate the financial impact for all perspectives
THE OUTPUTS OF A CATASTROPHE LOSS MODEL

- The EP curve provides a visual interpretation of loss potential

- Each point of the curve has an associated threshold and probability of exceedance
SUPPLY CHAIN CATS: 2011 THAI FLOODS

• Six large industrial estate ‘business clusters’ established on Chao Phraya flood plain in the 1990s
• Low levels of flood protection
• 2011 Sept-Nov floods lasted 4-9 weeks
• 7,510 industrial and manufacturing plants flooded,
SUPPLY CHAIN CATS: 2012 SUPERSTORM SANDY

• Caused widespread damage to the logistics and transportation networks in the US MidAtlantic region.

• Ports and terminals from Baltimore to New York were temporarily closed causing shipping carriers to either delay or reroute shipments for a week.

• Even after a month, Port Authority of NY & NJ only operating at 75 percent.
SUPPLY CHAIN CATS: XIRALLIC 2011 JAPAN EQ

• Sole manufacturer of a pearl-luster pigment paint that makes cars sparkle

• Plant suffered shaking damage in March 11th 2011 M9EQ

• Factory was situated in the initial radiation exclusion zone

• Site inaccessible until radiation release stabilized

• Production resumed May 8th 2011 – backlog cleared by September 2011
A\%(xB) indicates contribution factor A and maximum capacity B.

### Suppliers

<table>
<thead>
<tr>
<th>Topology</th>
<th># of main facility buildings / sites</th>
<th># of suppliers buildings / sites</th>
<th># of distributions buildings / sites</th>
<th>Total # of buildings / sites</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3rd Tier</td>
<td>4</td>
<td>2 / 2</td>
<td>8 / 7</td>
<td>9 / 8</td>
<td>Add Daikoku and Yokosuka</td>
</tr>
<tr>
<td>2nd Tier</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Disclaimer or model ports</td>
</tr>
<tr>
<td>1st Tier</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Facility

- Metal Forging
- Rear differential gears
- Transmission
- Assemble

### Distributions

- Domestic distributions
  - Tohoku
  - Ota
  - Kanagawa
  - Toki
  - Kansai
  - Fukuoka
  - HBC1
  - HBC2

- Global distributions
  - 12.5\%(x1.9)
  - 1.4\%(x1.9)
  - 1.8\%(x1.9)
  - 6.9\%(x1.9)

Additional suppliers

- Inomaki (90\%(x1.2))
- Ichitan (10\%(x1.2))
- Nakine
- Gifu
- MotorX Main
- MotorX TK
- Rear differential gears
- Metal Forging
- Transmission
- Assemble

A\%(xB) indicates contribution factor A and maximum capacity B.
COMBINING RESTORATION CURVES IN A CBI MODEL

Network downtime caused by the specified earthquake event

Days after an event

Restored function

Facility
Suppliers
Distributions
Combined Restoration

Facility
Suppliers
Distributions
Combined Restoration

0% 0% 0%
50% 100% 30%

0 0.5 1

0 0.5 1

0 0.5 1

0 0.5 1
### AVERAGE EDT (CBI RATIO)

**TOHOKU 2011**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Analysis</th>
<th>Description</th>
<th>Direct BI EDT (Yakita)</th>
<th>Scenario 1 Suppliers+ (Yakita+Main)+Distributions</th>
<th>Scenario 2 Suppliers+ (Yakita)</th>
<th>Scenario 4 Suppliers outside MX (Yakita)</th>
<th>Scenario 3 (Yakita)+Distributions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Analysis case 1</td>
<td>No inventory, no extra capacity</td>
<td>75.5 (2797%) 90pct: 137.6</td>
<td>7.5 (279%)</td>
<td>74.7 (2769%)</td>
<td>3.0 (110%)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Analysis case 2</td>
<td>With inventory, with extra capacity</td>
<td>65.3 (2421%) 90pct: 129.2</td>
<td>4.0 (149%)</td>
<td>64.7 (2398%)</td>
<td>2.7 (99%)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Analysis case 3</td>
<td>With inventory, with extra capacity 30 days inventory for Ketesa</td>
<td>53.3 (1974%) 90pct: 118.0</td>
<td>4.0 (149%)</td>
<td>52.1 (1929%)</td>
<td>2.7 (99%)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Analysis case 4</td>
<td>With inventory, with extra capacity 21 days inventory for Ketesa</td>
<td>57.6 (2135%) 90pct: 121.5</td>
<td>4.0 (149%)</td>
<td>56.5 (2095%)</td>
<td>2.7 (99%)</td>
<td></td>
</tr>
</tbody>
</table>

*Note: EDT indicates contribution factor A and maximum capacity B.*

**Average EDT Function (Scenario 1)**

- Analysis case 1
- Analysis case 4
- Analysis case 5
- Analysis case 6

*Restored function*
Probabilistic analysis produces a risk profile for the overall network and for each location of the network.

A MotorX operational Risk Curve is a profile of potential network downtime caused by any earthquake event occurring anywhere in Japan.

- Unique Risk Curve for each network, for each location of a network

March 11th Tohoku event (600 years)

14 days once in 57 years

60 days once in 500 years
WHAT IS THE COST-BENEFIT OF TAKING ACTION…?

Risk Curve supports traditional financial analysis of investment payback

Example risk improvement to the network Risk Curve

Company X  Target RT

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Cost</th>
<th>Reduction of Risk</th>
<th>Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-week</td>
<td>1000</td>
<td>2-weeks</td>
<td>500</td>
</tr>
<tr>
<td>2-weeks</td>
<td>100</td>
<td>1-month</td>
<td>50</td>
</tr>
<tr>
<td>1-month</td>
<td>10</td>
<td></td>
<td>10</td>
</tr>
</tbody>
</table>

Risk Curve supports traditional financial analysis of investment payback.
IDEALLY EACH ELEMENT OF SUPPLY IS TRACKED USING THE ‘SUPPLIER’S DATA SCHEMA’

- High Res location of supplier
- Buildings, Ages, Construction, etc
- Lifelines of the supplier
- Details (Code) for what is being supplied
- Flow of supplies (per day/week)
- Route of supply
- Key ports/airports
- Destination

- Information is also requested for the supplier’s own upstream sub-supply chain
THE SUPPLY CHAIN RISK MANAGEMENT SYSTEM IS USED TO EXPLORE REDUNDANCY AND MANAGE SHOCKS

Flows are viewed passing through the supply chain

What if a key supply is interrupted for a week?
What if a key supply is interrupted for three months?

Current Supplier
Onsite Inventory
Optional Supplier & ramp-up time
Offsite Warehousing
## USING CATASTROPHE RISK MODELS TO MEASURE SUPPLY CHAIN RISK

<table>
<thead>
<tr>
<th>Focus on unique suppliers/technology</th>
<th>Full range of potential catastrophes</th>
<th>Exceedance probability loss outputs</th>
<th>Explore risk costs to optimize supply chain</th>
</tr>
</thead>
</table>

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10 KEY DISASTERS FOR SUPPLY CHAIN RESILIENCE PLANNING

VEI 6 Eruption Mt Fuji

NEUS Hurricane and flooding *

M7.4 Tokyo Earthquake *

Rhine River flooding *
10 KEY DISASTERS FOR SUPPLY CHAIN RESILIENCE PLANNING

Mw7.2 Hayward Fault
Pearl River Delta Typhoon & Flooding
Cascadia M9 earthquake
Pandemic work disruption

* Indicate events that have occurred.
10 KEY DISASTERS FOR SUPPLY CHAIN RESILIENCE PLANNING

Mw7.8 Earthquake
Taiwan

Los Angeles M7.2
earthquake
PORT TRANSPORT INTERRUPTIONS – TOP 12 EARTHQUAKE ‘RISK’ (PROBABILITY X CONSEQUENCE) LOCATIONS

1. Nagoya
2. Yokohama*
3. Izmit
4. Oakland
5. Lazaro Cardenas
6. Chiba*
7. Los Angeles
8. Tokyo*
9. Seattle
10. Osaka@
11. Taichung
12. Kobe@

* / @ Potential to be hit by the same earthquake