Quantifying Supply Chain Resilience

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Overview

• Current State and Evolution of Supply Chain Resilience

• Quantifying Resilience Current State

• Industry Perspective and Actions

• Quantifying Resilience Challenges
Current State and Evolution of Supply Chain Resilience (SCR)

Evolu3on of SC Resilience

- Global Companies: GM, Cisco, Intel
  P&G, UPS, DHL

Data-based investment decisions
Options Developed
Willingness to act
Recognition/Awareness

9/11 Katrina Thai Floods Sendai

Arrow/Bar size suggests adoption
Supply Chain Resilience Current State

- Operational uncertainty still exists
  - Daily variation
  - Disruptions

- Options for addressing uncertainty plentiful & known

- But pursuing resilience is proving difficult for practitioners

Why is it so difficult? → Lots of open questions

- How resilient is our SC? How much resilience should our SC have?
- Do you know your Tier 1 suppliers? And their factory locations? How about T2, T3, T4+?
- So many sources of risk – where do we start?
- What is the ROI... on an investment that avoids a disruption? + - %?
- How much should we invest? And in what resilience initiatives?
- How to choose between investing in Growth or Resilience?
  - Growth always wins*

*Gary Lynch, The Risk Project, April 2015


How to choose between investing in Growth or Resilience?

Growth always wins*
Most of these questions are addressed by Quantifying Resilience....

But it is only emerging recently

Quantifying Resilience Current State
Quantifying Resilience: Early Contributions

- Hendricks and Singhal studies (2003, 2005, 2009) indicated shareholder wealth drop >10% for shipment or production delays, almost 7% with excess inventory
  - Helped socialize the importance and potential impact of SC glitches
  - But Zsidisin, Petkova and Dam (2016) studies suggest lower impact, ~1.94% impact from glitch announcement

- Measurement of resilience only recently surfacing in literature reviews
  - Most work on risk mgt, quantifying risk, vulnerabilities growing from early 2000s
  - Christopher and Peck (2003) put forward a qualitative risk assessment tool
  - Pettit (2008) and Pettit, Fiksel and Croxton (2010), earlier authors to write about measuring supply chain resilience, described optimal resilience, a ‘zone of resilience’ outside of which eroding profits or exposure to risk serve as measures. Conceptual. But also proposed use of Supply Chain Risk Assessment Model (SCRAM)
  - Klibi, Martel and Guitouni (2008, 2010) a seminal brief on measurement and the challenges that exist for researchers desiring to model for supply chain network design
  - Schmitt and Singh (2009) measured risk, assessed mitigation strategies cf risks
  - Paulsson, Nilsson and Wandel (2011) estimate disruption risk exposure into estimated and known result impacts

Quantifying Resilience: Promising recent work

- Aqlan and Lam (2015)
- Cardoso, Barbosa-Póvoa, Relvas and Novais (2015)
- Barroso, Machado, Carvalho and Machado (2015)
- Munoz and Dunbar (2015)
- Snoek (2016)
- Braud and Gong (2016)
Quantifying Resilience: Risk Management

• Many models for risk management
  – Assessing vulnerabilities, focused on various sources of risk
  – Kaplan and Mikes simple segmentation into 3 risk types and specific actions to take for each
    • Risk Report Card, Risk Event Card

Quantifying Resilience: Catastrophe Models

• Catastrophe Models
  – Limited loss data from rare occurrences, Property focused
  – Very effective at leveraging new emerging data streams
  – Collect physical characteristics data on natural disasters, terrorism and generate full spectrum of potential events, then tested and sensitivities for intensity; these are then applied to detailed property data to create a damage function – identifies type of damage expected for properties of different characteristics (construction, use, occupancy) and then assesses financial damage associated with the physical damage
  – Output is a loss forecast over a range of 10-100 years
  – Not detailed enough for practitioners, only considers physical damage to property
Quan3fying Resilience: REI, VaR

- **Value at Risk** — a measure of the peak value (revenue, profit, contribution) that is assessed to be at risk within a supply network, often measured at nodes and then combined to provide a network-wide value at risk.

- **Risk Exposure Index** (Simchi-Levi, 2012) provides an indexed risk rating of 0.0->1.0 based on the performance impact (revenue, margin, units) from disruption for each node. Uses Time to Recovery (TTR) at each supply chain node to identify the cost from a potential disruption, noting financial impact at the node and then across the network.

- **Time to Recovery (TTR)** per Cisco Systems, Inc. is “...based on the longest recovery time for any critical capability within a node, and is a measure of the time required to restore 100% output at that node following a disruption” (O’Connor 2009). Simchi-Levi defines it as “the time it would take for a particular node — a supplier facility, a distribution center, or a transportation hub — to be restored to full functionality after a disruption.”

- **Time to Survive (TTS)** — proposed by Simchi-Levi (2015) “is the maximum duration that the supply chain can match supply with demand after a node disruption.” Very useful to identify supply nodes where the TTR is longer than the TTS → blackout/ouage predictable.
Quantifying Resilience: Balanced Scorecard of Resilience

**BALANCED RESILIENCE SCORECARD**

<table>
<thead>
<tr>
<th>QUANTITATIVE</th>
<th>QUALITATIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value-at-Risk</td>
<td>Probabilities</td>
</tr>
<tr>
<td>Cost to Recover (TTR)</td>
<td>Cost to Mitigate</td>
</tr>
</tbody>
</table>

* SCRLC Risk Mgt Maturity Assessment, SCRAM Method, Cranfield/Christopher-Peck Method

- Multi-level assessment – node, supply chain, extended SC
- Various ways to understand the expected Business Impact
- Measure and quantify (Time to Recover (TTR))

Disruption Timeline Data Ex.

**Cost to Recover**

**Cost to Mitigate Consequences**

<table>
<thead>
<tr>
<th>Timeline Event</th>
<th>Steady State</th>
<th>Disruptive Event</th>
<th>Backup Supplier</th>
<th>Baseline Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steady State</td>
<td></td>
<td>Disruption of supply chain</td>
<td>Backup Supplier</td>
<td>Baseline Supply</td>
</tr>
<tr>
<td><strong>Total Business Impact</strong> AKA TTS or 'Time to Survive'</td>
<td>= Lost Sales Contribution + Increased Cost of Recovery</td>
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</tbody>
</table>

Ref.: Jaspar Siu and Santosh Stephen, 2015
Explanation: Computing Expected Business Impact

$$\text{Expected Business Impact} = \text{Total Business Impact} \times \text{Probability}$$

- Lost Contribution
  - Blackout Period x Part Volume Rate
  - Contribution / Unit
- Cost Increase
  - Backup Period x WIP Volume Rate
  - Cost Increase / Unit

Geo-political risk → Natural Disaster risk → Supplier risk → Process risk

Example: Expected Business Impact at a Node

Ref.: Jaspar Siu and Santosh Stephen, 2015
Resilience Analytics: Quantitative Data Needs

- Value-at-Risk
- Risk Exposure Index
- Expected Business Impact
- Cost to Recover
- Cost to Mitigate consequences
- Cost to Mitigate probabilities
- Time to recover
- Time to survive
- Blackout
- Time to backup

Ref.: Jaspar Siu and Santosh Stephen, 2015

Quantifying Resilience: An Assessment

- Risk Exposure Index & Value at Risk
  - Helps identify priorities, and quantify revenue or profit loss potential; but does not provide insight into which options to choose or how much to invest

- Expected Business Impact
  - Difficult to take into consideration different risk preferences and uncertainties

- Balanced Scorecard of Resilience
  - Provides a more holistic assessment, but depends on qualitative work in addition to quantitative assessment

- The Frontier
  - Defining the business investment case, getting full set of data to make choices is starting to take shape (e.g. DSL Ford study)
Industry Perspective and Action

Ongoing Mapping and Monitoring

• Design and install monitoring systems
  – Global event monitoring: geographic, political, weather
  – Supplier operational and financial health
  – Monitor entire network, find your sources

• Mapping monitoring services can help
  – Mapping upstream supply chain
  – Maintaining supplier data bases
  – Disaster tracking, monitoring, alert/notification management
  – Have helped companies mitigate
Cisco Resilience Index

Resiliency Index Overview

Key Elements Considered
- Single Sourced
- Component Supplier TTR
- End of Life Parts
- Supplier Financial Health
- Supplier BCP Compliance
- Non PSL and New Suppliers
- Dual Manufacturing Sites
- Qualified Alternate Sites
- Manufacturing TTR
- Test Equipment TTR

Supply Chain Risk Leadership Council

An industry council comprised of world class supply chain firms working together to develop and share supply chain risk management standards and best practices.

www.scrlc.com
### SCRLC Supply Chain Risk Mgt Maturity Model*

<table>
<thead>
<tr>
<th>Category</th>
<th>Sub-category</th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
<th>Stage 4</th>
<th>Stage 5</th>
<th>Initial Notes</th>
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</thead>
<tbody>
<tr>
<td>1A. Executive Leadership</td>
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<td>1B. Line/Functional Leadership</td>
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<td>1C. Governance</td>
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<td>1D. Resources &amp; Commitment</td>
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<td>1E. Program Communication</td>
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</tbody>
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### One company’s approach

- No “single system metric” to quantify supply chain risk
- Supply Chain risk reduction is part of Enterprise Risk Management
- Assess three factors
  - Impact, vulnerability and speed of onset
  - High, medium, low and some dimensions of each
  - Plot on Vulnerability – Impact chart to create relative priorities
- Executives are assigned to reduce the risk to an agreed to manageable level, making informed risk/reward based decisions
- Decisions based on qualitative and some quantitative information, committee input
**Proposed Standard Measures**

- Revenue protected by meeting risk criteria
- Time to Recover
- Time to Survive
- Value at risk
- Estimated Maximum Loss
- Probable Maximum Loss
- Likelihood of Occurrence
- Sole supplier
- Strategic Product Protection
- Critical sites protection
- Risk Mitigation Actions status
- Categorization of risk type
- Risk Investment cost

That's a lot of data!
Accessible?
Qualitative?
Calibrated?

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**Quantifying Resilience Challenges**
The Challenges & My Suggestions

- Focus on source of disruption risk or outcome from the disruption?
  - Most research is conducted on the many different sources of risk, rather than the predictable set of limited outcomes → Failure Modes.
Supply Chain Failure Modes/Predictable Outcomes

All disruptions result in a loss of one or more of these capacities:

- Capacity to acquire materials (supply)
- Capacity to ship/transport
- Capacity to communicate
- Capacity to convert (internal operations)
- Human resources (personnel)
- Financial flows


The Challenges & My Suggestions

• Focus on source of disruption risk or outcome from the disruption?
  – Most research is conducted on the many different sources of risk, rather than the predictable set of limited outcomes → Failure Modes.

• Refine the use of ‘Mitigation’
  – Mitigate the probability of a disruption? → Prevention, focus on source of risk
  – Mitigate the consequences of a disruption? → Resilience, focus on outcomes

• Finding and accessing the data
  – The raw data is not readily available and process not scalable
  – Identify proxies and processes that can work to get TTR, TTS, Blackout, Cost to mitigate consequences, Cost to recover

• Develop resilience analytics to enable the investment decision
  – Using new data sources, options analysis, tradeoffs; bring innovation (and marketing) into the process
Guidance we can provide today

- How resilient is our SC? Measure REI, VaR, EBI, TTR, TTS, Cost to recover, Cost to mitigate, Balanced Scorecard.

- Upstream mapping resources
  - Available in public domain.... But it requires constant attention

- Calculate ROI? + - %?
  - Enlist advocates and build the business case

- Growth or Resilience?
  - Resilience (especially flexibility) enables growth

So many sources of risk – where do we start? Focus on failure modes, predictable and limited # of outcomes

Which investment options? Structured options and resilience analytics


Growth or Resilience?
Resilience (especially flexibility) enables growth

Auto OEM Business Continuity Planning Executive

“Yes, I agree that investing in supply chain can absolutely drive growth – we just need to help the leadership see the connection.”
Thank You

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