Flexibility in Supply Chain Systems: Past, Present, and Future

Michael Lim
Department of Business Administration
University of Illinois @ Urbana-Champaign

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What is Flexibility?

Consider:

• 10 Production Plants (capacity = $\mu$)
• 10 Products with each $D \sim N(\mu, \sigma^2)$

How to build flexibility into the system to minimize the unmet demand?
“Flexibility is the ability to produce different types of products in the same manufacturing plant or production line at the same time. Increasing flexibility is a key strategy for improving supply chain responsiveness in the face of uncertain future demand.”

Cachon and Terwiesch (2011)
Chaining Guideline

To be most effective for meeting customers’ demand, flexibility should be added in the configuration of fewer and longer chains.
Chaining Flexibility (*Jordan & Graves 1995*)

**Benefit of Chaining Configuration**

- **Performance of two configs under various capacities**
  - 10 demand nodes with $E[D] = 1,000$
  - 10 supply nodes; varying capacity $C = 500$ to $1,500$

- **Value of flexibility depends on the capacity**
  - The performance gap is the widest when $E[D] = C$

- **Flexibility and capacity are “substitutes”**
Past: Literature Review (1995-late 2000s)

Chaining in various Operations Management Literature

- **Cross-trained workforce**: Hopp et al. (2004), Iravani et al. (2005; 2007)
- **Service systems** (call centers): Gurumurhi and Benjafaar (2004), Bassamboo et al. (2008; 2010)
- **Transshipment Logistics**: Herer et al. (2006), Lien et al. (2011)
- **Multi-echelon supply chains**: Garavelli (2003), Graves and Tomlin (2003), Hopp et al. (2010)
- **Healthcare process**: Murray (2000), Inram et al. (2005)

Chaining in Industry

- **Ford** (Chelst et al., 2001), **General Motors** (Jordan et al. 2004), **Chrysler** (LaSorda, 2004), **Toyota** (Hopp et al. 2005)
- **IBM e-business** (Shi & Daniels 2003), **IBM semiconductor** (Hood 2005)
- **Pepsi** (Simchi-Levi 2007), **PCB** (Chang et al., 2002), **Food-from-the-Heart** (Chou et al., 2005)
Refinement of J-G’s under SC Disruption

Are insights from JG always true?
What if we incorporate supply chain disruptions?

Some Evidences….
- Tomlin and Wang (2005), Mak and Shen (2009): Conditions that flexibility is not preferred
- Snyder and Shen (2006): Strategies for SU are often opposite to DU
- Bish et al. (2005), Muriel et al. (2006): Excessive flexibility are not always cost-effective
- Qi and Shen (2007), Schmitt et al. (2007) and more on…

Research Question (Lim, Bassamboo, Chopra, Daskin 2010)
Understand how J-G's flexibility guideline performs (and should be refined) when random disruptions are taken into account
Flexibility with Disruptions (Lim et al. 2010)

Symmetric and balanced system

Two types of Disruptions:
- Link Failure (LF), Node Failure (NF)

Measure of disruption: Fragility
- Difference in the expected total cost before and after disruptions
- Degree of system degradation due to disruptions

Key Take-aways:
1. When disruption probability is low (Single failure):
   - If more susceptible to LF → decrease the size of chain (Containment)
   - If more susceptible to NF → increase the size of chain (Coverage)
2. When disruption probability is high (Multiple failures):
   - Containment becomes very effective for both
3. Investment in “capacity” is essential, as flexibility alone is not enough
**Present**: Recent (working) Papers

**Supply Chain Disruption and Flexibility**

- To invest in prevention or flexibility?: Benaïcha et al. (2013), Saghafian and Van Oyen (2013)
- Flexible network on global supply chain: Tomlin (2014)
- Chaining and demand allocation with disruptions: Ben-Aicha et al. (2014)
- Integration with operations: Simchi-Levi et al. (2014)

**Theoretical Advancement in Flexibility/Chaining Structure**

- Asymmetric System: Deng and Shen (2013)
Notable Recent Research

Technical Advancement in Characterizing the Chaining Performance

   - Supermodularity
   - Decomposition

2. Desir et al. 2014
   - Optimality of connected chains using coupling and swapping argument

Increasing Robustness with Joint Inventory-Flexibility Consideration

Simchi-Levi et al. 2014

1. Adding extra degree of flexibility in K-chains

2. Implication to assemble-to-order system:
   - Decouple recurrent supply fluctuation from supply disruption
   - With high flexibility → inventory common components
   - With low flexibility → inventory non-common components
**Future**: Where do we go from here?

Remaining challenges:

- Maybe a breakthrough?:
  - Desir, Goyal, Wei, Zhang (2014, working paper)
- Characterization for broader class of flexible configuration:
  - Asymmetric configuration, Non-balanced system, Correlated system

Merging theory to practice

- Integrating with additional features
  - Consideration of other logistics drivers?
- More applications?
- MIT-Ford collaboration (HBR 2014)
Thank You!

mlim@Illinois.edu