Supply Chain Supernetworks with Suppliers Risk Diversification

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Reliable Supply Chain

- Starts from reliable suppliers
- Supplier selection multicriteria
  - Benefits vs.Risks

Suppliers Selection

- Single source
  - Improved bargaining power to reduce costs
  - Decreased effort to track supplier performance and manage relationships
  - Improved innovation and design collaboration
  - Improved plan synchronization and information exchange
  - Improved supplier responsiveness

Cost Reduction

Suppliers Selection

Risk Category	Examples
Capacity Risk	• Output variability / availability • Lead time variability
Catastrophic Risk	• Natural disasters • War & terrorism
Quality Risk	• Specification non-compliance
Financial Risk	• Foreign exchange rates • Vendor liquidity / viability
Management Risk	• Embezzlement • Fraud
Contractual Risk	• Intellectual property protection
Market Risk	• Increased competitiveness from global competitors

Risks

Risks from suppliers

- Japan earthquake and tsunami
  - Parts shortage
    - Automobile industry: Toyota, Ford, GM, Honda,…
    - Electronic companies: Smart Phones, iPad,…
      - the earthquake-damaged Japanese plants produce 25 percent of the world's silicon wafers

The Hackett Group's Key Issues Study

Suppliers Selection

- Multiple sources
  - Reduce risks and disruption
  - Maintain a steady competition
  - Improve flexibility

Choice, Flexibility and Competition

Risks from the manufacturers

- Toyota's recall and "stop sale order" affected its part supplier CTS
  - Toyota represents 3% of its annual sales
  - General Motors, Ford and Chrysler represented 5% of total CTS sales

Assumptions

- Without lost of generality, we consider one part/material suppliers in the network
- There are *M* suppliers who compete with each other to supply the part/material to the manufactures. A typical one is called *i*
- There are *N* manufacturers producing a homogeneous product in a competitive way. A typical one is called *j*
- There are *L* retailers who serve the *O* markets in a competitive way. A typical retailer is called *l*; and a market is denoted as *k*
- Market demands are elastic that are functions of market prices

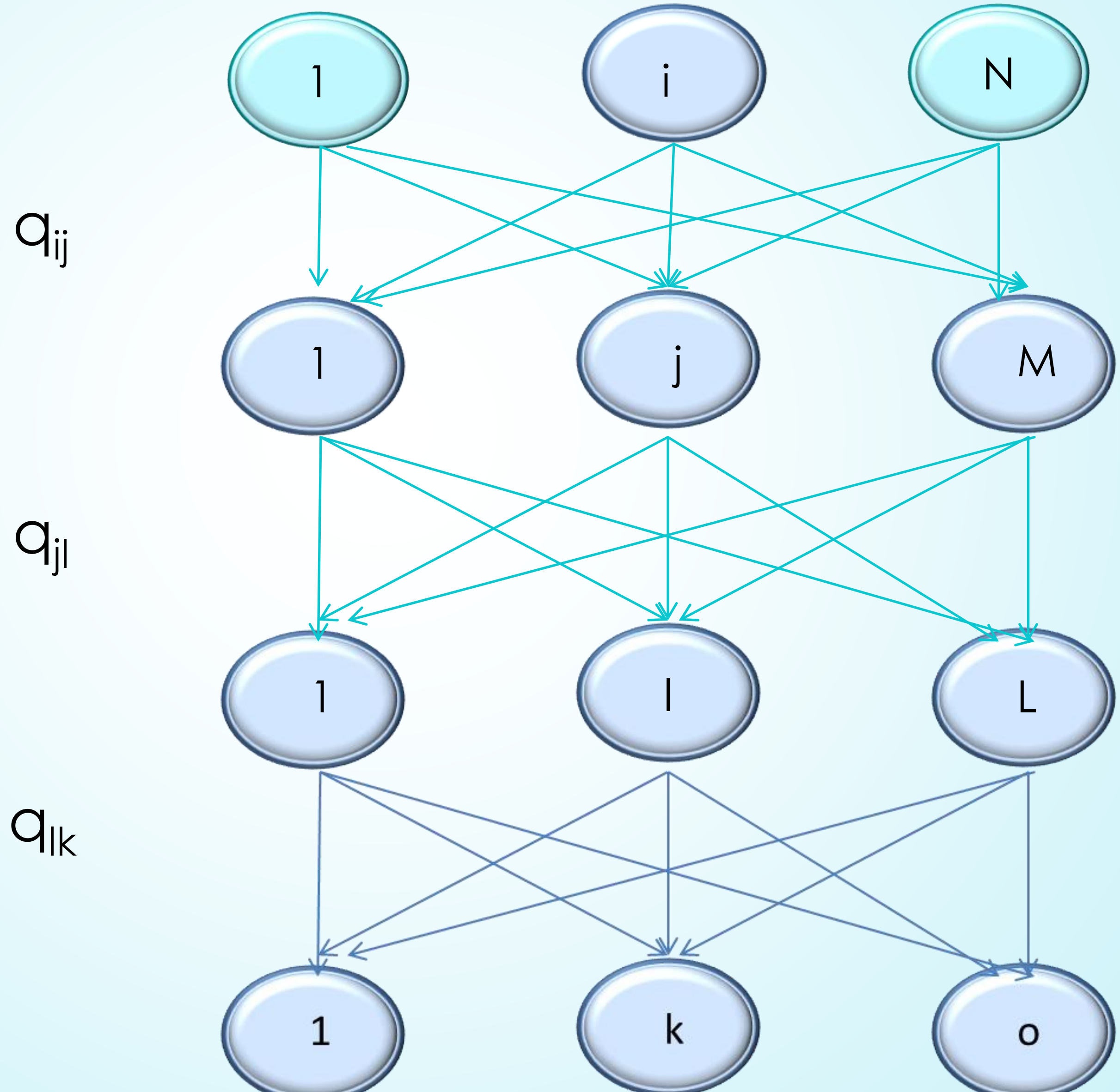
Supply Chain Supernetwork

Suppliers

Manufacturers

Retailers

Markets



Suppliers Risk Diversification

In order to reduce risk, in practice, suppliers often access the risk factors of manufacturers and determine the allocation parameters of their parts.

Assume the allocation parameter of supplier *i* to manufacturer *j* is α_{ij}, which could the maximum percentage supplier *i* will sell to manufacturer *j*.

Suppliers

- Production costs
- Transaction costs with manufacturers
- Revenues by selling parts to manufacturers

Supplier i, *i=1,…,N*

Maximize profit

$$= \sum_{j=1}^{M} \rho_{ij}^{1} q_{ij} - f_i(Q^1) - \sum_{j=1}^{M} c_{ij}(q_{ij})$$

s.t.

$$q_{ij} \le \alpha_{ij} \sum_{j=1}^{M} q_{ij}, \forall j$$

$$q_{ij} \ge 0, \forall j$$

Optimality Conditions

$$\left[-\rho_{ij}^{1}+\frac{\partial f_i(Q^{1*})}{\partial q_{ij}}+\frac{\partial c_{ij}(q_{ij}^{*})}{\partial q_{ij}}+\alpha_{ij}\xi_{ij}^{1*}-\xi_{ij}^{1*}\right]\times\left[q_{ij}-q_{ij}^{*}\right]$$

$$+\left[\alpha_{ij}\sum_{j=1}^{M}q_{ij}^{*}-q_{ij}^{*}\right]\times\left[\xi_{ij}^{1}-\xi_{ij}^{1*}\right]\geq 0,\forall i,j$$

Manufacturers Risk Diversification

Manufacturers, in turn, also access the risk factors of the suppliers and determine the order allocation parameters

The order allocation parameters from manufacturer j to supplier i is denoted β_{ij}, which might represent the order percentage from supplier i

Manufacturers

Production costs	Transaction costs with suppliers	Transaction costs with retailers	Purchasing costs	Revenues by selling products to retailers

Manufacturer j, *j=1,…,M*

Maximize Profit

$$= \sum_{l=1}^{L} \rho_{jl}^{2} q_{jl} - f_j(Q^2) - \sum_{i=1}^{N} \hat{c}_{ij}(q_{ij}) - \sum_{l=1}^{L} c_{jl}(q_{jl}) - \sum_{i=1}^{N} \rho_{ij}^{1} q_{ij}$$

s.t.

$$q_{ij} \le \beta_{ij} \sum_{i=1}^{N} q_{ij}, \forall i$$

$$\sum_{i=1}^{N} \gamma_j q_{ij} \ge \sum_{l=1}^{L} q_{jl}$$

$$q_{ij} \ge 0, q_{jl} \ge 0, \forall i, l$$

Optimality Conditions

$$\left[\frac{\partial \hat{c}_{ij}(q_{ij}^{*})}{\partial q_{ij}} + \rho_{ij}^{1} - \xi_{ij}^{2*} + \xi_{ij}^{2*}\beta_{ij} + \xi_{j}^{3*}\gamma_{j}\right] \times \left[q_{ij} - q_{ij}^{*}\right]$$

$$+\left[\frac{\partial c_{jl}(q_{jl}^{*})}{\partial q_{jl}} + \frac{\partial f_{j}(Q^{2*})}{\partial q_{jl}} - \rho_{jl}^{2} - \xi_{j}^{3*}\right] \times \left[q_{jl} - q_{jl}^{*}\right]$$

$$+\sum_{i=1}^{N}\left[\beta_{ij}\sum_{i=1}^{N} q_{ij}^{*} - q_{ij}^{*}\right] \times \left[\xi_{ij}^{2} - \xi_{ij}^{2*}\right] + \left[\sum_{i=1}^{N}\gamma_{j} q_{ij}^{*} - \sum_{l=1}^{L} q_{jl}^{*}\right] \times \left[\xi_{j}^{3} - \xi_{j}^{3*}\right] \geq 0$$

Retailers and Markets

- Transaction costs with manufacturers
- Handling costs
- Purchasing costs
- Revenue made from the markets
- Selling prices are market driven
- Demands are elastic

Retailer l, *l*=1,…,*L*

Retailer *l* serves the markets (*k*=1,…,O)

$$\rho_{lk}^{2*} + c_{lk}(Q^3) \begin{cases} = \rho_k^{3*}, \text{ if } q_{lk}^* \geq 0 \\ \geq \rho_k^{3*}, \text{ if } q_{lk}^* = 0 \end{cases}$$

$$d_k(\rho^{3*}) \begin{cases} = \sum_{l=1}^{L} q_{lk}^*, \text{ if } \rho_k^{3*} \geq 0 \\ \leq \sum_{l=1}^{L} q_{lk}^*, \text{ if } \rho_k^{3*} = 0 \end{cases}$$

Market Equilibrium Conditions

$$\left[\rho_{lk}^{2} + c_{lk}(Q^{3*}) - \rho_{k}^{3*}\right] \times \left[q_{jl} - q_{jl}^{*}\right]$$

$$+\sum_{k=1}^{O}\left[\sum_{l=1}^{L} q_{lk}^{*} - d_{k}(\rho^{3*})\right] \times \left[\rho_{k}^{3} - \rho_{k}^{3*}\right] \geq 0$$

Variational Inequality Formulation is developed

To determine

- the quantities that each supplier send to each manufacturer
- the quantities that each manufacturer sells to each retailer
- The quantities that each retailer sells to each market
- The part selling prices
- The product selling prices
- The market prices
- The market demands

Variational Inequality Formula

Determine $(Q^{1*}, Q^{2*}, Q^{3*}, \xi^{1*}, \xi^{2*}, \xi^{3*}, \rho^{3*})$ to solve the VIP:

$$\sum_{i=1}^{N}\sum_{j=1}^{M}\left[\frac{\partial f_i(Q^{1*})}{\partial q_{ij}} + \frac{\partial c_{ij}(q_{ij}^{*})}{\partial q_{ij}} + \frac{\partial \hat{c}_{ij}(q_{ij}^{*})}{\partial q_{ij}} - \xi_j^{3*}\gamma_j - (1-\alpha_{ij})\xi_{ij}^{1*}\right.$$

$$\left. -(1-\beta_{ij})\,\xi_{ij}^{2*}\right]\times\left[q_{ij} - q_{ij}^{*}\right] + \sum_{i-1}^{N}\sum_{j=1}^{M}\left[\alpha_{ij}\sum_{j=1}^{M} q_{ij}^{*} - q_{ij}^{*}\right]\times\left[\xi_{ij}^{1} - \xi_{ij}^{1*}\right]$$

$$+\sum_{j=1}^{M}\sum_{l=1}^{L}\left[\frac{\partial c_{jl}(q_{jl}^{*})}{\partial q_{jl}} + \frac{\partial f_j(Q^{2*})}{\partial q_{jl}} + c_{lk}(Q^{3*}) - \xi_j^{3*}\right]\times\left[q_{jl} - q_{jl}^{*}\right]$$

$$+\sum_{i=1}^{N}\sum_{j=1}^{M}\left[\beta_{ij}\sum_{i=1}^{N} q_{ij}^{*} - q_{ij}^{*}\right]\times\left[\xi_{ij}^{2} - \xi_{ij}^{2*}\right] + \sum_{j=1}^{M}\left[\sum_{i=1}^{N}\gamma_j q_{ij}^{*} - \sum_{l=1}^{L} q_{jl}^{*}\right]\times\left[\xi_j^{3} - \xi_j^{3*}\right]$$

$$+\sum_{k=1}^{O}\left[\sum_{l=1}^{L} q_{lk}^{*} - d_k(\rho^{3*})\right]\times\left[\rho_k^{3} - \rho_k^{3*}\right] \geq 0,$$

$$\forall (Q^1, Q^2, Q^3, \xi^1, \xi^2, \xi^3, \rho^3) \in \square^{NM+ML+LO+NM+NM+M+O}$$

Results

Existence: under certain conditions the solution to the VIP exists.

We solve the VIP problem using the Modified Projection Method.

Thank you