Supply Chain Network Design

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Disruption in Supply Chain

- Disruptions occur in supply chains, and their negative financial and technical impacts make the recovery process very slow.

Capacitated Supply Chain Network Design

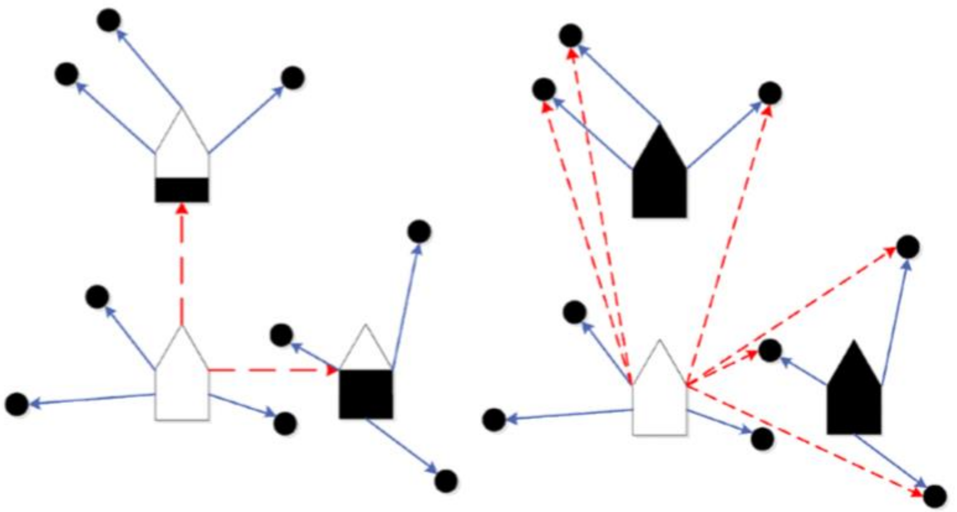
- A capacitated supply chain network design (SCND) model under random disruptions both in facility and transportation is presented.
- The model seeks to determine the optimal location and types of distribution centers (DC) and also the best plan to assign customers to each opened DC.

Improved Design

Assumptions:

- (1) Failure of DCs might be partial, i.e. a disrupted DC might still be able to serve with a portion of its initial capacity;
- (2) The lost capacity of a disrupted DC shall be provided from a non-disrupted one;
- (3) The lost capacity fraction of a disrupted DC depends on its initial investment amount in the design phase.

Improved Design



Improved vs Traditional

Indices & Sets

k	Index of customers; $k \in K$
i, j	Index of potential locations of DCs; $j \in J$
n	Index of available investment levels for opening and operating unreliable DCs; $n \in N$
r	Index of available unsafe transportation modes between DCs and customers; $r \in R$

Parameters - Costs

fU_{jn}	Fixed cost of opening and operating unreliable DC at j with investment level n;
fR_j	Fixed cost of opening and operating reliable DC at j;
e_{jkr}	Transportation cost from unreliable DC at j to customer k with unsafe transportation mode r.

Parameters - Costs

dp_{jk}	Transportation cost in the primary assignment from unreliable DC at j to customer k with safe transportation mode;
db_{jk}	Transportation cost in the secondary assignment from unreliable DC at j to customer k with safe transportation mode;
dr_{jk}	Transportation cost from reliable DC at j to customer k;
C_{ij}	Transportation cost from reliable DC at i to unreliable DC at j ($i \neq j$).

Additional Parameters

D_k	Demand of customer k;
κ_j	Capacity of unreliable DC at j;
τ_{jn}	Percentage of total capacity of unreliable DC at j that is affected by disruption when it is opened with investment level n;
q_j	Disruption probability in unreliable DC at j;
π_{jkr}	Disruption probability between DC at j and customer k when the unsafe transportation mode r is used.

Decision variables

XU_{jn}	1, if unreliable DC is opened at j with investment level n; 0, otherwise
XR_j	1, if reliable DC is opened at j; 0, otherwise
YR_{jk}	1, if customer k is assigned to reliable DC at j; 0, otherwise

Decision variables

YM_{jkr}	1, if customer k is assigned to unreliable DC at j with unsafe transportation mode r in the primary assignment; 0, otherwise
YS_{jk}	1, if customer k is assigned to unreliable DC at j with safe transportation mode in primary assignment; 0, otherwise
T_{ij}	Amount of goods to be shipped from reliable DC at i to unreliable DC at j ($i \neq j$)

Assignment of customers

- Constraint (2) ensures that each customer is assigned exactly to one DC and one transportation mode.

$$\sum_{j}\left(\sum_{r} YM_{jkr} + YS_{jk} + YR_{jk}\right) = 1 \qquad \forall k \qquad (2)$$

Reliable DC

- Constraint (3) guarantees that at least one reliable DC is located based on *goods sharing strategy*.

$$\sum_{j} XR_j \geq 1 \qquad (3)$$

Max One DC per Location

- Constraint (4) states that reliable and unreliable DCs cannot be located at same potential location *j*, simultaneously.

$$XR_j + \sum_n XU_{jn} \leq 1 \qquad \forall j \quad (4)$$

Location - Allocation

- Constraints (5) and (6) link the location and allocation variables in unreliable and reliable DCs, respectively. Constraint (5) also denotes the capacity constraint associated with unreliable DCs.

$$\sum_k D_k \left(\sum_r YM_{jkr} + YS_{jk} \right) \leq \sum_n \kappa_j \, XU_{jn} \qquad \forall j \quad (5)$$

$$YR_{jk} \leq XR_j \qquad \forall j, k \quad (6)$$

Sharing Strategy

- Constraint (7) ensures that in disruption situation goods cannot be shipped for potential node *i*, unless a reliable DC is opened at it.

$$T_{ij} \leq \sum_{k} D_k \cdot XR_i \qquad \forall i, j \quad (7)$$

Ship to unreliable DC

- Constraint (8) ensures that in a disruption situation, goods cannot be shipped to potential node j, unless an unreliable DC is opened at it.

$$T_{ij} \leq \kappa_j \sum_n XU_{jn} \qquad \forall i, j(i \neq j) \quad (8)$$

Capacity

- Constraint (9), states that for each unreliable DC at *j*, sum of shipped goods from reliable DCs and total capacity which is not affected by disruption, must be greater than total demands of its assigned customers.

$$\sum_i T_{ij} + \kappa_j \left(\sum_n (1 - \tau_{jn}) XU_{jn} \right) \geq \sum_k D_k \left(\sum_r YM_{jkr} + YS_{jk} \right) \qquad \forall j \quad (9)$$

Nature of Decision Variables

$$XR_j, XU_{jn}, YM_{jkr}, YS_{jk}, YR_{jk} \in \{0,1\}$$

$$T_{ij} \geq 0$$

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Objective Function

Objective function (1) aims to minimize total fixed cost of opening DCs, cost of assigning customers to the DCs, and expected cost of allocation to unreliable DCs in disruption situation. The 1st & 2nd terms represent the fixed cost of locating unreliable and reliable DCs, respectively. The 3rd term indicates the cost of assigning customers to reliable DCs. The 4th and 5th terms state the expected cost of assigning customers to unreliable DCs in primary assignment if unsafe and safe transportation modes are used, respectively. The 6th term interprets the expected cost of assigning customers to unreliable DCs in disruption situation if unsafe mode in primary assignment is adopted. Finally the 7th term depicts the expected costs of shipping goods from reliable to unreliable DCs during disruption in unreliable DCs.

$$Min \quad \sum_j \sum_n fU_{jn} XU_{jn} + \sum_j fR_j XR_j + \sum_j \sum_k dr_{jk} D_k YR_{jk} + \sum_j \sum_k \sum_r (1-\pi_{jkr}) e_{jkr} D_k YM_{jkr}$$

$$+ \sum_j \sum_k dp_{jk} D_k YS_{jk} + \sum_j \sum_k \sum_r \pi_{jkr} db_{jk} D_k YM_{jkr} + \sum_i \sum_j \sum_n q_j C_{ij} XU_{jn} T_{ij} \qquad (1)$$

END