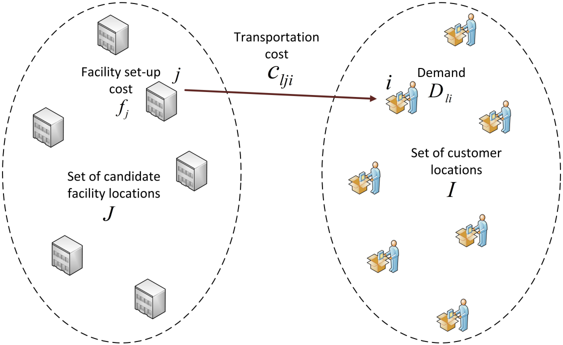
Greenfield Analysis to Find the Optimal Locations for New Facilities

Two-Stage Network Model for Facility Location Design



Two-Stage Network Model for Facility Location Design (contd.)

The objective of the network designer:

- **Minimizing the total cost** including transportation and facility operating costs.

Factors:

- **Optimal number and the optimal locations** of warehouses chosen from a given set of potential locations
- **Quantity of the products** to be shipped from each facility to the customer site

Two-Stage Network Model for Facility Location Design (contd.)

Necessary data:

- Set of potential locations of the facilities (e.g. warehouses) and set of customers
- Demand of the products at the customer locations
- Transportation cost per unit amount of product from each potential facility location to customer location
- Maximum capacity of each facility

Mathematical Notations

Indices:

- I : Set of customer locations indexed by i
- J : Set of candidate facility locations indexed by j
- L : Set of products indexed by l

Model variables:

- X_j : 1 if a facility is set up at location j, 0 otherwise
- Y_{lji} : Quantity of product l to be shipped from the facility at location j to customer site i

Mathematical Notation (contd.)

Model Parameters:

- D_{li} : Demand for product l at customer location i
- f_j : Fixed operating and maintenance cost of a facility at candidate site j
- c_{lji} : Unit cost of shipping the product l from facility location j to customer location i
- U_{max_j} : Maximum capacity of facility at site j

Optimization Problem Formulation

Objective function to be minimized:

$$f_1 = \underbrace{\sum_j f_j X_j}_{\text{Operating cost of facilities}} + \underbrace{\sum_l \sum_j \sum_i c_{lji} Y_{lji}}_{\text{Transportation cost from facilities to customers}}$$

Optimization Problem Formulation (contd.)

Constraints:

- Each customer site demand should be fullfilled for each of the products.

$$\sum_{j} Y_{lji} = D_{li}, \forall l \in L, i \in I$$

- A facility site cannot serve a customer site unless that facility is opened.

$$Y_{lji} - D_{li}X_j \leq 0, \forall l \in L, j \in J, i \in I$$

Optimization Problem Formulation (contd.)

Constraints (contd.):

- Quantity of each product supplied from a facility to the customers must be less than the maximum capacity of that facility.

$$\sum_{l} \sum_{i} Y_{lji} \leq U_{max_j} X_j, \ \forall j \in J$$

- Binary restriction

$$X_j \in \{0, 1\}, \forall j$$

- Non-negative integer restriction

$$Y_{lji} \in \mathbb{Z}^+, \ \forall l, j, i$$

Results

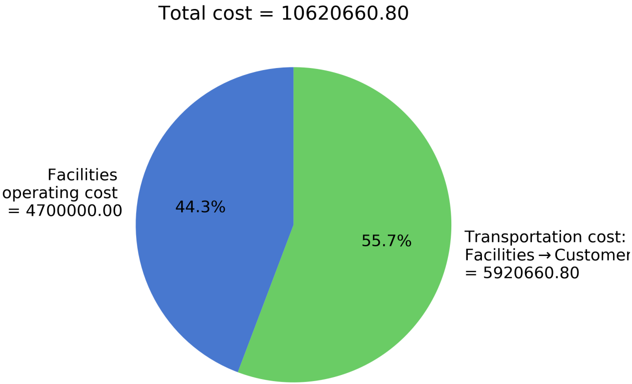


Figure: Pie chart for the cost.

Results (contd.)

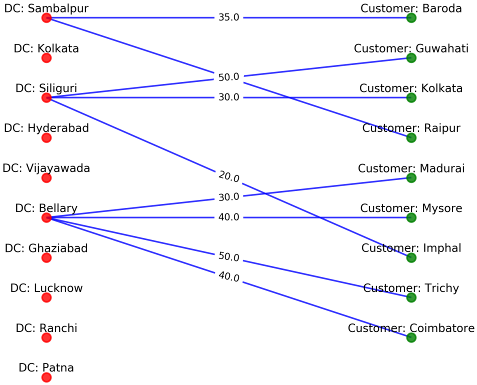


Figure: Transportation graph for product 1.

Results (contd.)

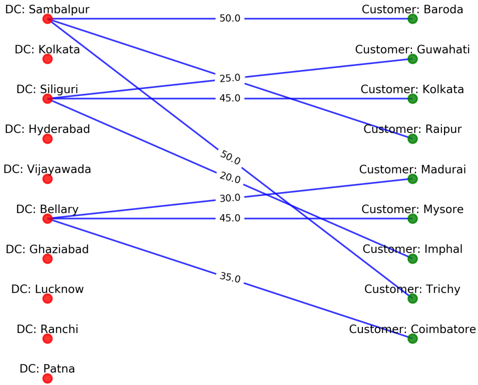


Figure: Transportation graph for product 2.

Results (contd.)

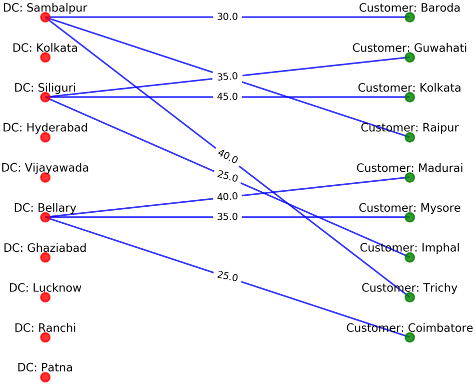


Figure: Transportation graph for product 3.

Results (contd.)

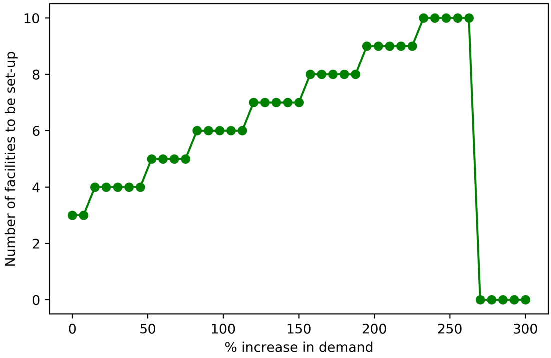


Figure: Change in number of DCs to be set up as demand is increased.

Results (contd.)

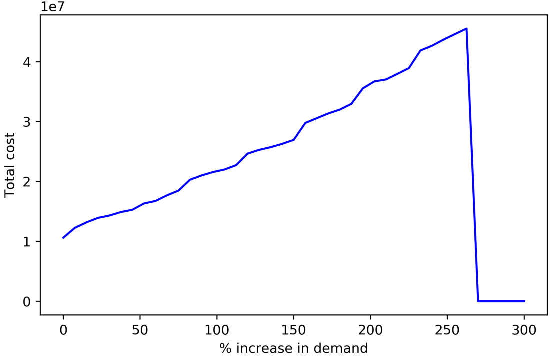
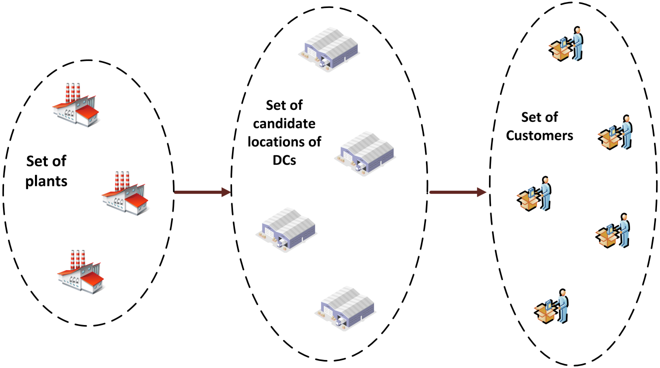


Figure: Change in total cost as demand is increased.

Three-Stage Network Model for Facility Location Design



Three-Stage Network Model for Facility Location Design (contd.)

The objective of the network designer:

- **Minimizing the total cost** including transportation (factory $\rightarrow$ facility and facility $\rightarrow$ customer) and facility operating cost.

Factors:

- **Optimal number and the optimal locations** of warehouses chosen from a given set of potential locations
- **Quantity of the products** to be shipped from each factory to the DCs and then from each DC to the customer sites

Three-Stage Network Model for Facility Location Design (contd.)

Necessary data:

- Set of factories, potential locations of the facilities (e.g. warehouses) and set of customers
- Demand of the products at the customer locations
- Supply limit of each product at the factories
- Transportation cost per unit amount of product from each factory to facility locations and then from each facility location to customer
- Maximum capacity of each facility

Mathematical Notations

Indices:

- I : Set of customer locations indexed by i
- J : Set of candidate locations for DCs indexed by j
- K : Set of manufacturing plants indexed by k
- L : Set of products indexed by l

Model Parameters:

- D_{li} : Demand for product l at customer location i
- S_{lk} : Supply of product l at plant k

Mathematical Notations (contd.)

Model Parameters (contd.):

- U_{max_j} : Maximum capacity of DC at candidate site j
- f_j : Fixed operating and maintenance cost of a facility at candidate site j
- c_{lkj}^{pd} : Unit cost of shipping the product l from plant $k \rightarrow$ DC at candidate location j
- c_{lji}^{dc} : Unit cost of shipping the product l from DC at candidate location $j \rightarrow$ customer site i

Mathematical Notation (contd.)

Model variables:

- X_j : 1 if a DC is set up at location j, 0 otherwise
- z^{pd}_{lkj} : Quantity of product l to be shipped from plant $k \rightarrow$ DC at candidate location j
- z^{dc}_{lji} : Quantity of product l to be shipped from DC at candidate location $j \rightarrow$ customer site i

Optimization Problem Formulation

Objective function to be minimized:

$$f_1 = \underbrace{\sum_j f_j X_j}_{\text{Operating cost of DCs}} + \underbrace{\sum_l \sum_k \sum_j c^{pd}_{lkj} z^{pd}_{lkj}}_{\text{Transportation cost from plants to DCs}} + \underbrace{\sum_l \sum_j \sum_i c^{dc}_{lji} z^{dc}_{lji}}_{\text{Transportation cost from DCs to customers}}$$

Optimization Problem Formulation (contd.)

Constraints:

- Quantity of each product shipped from a plant must be less than its supply

$$\sum_{j} z_{lkj}^{pd} \leq S_{lk}, \forall l \in L, k \in K$$

- Quantity of each product shipped from DCs must satisfy the demand of each customer site

$$\sum_{i} z_{lji}^{dc} \leq D_{li}, \forall l \in L, i \in I$$

Optimization Problem Formulation (contd.)

Constraints (contd.):

- Quantity of each product shipped from plants to a DC candidate location must be less than the maximum throughput of DC at that location.

$$\sum_{l} \sum_{k} z_{lkj}^{pd} \leq U_{max_j}, \forall j \in J$$

- Quantity of each product shipped from a DC candidate location to customers must be less than the maximum throughput of DC at that location.

$$\sum_{l} \sum_{i} z_{lji}^{dc} \leq U_{max_j}, \forall j \in J$$

Optimization Problem Formulation (contd.)

Constraints (contd.):

- Total incoming products at a DC candidate location must be equal to the total outgoing products.

$$\sum_k z_{lkj}^{pd} = \sum_i z_{lji}^{dc}, \forall l \in L, j \in J$$

- Binary restriction

$$X_j \in \{0, 1\}, \forall j$$

- Non-negative integer restriction

$$z_{lkj}^{pd} \in \mathbb{Z}^+, \ \forall l, j, k$$

$$z_{lji}^{dc} \in \mathbb{Z}^+, \ \forall l, j, i$$

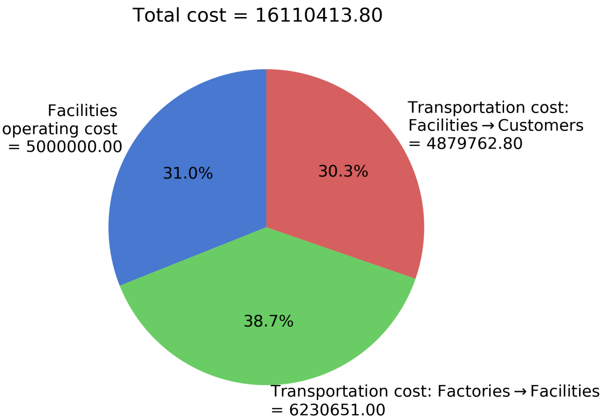


Figure: Pie chart for the cost.

Results (contd.)

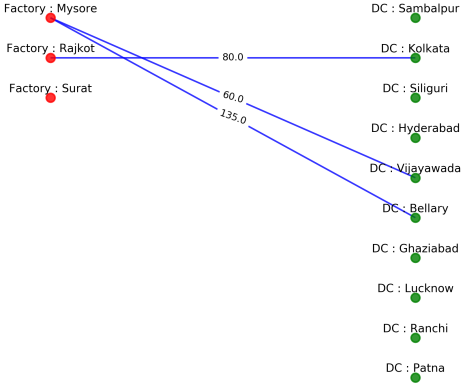


Figure: Transportation graph Factory → DC for product 1.

Results (contd.)

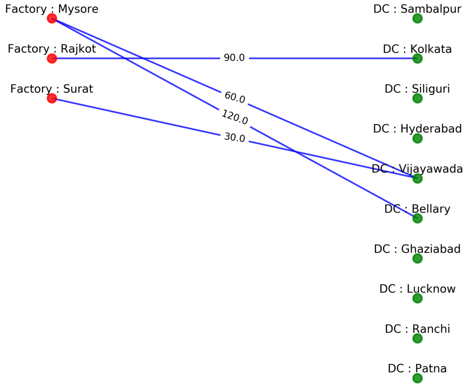


Figure: Transportation graph Factory $\rightarrow$ DC for product 2.

Results (contd.)

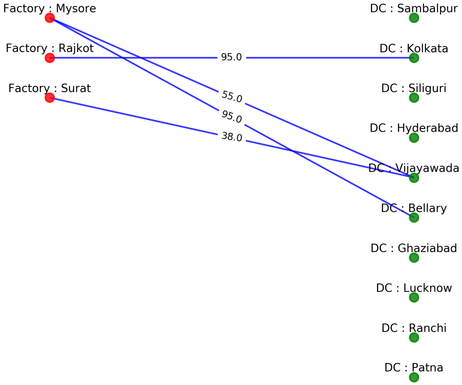


Figure: Transportation graph from Factory → DC for product 3.

Results (contd.)

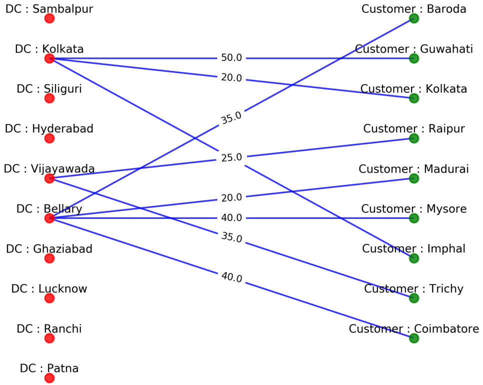


Figure: Transportation graph from DC → Customer for product 1.

Results (contd.)

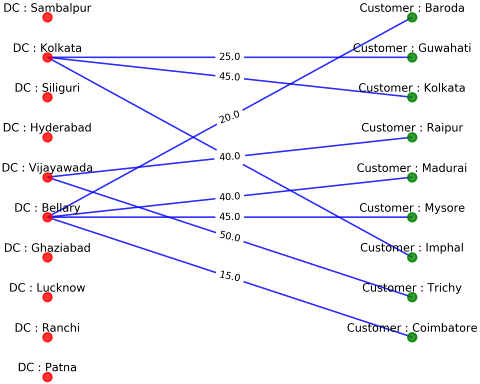


Figure: Transportation graph from DC → Customer for product 2.

Results (contd.)

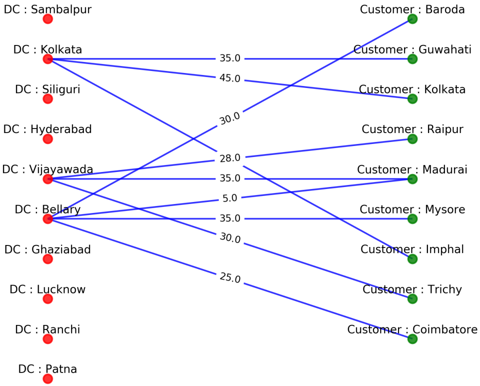


Figure: Transportation graph from DC $\rightarrow$ Customer for product 3.

Results (contd.)

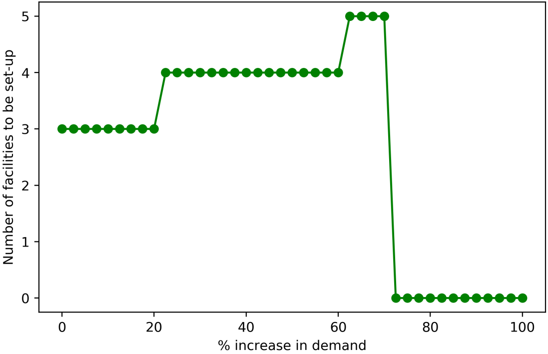


Figure: Change in number of DCs to be set up as demand is increased.

Results (contd.)

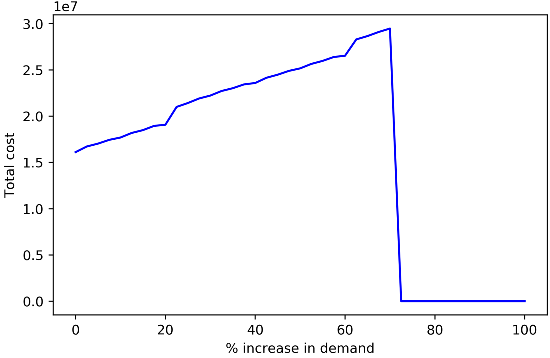


Figure: Change in total cost as demand is increased.

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