Modelling Logistics Network for Airplane Spare Parts

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Decision Variables

j = Depots
p = parts
k = Customer Locations
s = supplier

1. Depot In Use (d_j) = This is a binary variable that will represent if depot j location **i** is open. d_j = 1 → Depot is open, d_j= 0 → Depot is closed

2. Supplier to Depot Shipment ($sd_{s,p,j}$) = This will represent the quantity of parts p from supplier s to depot j.

3. Depot to customer Shipment Orders ($dc_{p,k}$) = This will represent the quantity of parts p from depot s to customer location k.

Constraints

1. Supplier Weight Limit: Each supplier can ship up to 200,000 kg of parts per year. S1 is special as they can supply unlimited weights of product.

$$\text{For each supplier } s \in \text{suppliers}, s \neq \text{S1:}$$
$$\sum_{p \in \text{parts}} \sum_{j \in \text{depots}} sd_{s,j,p} \cdot \text{Part Weight}_p \leq 200{,}000$$

2. Depot Capacity Limit: Each depot has a maximum shipment capacity it can handle inbound and outbound, with Chicago having a higher capacity than others. Depot capacity is defined as a variable that will represent capacity amounts.

$$\text{For each depot } j \in \text{depots:}$$
$$\left(\sum_{s \in \text{suppliers}} \sum_{p \in \text{parts}} sd_{s,j,p} \cdot d_j \right) + \left(\sum_{k \in \text{customers}} \sum_{p \in \text{parts}} dc_{j,k,p} \cdot d_j \right) \leq \text{Operating Capacity of Depot}_j \cdot d_j$$

3. Demand Fulfillment: The demand for each part at each customer location must be exactly met by the shipments from depots.

For each part $p \in$ parts,and each customer $k \in$ customers:

$$\sum_{j \in \text{depots}} dc_{j,k,p} = \text{Customer Demand}_{p,k}$$

4. Service Level Constraint: Each customer must be within a certain distance from at least one open depot, ensuring service levels are maintained. The service level can be adjusted accordingly.

For each customer $k \in$ customers:

$$\sum_{j \in \text{depots}} \text{Price is within service level proxy}_{k,j} \cdot d_j \geq 1$$

5. Shipments Linked to Depot Status: Shipments from suppliers to depots and from depots to customers can only occur if the relevant depot is open.

For each supplier $s \in$ suppliers,depot $j \in$ depots,and part $p \in$ parts:

$$sd_{s,j,p} \leq \text{Capacity of Depot}_j \cdot d_j$$

For each depot $j \in$ depots,customer $k \in$ customers,and part $p \in$ parts:

$$dc_{j,k,p} \leq \text{Capacity of Depot}_j \cdot d_{\mathrm{j}}$$

6. Inventory Balance at Depots: The total quantity of each part received at each depot from all suppliers must equal the total quantity shipped out to all customers, ensuring inventory accuracy.

For each depot $j \in$ depots,and part $p \in$ parts:

$$\left(\sum_{s \in \text{suppliers}} sd_{s,j,p}\right) = \left(\sum_{k \in \text{customers}} dc_{j,k,p}\right)$$

Objective Function

The goal is to minimize the total cost, which consists of:

1. Fixed Costs for Using Depots: A fixed cost for each depot that is in use.

2. Transportation Costs from Suppliers to Depots: Costs based on the weight of parts shipped from suppliers to depots.

3. Transportation Costs from Depots to Customers: Costs based on the weight of parts shipped from depots to customers.

$$
\begin{aligned}
\min\Bigg(& \sum_{j\in\text{depots}} \left(\text{Fixed Cost of Operating a Depot}_{j,1} \cdot d_j\right) \\
& + \sum_{s\in\text{suppliers}, j\in\text{depots}, p\in\text{parts}} \left(\text{Transit Cost for Shipping to Depot}_{s,j} \cdot sd_{s,j,p} \cdot \text{Part Weight}_p\right) \\
& + \sum_{j\in\text{depots}, k\in\text{customers}, p\in\text{parts}} \left(\text{Transit Cost for Shipping to Customers}_{k,j} \cdot dc_{j,k,p} \cdot \text{Part Weight}_p\right)\Bigg)
\end{aligned}
$$