The Warehouse Location-Allocation Problem

Warehouse Location-Allocation Project | Author: ZORGANE Zakaria | Code Repository: Link

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Overview:

The Warehouse Location-Allocation Problem is a critical logistics and supply chain optimization challenge faced by many organizations. This problem involves deciding the optimal locations for warehouses and allocating customer demand to these warehouses in a way that minimizes the total distance traveled while ensuring customer demand is met.

In this project, we tackle the Warehouse Location-Allocation Problem using linear programming and the PuLP library in Python. We aim to find the optimal locations for a limited number of warehouses to serve multiple customers across different cities. Our objective is to minimize the total distance traveled in delivering products to customers while meeting the demands of each customer.

Key Components:

Input Data: We take input data from an Excel file This data includes the distances between cities and the demand from various customers.

Fig1: distance data

Warehouse	city 1	city 2	city 3	city 4	city 5	city 6	city 7
city 1	0	2304	2528	950	906	947	1475
city 2	2304	0	2829	1776	2310	1475	2192
city 3	2528	2829	0	3123	1965	2134	1187
city 4	950	1776	3123	0	1699	1149	1926
city 5	906	2310	1965	1699	0	842	915
city 6	947	1475	2134	1149	842	0	922
city 7	1475	2192	1187	1926	915	922	0

Table1: Demand by city

City	Demand
City 1	10,000
City 2	20,000
City 3	33,000
City 4	9,000
City 5	60,000
City 6	2,500
City 7	35,000

Decision Variables: We use decision variables to determine whether to establish a new warehouse in a city and how much demand to allocate from each customer to the selected warehouses.

- **Flows (X):** These variables represent whether goods are flowing from a specific warehouse to a particular city. They are binary variables, taking a value of 1 if goods are flowing from the warehouse to the city and 0 otherwise. These variables help us determine the routing of products from warehouses to cities.

- **New Warehouses (Y)**: These binary variables represent whether a particular warehouse is selected as a new facility for allocation. They take a value of 1 if the warehouse is selected as a new facility and 0 otherwise. These variables are essential for deciding which warehouses should be open to minimize the total transportation distance.

These decision variables play a crucial role in determining the optimal allocation of goods from warehouses to cities while considering constraints and minimizing transportation costs. They allow us to make decisions on which warehouses should be operational and how goods should be routed to meet customer demands efficiently.

Objective Function (Minimize Total Transportation Distance):

The goal of this objective function is to minimize the sum of the distances between selected warehouses and the cities they serve, weighted by the demand from those cities. It is represented as:

$$Minimize \sum_{w} \sum_{c} Demand[c] \times Flows[w,c] \times Distance[w,c]$$

Here's an explanation of the components:

- w : Represents each warehouse.
- c : Represents each city.
- Demand[c]: Represents the demand for products from each city.
- Flows[w,c]: Represents a binary variable (0 or 1) indicating whether products flow from the selected warehouse w to city c.
- Distance[w,c]: Represents the distance between warehouse w and city c.

The objective function aims to find the optimal combination of flows that minimizes the total transportation distance while satisfying the demand of all cities. Minimizing this distance helps reduce transportation costs and improve the efficiency of the warehouse allocation.
In simpler terms, we're trying to allocate warehouses in a way that minimizes the distance products need to travel to reach customers, ultimately reducing transportation expenses.

Constraints:

We enforce constraints to ensure that each customer's demand is satisfied, each city has a limit on the number of warehouses it can have, and the total number of warehouses is limited.

1. Demand Satisfaction Constraint:

For each city (c), ensure that the total flow from all warehouses (w) to that city equals 1, indicating that the demand of the city is satisfied by exactly one warehouse.

$$\Sigma\ [\text{Flow}(w, c) \text{ for all warehouses } (w)] = 1, \text{ for all cities } (c)$$

2. Number of warehouses Constraint:

Specify the number of warehouses to be selected. In this case, we aim to select three warehouses.

$$\Sigma\ [\text{New\_Warehouse}(w)] = 3, \text{ for all warehouses } (w)$$

3. Warehouse Assignment Constraint:

Ensure that a new warehouse (New_Warehouse) variable is set to 1 if and only if there is at least one flow from that warehouse to any city. This constraint enforces that a new warehouse must be chosen if it serves any city.

$$\text{New\_Warehouse}(w) \geq \text{Flow}(w, c) \text{ for all cities } (c), \text{ for all warehouses } (w)$$

For each warehouse (w), we ensure that the New_Warehouse variable is greater than or equal to the Flow(w, c) for all cities (c). If any Flow(w, c) is 1 (indicating that warehouse w serves city c), then New_Warehouse(w) must be set to 1.

Optimization:

We use linear programming techniques to find the optimal solution to this problem.
The objective of this optimization problem is to minimize the total distance traveled by goods from warehouses to cities while satisfying the demand of each city and considering the constraints imposed.
The goal is to find the allocation of warehouses to cities (flows) and determine which warehouses are selected as new warehouses (New_Warehouse) to minimize the total distance traveled while ensuring that each city's demand is satisfied.
The optimization problem is formulated as a Linear Programming (LP) problem

Code execution : click here to view the code

Upon solving the optimization problem, the code provides insights into the selected warehouses, the flows between warehouses and cities, and the demand satisfied by each warehouse. Here's a breakdown of the results:

1. Selected Warehouses:

The code identifies the warehouses that have been selected for operation. These selected warehouses are essential for serving the cities and satisfying the demand.

2. Flows between Warehouses and Cities:

For each selected warehouse, the code displays the flows from that warehouse to the cities it serves. It shows the quantity of goods (flows) moving from each selected warehouse to specific cities.
This information helps in visualizing the distribution of goods from the selected warehouses to the cities.

3. Demand Satisfied by Each Warehouse:

The code calculates and displays the demand satisfied by each selected warehouse.
It sums up the demand for all cities served by a particular warehouse.
This metric provides insights into the efficiency and capacity utilization of each chosen warehouse.

4. Total Demand Satisfied:

Finally, the code calculates and presents the total demand satisfied by all the selected warehouses.
This total represents the cumulative demand met by the chosen distribution network.
It is a crucial measure of the overall effectiveness of the solution.

These results allow decision-makers and stakeholders to understand which warehouses have been selected, how goods are distributed to cities, and the extent to which customer demand is satisfied. This information is valuable for optimizing supply chain logistics, minimizing transportation costs, and ensuring efficient inventory management.

By displaying these results, the code provides a comprehensive overview of the warehouse allocation and distribution plan, aiding in data-driven decision-making for logistics and operations.

Results Summary:

Objective Value (Total Distance): 58481000

The optimization successfully minimized the total distance, which represents transportation costs, for the selected warehouses.

the following details provide insights into the selected warehouses and flows:

Selected Warehouses: ['city 2', 'city 3', 'city 5']

this means these 3 cities will be the location of our new warehouses.The code determined which warehouses should be selected to minimize transportation costs while satisfying customer demands.

Flow Details:

- Flow from city 2 to city 2: 1.0
- Flow from city 3 to city 3: 1.0
- Flow from city 5 to city 1: 1.0
- Flow from city 5 to city 4: 1.0
- Flow from city 5 to city 5: 1.0
- Flow from city 5 to city 6: 1.0
- Flow from city 5 to city 7: 1.0

For each selected warehouse, the code provides information on the flows from the selected warehouse to each city. It indicates the amount of goods transported from each selected warehouse to each city.

The results show the effectiveness of the selected warehouses in serving the various cities while minimizing transportation costs.