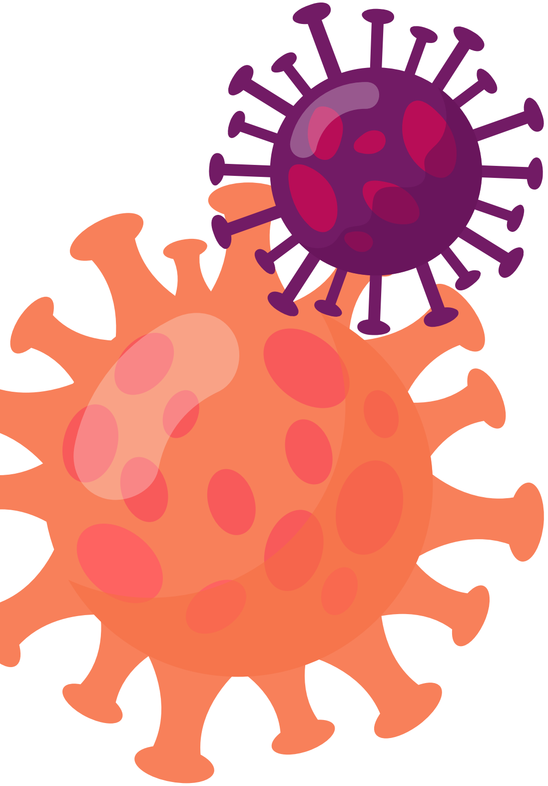


Vaccine Distribution Optimization for Montréal's COVID-19 Response

MGSC 662 : Group 3855 - 1

Problem Context

Business Context: The distribution of COVID-19 vaccines across Montréal’s regions poses several challenges. Due to differing demand patterns, driven by varying infection rates, population densities, and other factors, some regions may experience vaccine shortages while others have surpluses. Efficiently addressing this distribution imbalance is crucial for ensuring the health and safety of residents, accelerating the return to normalcy, and optimizing the use of limited resources.

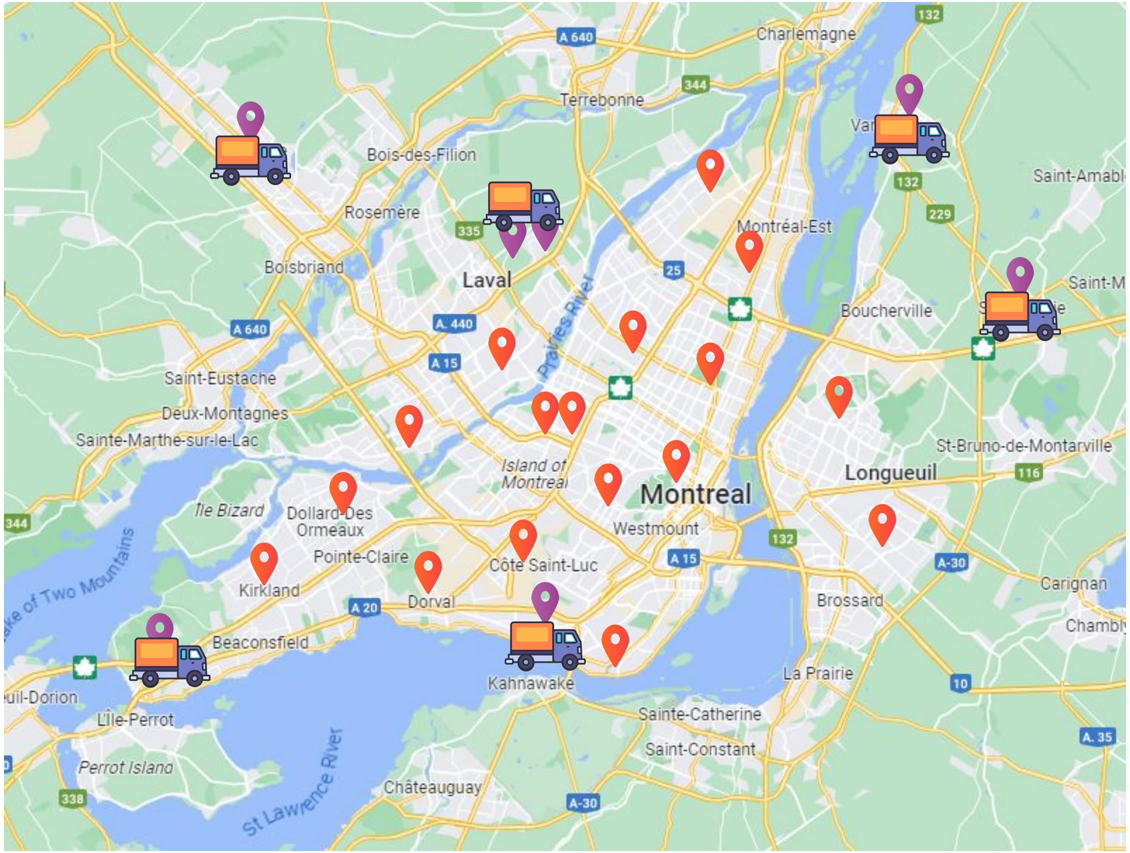
Objective: The objective is to determine the best strategy for distributing COVID-19 vaccines across various regions in Montréal. Specifically, the goal is to minimize the total associated costs, which include the cost of obtaining the vaccines from suppliers, the transportation costs to deliver them to different regions, and potential penalties related to not meeting the vaccine demand in each region.

Problem Context

Covid Vaccine Distribution Centers (Suppliers) = i

Regional Vaccination Centers (Buyer) = j

* One Supplier can supply any region and 1 region can be supplied by any supplier



Problem Context

Category : Unbalanced Inventory Problem

Problem: We have a higher daily vaccine demand than we have supply. For 1 day, we want to distribute the supply we do have as optimally as possible all the while incurring the least transportation costs and unmet demand penalties.

Covid Vaccine Distribution Centers (Suppliers) = i

Regional Vaccination Centers (Buyer) = j

DATA WE HAVE

01 Supplier data : Supplier Location, Supply quantity of vaccine i, vaccine i price

02 Region data : Vaccination Center location, demand quantity from region j, storage capacity in region j

03 Transportation Costs : matrix of cost of transportation from supplier i to region j

04 Unmet demand costs : Penalty value of every unit of unmet demand in region j

Goals of Optimization

1

MINIMIZE DAILY TRANSPORTATION COSTS OF VACCINES FROM SUPPLIER I TO REGION J

2

MINIMIZE URGENCY PENALTY RELATED TO UNMET DEMAND IN REGION J

3

MINIMIZE COSTS RELATED TO UNMET DEMAND IN REGION J

Objective Function

$$Z=\sum_{i,j}(p_i+t_j)\times x_{ij}+\alpha\sum_j(c_j\times d_j)/x_{ij}+\sum_j y_j\times m_j$$

Cost of Procurement and Transportation

Penalty for Unmet Demand Based on COVID-19 Cases and Death Rates (Urgency of meeting demand)

Costs incurred for Unmet Demand ($)

The overall objective is to minimize the combined cost of procuring and transporting vaccines while considering penalties for unmet demand and monetary healthcare fees associated to unmet demand. The α factor allows adjusting the urgency of meeting demand relative to the procurement and transportation costs and healthcare costs.

Objective Function : Cost of Procurement and Transportation

$$Z=\sum_{i,j}(p_i+t_j)\times x_{ij}$$

This part represents the total cost of procuring and transporting vaccines from suppliers to regions.

p_i : Price of one vaccine from supplier i.
t_j : Transportation cost to region j.
x_{ij} : Number of vaccines transported from supplier i to region j.

Objective Function : Penalty for Unmet Demand Based on COVID-19 Cases and Death Rates (Urgency of meeting demand)

$$+\alpha \sum_j (c_j d_j)/x_{ij}^*$$

This part represents the penalty associated with unmet demand in highly critical areas (urgency), taking into account COVID-19 cases and death rates. Hence, the penalty is higher when fewer vaccines are transported to critical areas.

α: Weighting factor representing the importance of meeting demand relative to the cost of meeting demand and transportation cost.
c_j : Number of COVID-19 cases in region j.
d_j : Death rate in region j.
x_{ij} : Number of vaccines transported from supplier i to region j.

* We will make this linear by replacing the division by a variable. This is just to show the logical idea process behind it.

Objective Function : Costs Incurred for Unmet Demand ($ associated with someone catching Covid)

$$+\sum_j y_j \times m_j$$

This part represents the monetary penalty associated with unmet demand in each region.

m_j: monetary cost for 1 person catching serious case of Covid (healthcare fees).
y_j : Unmet demand for vaccines in region j.

* Average cost for COVID-19 ICU patients estimated at more than $50,000 (https://www.cbc.ca/news/health/cihi-covid19-canada-hospital-cost-1.6168531)

Decision Variables

1

X_{ij} : Number of vaccines transported from supplier i to region j

2

y_j : Unmet demand for vaccines in region j

Parameters (Data)

p_i	Price of one vaccine from supplier i
t_j	Transportation cost to region j
c_j	Number of COVID-19 cases in region j
d_j	Death rate in region j
α	Weighting factor representing the importance of meeting demand relative to the procurement and transportation cost
m_j	Costs associated with 1 person not getting vaccinated (healthcare)

Constraints

Supply Constraints:

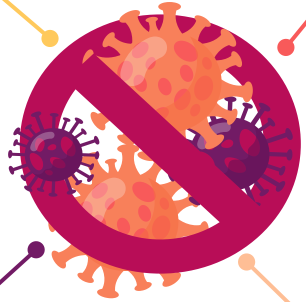
Ensure that the number of vaccines dispatched from a supplier doesn't exceed its supply.

$$\Sigma_j X_{ij} \leq Supply_i$$

Demand Constraints:

Ensure that the number of vaccines received by a region doesn't exceed its requirement.

$$\Sigma_j X_{ij} \leq Demand_j$$



Unmet Demand Constraints:

This captures the difference between actual demand and the sum of vaccines sent to that region. It ensures that the unmet demand yj in a region is the difference between the actual demand and the vaccines supplied.

$$y_j = Demand_j - \Sigma_i X_{ij}$$

Non-negativity Constraints:

Ensure that the numbers of vaccines being moved and the unmet demand are non-negative.

$$X_{ij} \geq 0 \text{ , } y_j \geq 0$$