OR LAB PROJECT

GROUP – 3

TEAM MEMBERS

- SAMSRHITHA BURA 22IM10012
- INALA JAHNAVI MEHAR SAI 22IM10016
- SEMANTI GHOSH 22IM10036
- VANKUDOTH SAI PRIYA 22IM10043

INTRODUCTION

Most firms break Supply Chain Management down into five elements

Planning

figuring out how to meet customer and manufacturer demands

Sourcing

building solid relationships with suppliers and working with them

Manufacturing

dividing production tasks into subtasks

Delivering

sending goods to end users through various channels

Returning

accepting defective, faulty or unwanted products, usually for resale

LITERATURE

1

Supply chain optimization makes the best use of data analytics to find an optimal combination of factories and **distribution** centers to match **supply** and **demand.**

2

Because of the current surge in **shipping costs**, companies start to challenge their current footprint to adapt to the post-covid “New Normal”.

3

In this presentation, we will present a simple methodology using **Linear Programming** for **Supply Chain Optimization** considering Fixed production costs of facilities ($/Month), Variable production costs per unit produced ($/Unit), Shipping costs ($), Customer’s demand (Units)

INDUSTRIAL PROBLEMS & EXAMPLES

1. **Retail Supply Chain Optimization:** A retail chain with multiple warehouses and stores needs to efficiently allocate products from warehouses to stores while minimizing transportation costs and ensuring that each store meets its demand. This optimization problem helps in determining the most cost-effective way to distribute products.

2. **Manufacturing Inventory Management:** A manufacturing company with multiple production facilities needs to decide how much inventory to keep at each location to meet future demand while minimizing inventory holding costs. This problem helps in optimizing inventory levels across different locations in the supply chain.

3. **Logistics and Distribution:** A logistics company needs to optimize its transportation routes and warehouse assignments to deliver goods to customers with minimal cost and time. This optimization problem helps in determining the most efficient distribution network and routing plan.

INDUSTRIAL PROBLEMS & EXAMPLES

4. **E-commerce Fulfillment:** An e-commerce company needs to manage inventory across warehouses and fulfill customer orders efficiently. By solving this optimization problem, the company can minimize storage and transportation costs while ensuring timely delivery to customers.

5. **Healthcare Supply Chain:** Hospitals and healthcare facilities need to manage their supply chain effectively to ensure the availability of medical supplies while minimizing costs. This optimization problem helps in optimizing inventory levels and distribution routes for medical supplies.

PROBLEM STATEMENT

- In an international manufacturing company, there are markets in 5 countries. The market can have a high capacity/low capacity production factory. The local market's demand (market in the same country) is always met first.

- If there is excess it is shipped to another country where there is a requirement.
- The total cost, production cost and freight cost must be minimized

MODEL

ASSUMPTIONS

- Fixed and Variable costs are independent of the period of production.
- 1 shipping container can contain 1000 units
- Demand is assumed to be constant every month.

ASSUMPTIONS

- **Manufacturing Facility Fixed Costs**
  - Capital Expenditure for the equipment (Machines, Storage, ..)
  - Utilities (Electricity, Water, ..)
  - Factory management, administrative staff
  - Space Rental

- **Production Variable Costs**
  - Production lines operators
  - Raw materials

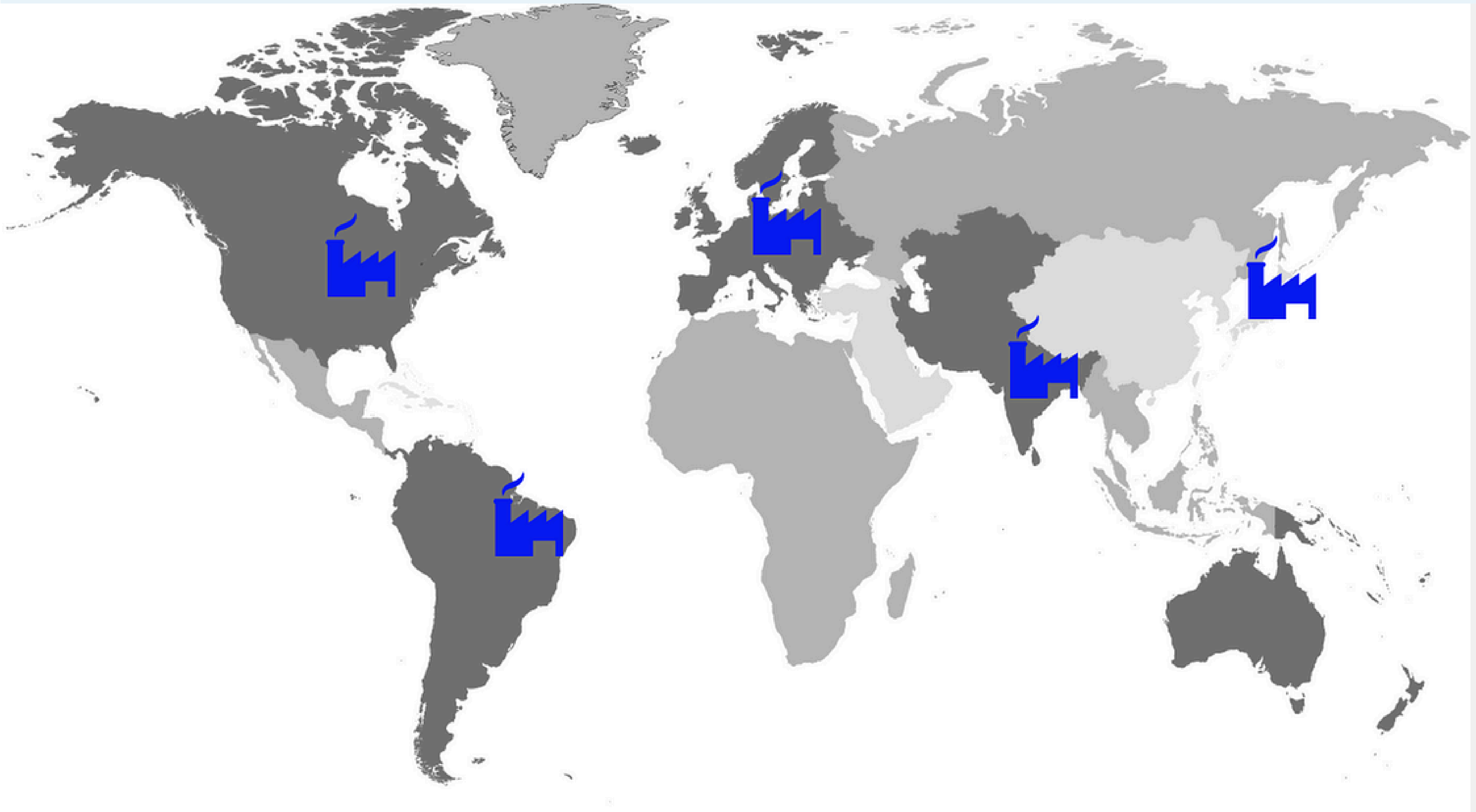
NOTATIONS AND MODEL PARAMETERS

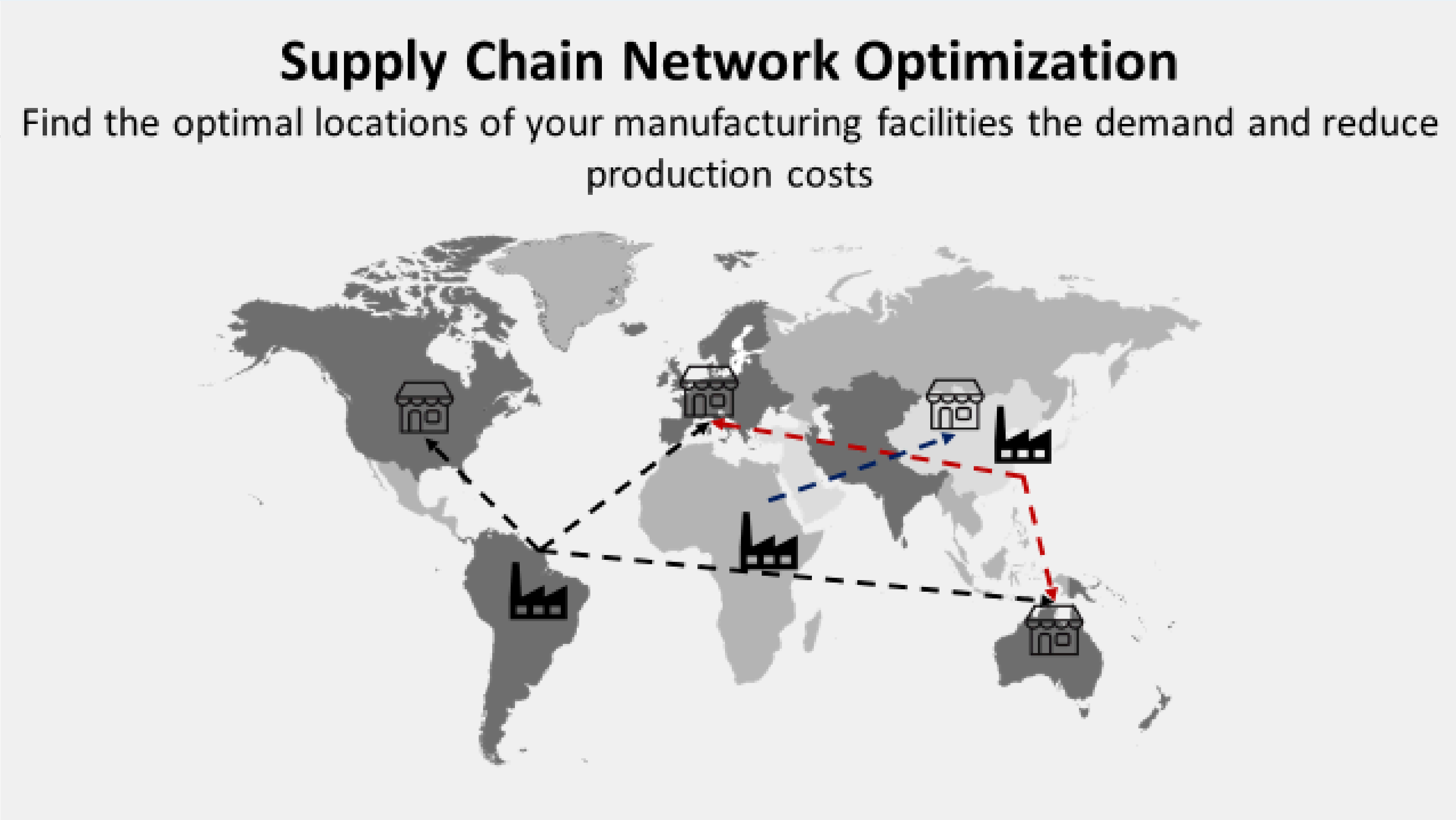
- i = 1..5, representing the 5 markets, {USA, German, Japan, Brazil, India}
- s = 1 representing the high-capacity production factories and
  2 representing the low-capacity production factories
- d_i – no. of units demanded in the market i per month.
- C_{is} – The no. of units produced in s^{th} production factory, i^{th} market
- f_{is} – fixed cost for s^{th} production factory, i^{th} market per month.
- vp_{is} – variable production cost per unit produced in market i.
- t_{ij} – variable shipping cost (freight cost) from market i to market j per
  container.

DECISION VARIABLES

- x_{ij} : no. of units shipped from market i to market j
- y_{is} : Binary variables, i.e., 0 or 1, indicating the establishment of production factory s in market i.

DESCRIBING MODEL WITH SCHEMATIC DIAGRAM





OBJECTIVE FUNCTION

MINIMIZING THE COST

Total variable cost of production

+ Total fixed cost of production

+ Total freight (transportation) cost.

CONSTRAINTS

1. Fulfilling the demand of customers in each market.
2. Total no. of units shipped from market l to other markets is less than or equal to the capacity of units produced in i.

MATHEMATICAL FORMULATION

$$\text{Minimise: } Z = \sum_{i=1}^{5} \sum_{s=1}^{2} f_{ij} * y_{is} * 1000 + \sum_{i=1}^{5} \sum_{j=1}^{5} x_{ij} * (vp_i + t_{ij} * 0.001)$$

Subject to:

$$\sum_{i=1}^{5} x_{ij} = d_j \quad \forall \; j = 1, 2, \ldots, 5$$

$$\sum_{j=1}^{5} x_{ij} = \sum_{s=1}^{2} C_{is} * y_{is} \quad \forall \; i = 1, 2, \ldots 5$$

$$x_{ij} \geq 0 \quad \forall \; i = 1, 2, \ldots 5, \; j = 1, 2, \ldots 5$$

$$y_{is} \in \{0, 1\}$$

METHODOLOGY

We have used **Python**, **Panda Library**, and **PuLP** to solve the Linear Programming for Supply Chain Optimization and generated the output

RESULTS

Objective value: 94431000.00000000
Enumerated nodes: 0
Total iterations: 10
Time (CPU seconds): 0.08
Time (Wallclock seconds): 0.08

Option for printingOptions changed from normal to all
Total time (CPU seconds): 0.09
(Wallclock seconds): 0.09

Total Costs = 94,431,000 ($/Month)

Status: Optimal
('Brazil','High') = 0.0
('Brazil','Low') = 1.0
('Germany','High') = 0.0
('Germany','Low') = 0.0
('India','High') = 1.0
('India','Low') = 0.0
('Japan','High') = 1.0
('Japan','Low') = 0.0
('USA','High') = 1.0
('USA','Low') = 0.0

('Brazil','Brazil') = 145000.0
('Brazil','Germany') = 0.0
('Brazil','India') = 0.0
('Brazil','Japan') = 0.0
('Brazil','USA') = 250000.0
('Germany','Brazil') = 0.0
('Germany','Germany') = 0.0
('Germany','India') = 0.0
('Germany','Japan') = 0.0
('Germany','USA') = 0.0
('India','Brazil') = 0.0
('India','Germany') = 90000.0
('India','India') = 160000.0
('India','Japan') = 0.0
('India','USA') = 1250000.0

('Japan','Brazil') = 0.0
('Japan','Germany') = 0.0
('Japan','India') = 0.0
('Japan','Japan') = 1500000.0
('Japan','USA') = 0.0
('USA','Brazil') = 0.0
('USA','Germany') = 0.0
('USA','India') = 0.0
('USA','Japan') = 200000.0
('USA','USA') = 1300000.0

DISCUSSION : THE DATA USED

(Units/month)	Demand
USA	2 800 000
Germany	90 000
Japan	1 700 000
Brazil	145 000
India	160 000

K$/month	Low	High
USA	6500	9500
Germany	4980	7270
Japan	6230	9100
Brazil	3230	4730
India	2110	6160

Capacity (kUnits/month)	Low	High
USA	500	1500
Germany	500	1500
Japan	500	1500
Brazil	500	1500
India	500	1500

DISCUSSION : THE DATA USED

Freight Costs ($/Container)	USA	Germany	Japan	Brazil	India
USA	0	12250	1100	16100	8778
Germany	13335	0	8617	20244	10073
Japan	15400	22750	0	43610	14350
Brazil	16450	22050	28000	0	29750
India	13650	15400	24500	29400	0

Variable Costs ($/Unit)	USA	Germany	Japan	Brazil	India
USA	12	12	12	12	12
Germany	13	13	13	13	13
Japan	10	10	10	10	10
Brazil	8	8	8	8	8
India	5	5	5	5	5

CONCLUSION

- The supply chain optimization model aimed to minimize total costs by efficiently allocating production and transportation resources across five countries.
- It successfully balanced demand fulfillment, capacity constraints, and cost minimization objectives.
- The optimal solution showed activation of production plants based on binary decisions and optimal transportation routes determined using continuous variables. .
- Prioritizing local market demand before considering shipments to other countries ensured efficient resource utilization.
- Overall, the model enabled the company to operate cost-effectively and competitively in the global market

REFERENCES

- Kostikov E et. al. provides a model that allows for the central warehouse's optimal location and minimizes transportation costs from the central warehouse to sub-warehouses/branches located in individual EU countries for varying demands.

- Kumar, S. presents a hybrid optimization approach (mathematical modeling & simulation) considering conflicting objectives like minimizing transportation cost, and minimizing storage cost (inventory holding cost).

- Igor Shvab provides a comprehensive approach for optimization modeling using SciPy, PuLP, Pyomo.

APPENDIX

```
import pandas as pd
from pulp import *

# Importing Manufacturing Costs
manvar_costs = pd.read_excel('variable_costs.xlsx', index_col = 0)
# Importing Freight Costs
freight_costs = pd.read_excel('freight_costs.xlsx', index_col = 0)
# Variable Cost
var_cost = freight_costs/1000 + manvar_costs
# Importing Plant Fixed Costs
fixed_costs = pd.read_excel('fixed_cost.xlsx', index_col = 0)
# Importing quantity of Low Capacity and High Capacity production factory
cap = pd.read_excel('capacity.xlsx', index_col = 0)
# Importing Demand
demand = pd.read_excel('demand.xlsx', index_col = 0)

# Parameters
loc = ['USA', 'Germany', 'Japan', 'Brazil', 'India']
size = ['Low', 'High']

# Initialize]ing Class
model = LpProblem("Supply Chain Optimization", LpMinimize)
```

APPENDIX

```
# Decision Variables
x = LpVariable.dicts("production_", [(i,j) for i in loc for j in loc],
                     lowBound=0, upBound=None, cat='continuous')
y = LpVariable.dicts("plant_",
                     [(i,s) for s in size for i in loc], cat='Binary')

# Objective Function
model += (lpSum([fixed_costs.loc[i,s] * y[(i,s)] * 1000 for s in size for i in loc])
          + lpSum([var_cost.loc[i,j] * x[(i,j)]   for i in loc for j in loc]))

# Constraints
for j in loc:
    model += lpSum([x[(i, j)] for i in loc]) == demand.loc[j,'Demand']
for i in loc:
    model += lpSum([x[(i, j)] for j in loc]) <= lpSum([cap.loc[i,s]*y[(i,s)] * 1000
                                                      for s in size])

# Solving the Model
model.solve()
print("Total Costs = {:,} ($/Month)".format(int(value(model.objective))))
print('\n' + "Status: {}".format(LpStatus[model.status]))


# Dictionnary
dict_plant = {}
dict_prod = {}
for v in model.variables():
    if 'plant' in v.name:
        name = v.name.replace('plant__', '').replace('_', '')
        dict_plant[name] = int(v.varValue)
        p_name = name
    else:
        name = v.name.replace('production__', '').replace('_', '')
        dict_prod[name] = v.varValue
    print(name, "=", v.varValue)
```

THANK YOU