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Minimizing the production and logistics costs for a microchip manufacturer by optimal facility and carrier assignment

Hamzauddin Siddiqui, [REDACTED]
[REDACTED]

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Microchip: The Invisible "Brain" of Modern Life

- **What is it?** A dime-sized silicon square acting as the brain for all electronics.
- **Why it matters?** The foundation of modern life powering phones, cars, banking, medical equipment and more.
- **High Value Density:** Extremely lightweight yet valuable.

Example: A < 50g processor can cost ~ €520



<https://www.widexpro.com/en/blog/global/how-the-chip-transformed-the-industry/>

Motivation

1. **Global Impact:** Unoptimized networks pose a risk
2. **Profitability:** High initial investments leave little room for operational inefficiency

AUTOS

Chip shortage expected to cost auto industry \$210 billion in revenue in 2021

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<https://www.cnbcm.com/2021/09/23/chip-shortage-expected-to-cost-auto-industry-210-billion-in-2021.html>

TSMC begins work on 'world's most advanced' chip fab, costs \$48.5 billion for 1.4nm production

TSMC's new semiconductor facility in Taiwan is the most expensive it's built so far: costs \$48.5 billion to build, ready for next-gen A14 (1.4nm) silicon.

<https://www.tweaktown.com/news/108754/tsmc-begins-work-on-worlds-most-advanced-chip-fab-costs-dollars48.5-billion-for-1.4nm-production/index.html>

Structure

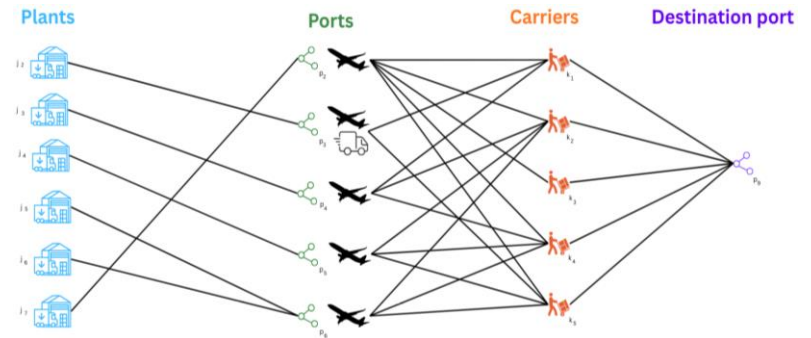
1. Problem Description
2. Data Understanding and Visualization
3. Challenges & Assumptions
4. Data Preparation
5. Model Formulation
6. Outlook & Question

1. Problem Description

- 9,215 orders need to be fulfilled; each order has a specified time window and service type
- The company has multiple plants and carriers which produce a range of products and charge different prices depending on the order weight, respectively

Decisions: Assign a path for each order from its origin plant through intermediate ports to their final port and select the transportation carrier

Objective: Minimize transportation and production costs



2. Data Understanding and Visualization – *Available Data*



Orders: Customer ID, Date, Required Service Type, Throughput Time, Flexibility, Product ID and Number of required units.



Freight Rates: Origin, Destination, Weight Brackets, Costs, Mode and Throughput time.



Plant Costs: Cost of producing one unit at every plant.



Plant Capacity: Maximum orders a plant can fulfill in a day.



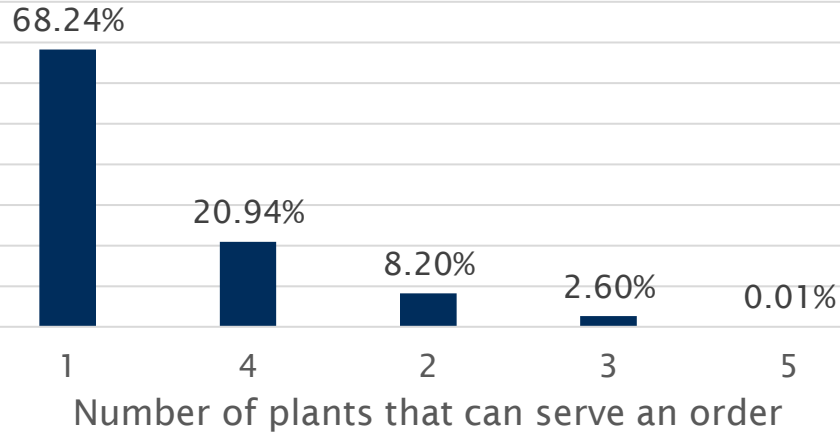
Products per Plant: Which products are available at which plant.



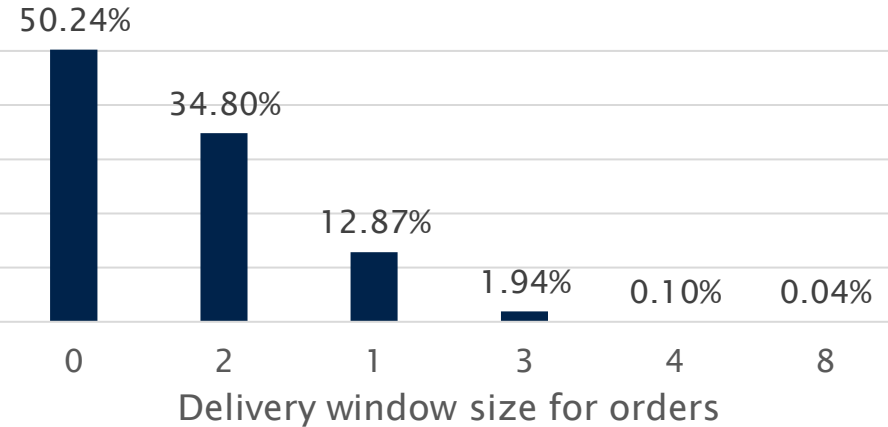
Plant and Ports: Which plants are linked to which ports.

2. Data Understanding and Visualization – *Flexibility*

Production Flexibility

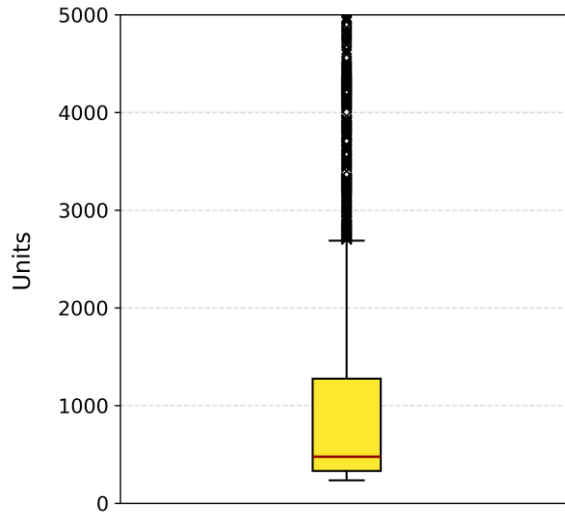


Delivery Flexibility

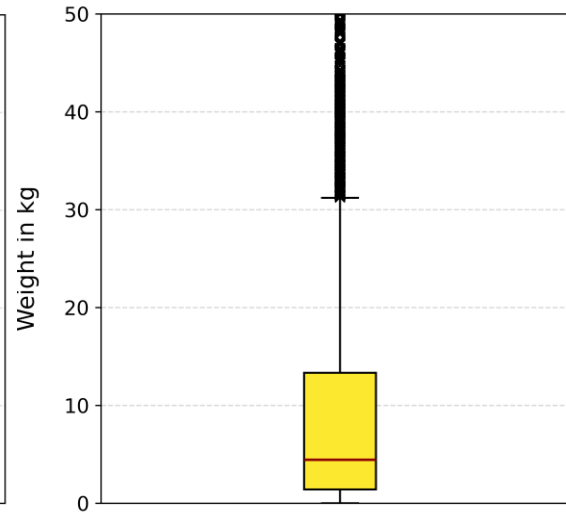


2. Data Understanding and Visualization – *Order size*

Unit Quantites of Orders

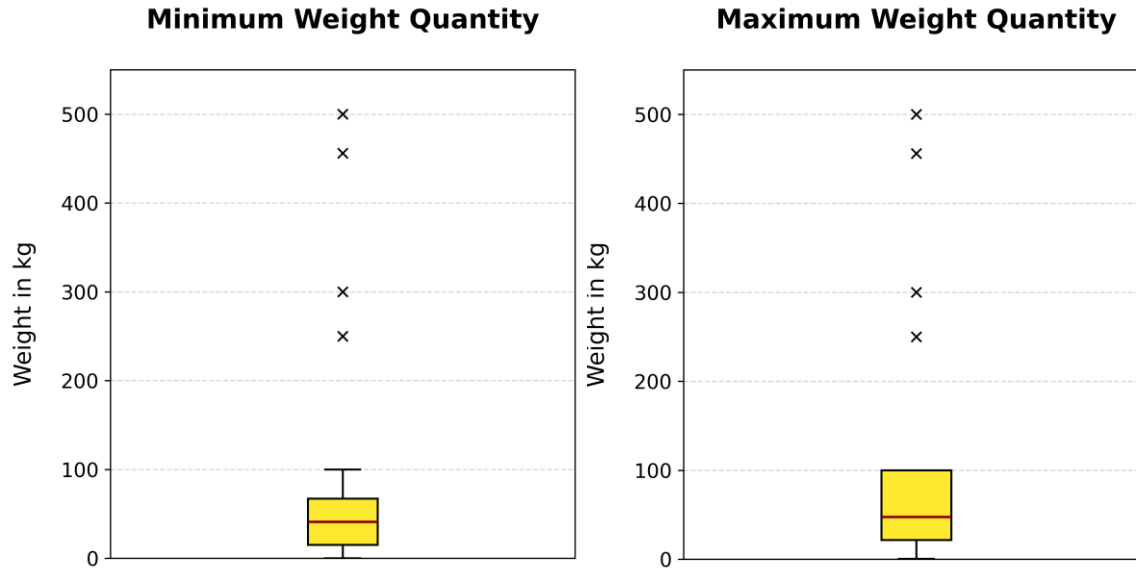


Weights per Order



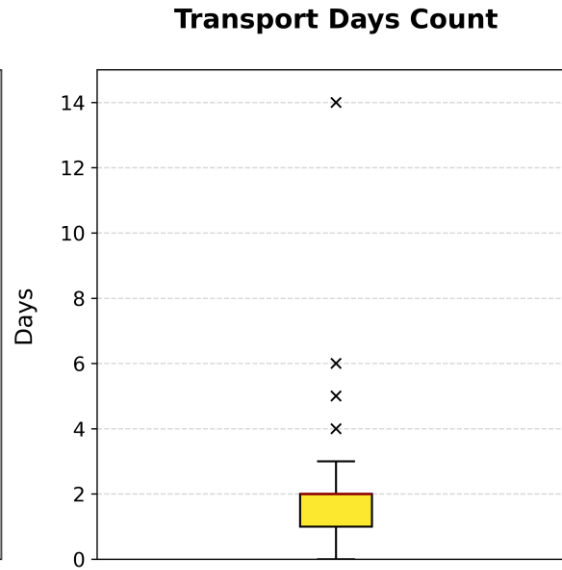
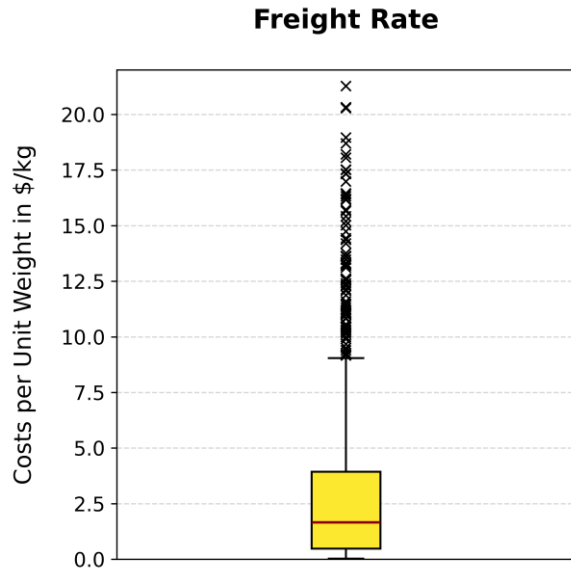
- Many small/light and few big/heavy orders

2. Data Understanding and Visualization – *Weight quantities*



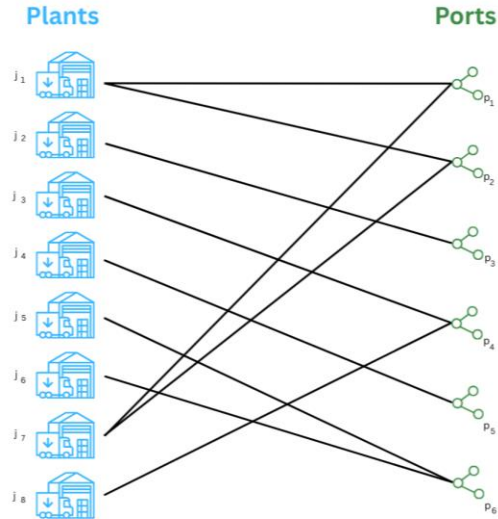
- All ground transports have same weight intervall [0; 5000]

2. Data Understanding and Visualization – *Other insights*



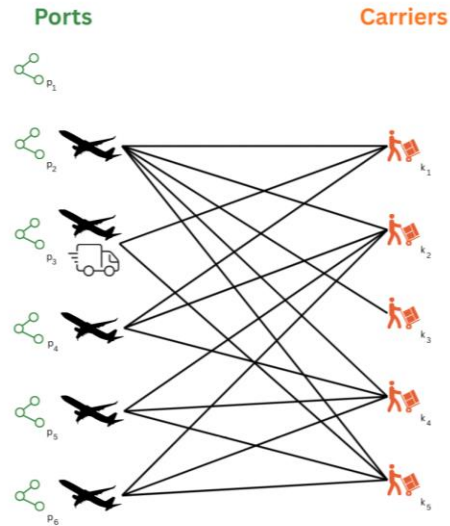
- Higher freight rates for ground transport
- Fast transport for most orders

2. Data Understanding and Visualization – *Network of 1st stage*



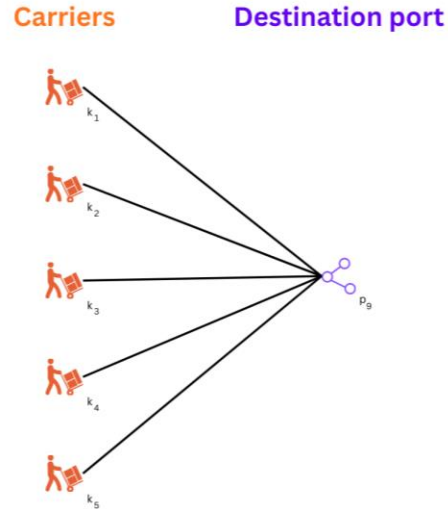
- Each plant is connected to one or multiple ports

2. Data Understanding and Visualization – *Network of 2nd stage*



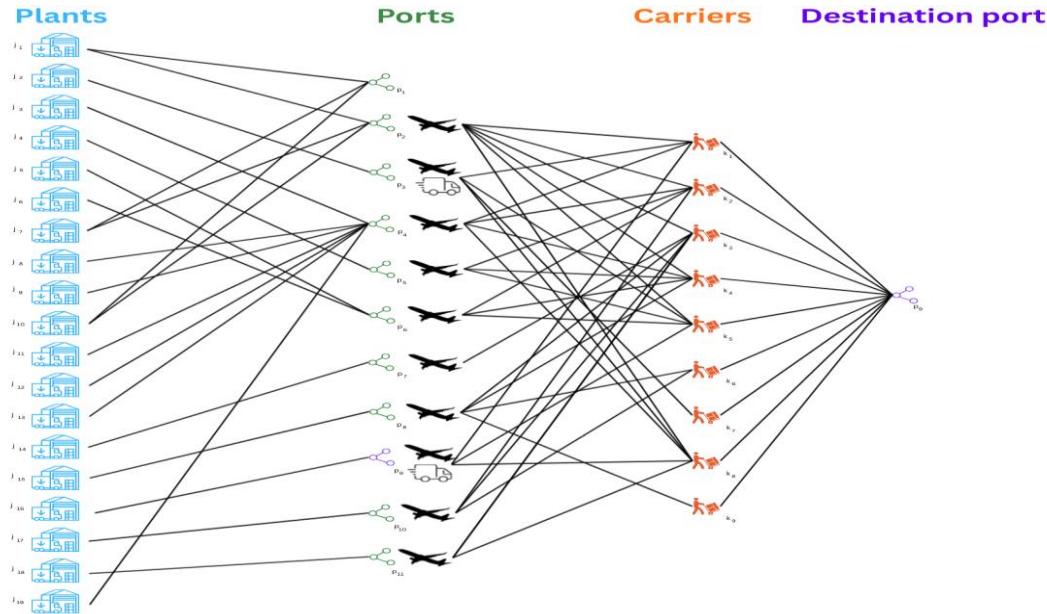
- Ports are being served by different carriers
- Port 1 is not being served
- Just port 3 and 9 have the option of air and ground mode

2. Data Understanding and Visualization – *Network of 3rd stage*



- All carriers deliver to one final destination (port 9)

2. Data Understanding and Visualization – *Complete Network*



- 19 plants, 10 ports and 9 carriers
 - Each order has upto 300 combinations to choose from
- Leads to more than a million options in total

3. Challenges and Assumptions

Challenges	Assumptions
Unavailable freight rates in some cases	Take average freight rates
Special customers with infeasible requirements	Ignore special customers to achieve a feasible solution
The daily plant capacity is too small	The plant capacity is for orders not units

4. Data Preparation

- Calculating the customer time windows
- Fixing errors and unavailable data
- Separating the existing solution and categorizing the data into parameters and decision variables

5. Model Formulation

Sets:

- $I = \{1, \dots, 9215\}$: Set of all orders
- $J = \{1, \dots, 19\}$: Set of all plants (warehouses)
- $K = \{1, \dots, 9\}$: Set of all carriers
- $P = \{1, \dots, 10\}$: Set of all origin ports
- $D = \{1, \dots, 9\}$: Set of planning days (May 26 – June 3, 2013)

5. Model Formulation

Parameters:

- WC_{ij} : Warehouse cost for order i at plant j
- FC_{ikpd} : Freight cost for order i via carrier k , port p on day d
- Cap_j : Daily capacity of plant j (orders per day)
- $Prod_{ij}$: 1 if product for order i is available at plant j , 0 otherwise
- Net_{jp} : 1 if plant j connects to port p , 0 otherwise

5. Model Formulation

Parameters:

- $Route_{kps}$: 1 if carrier k serves route from port p with service level s,
0 otherwise
- ES_i : Earliest allowed shipping date for order i
- LS_i : Latest allowed shipping date for order i
- SL_i : Required service level for order i (DTD/DTP/CRF)

5. Model Formulation

Decision Variable:

- $x_{ijkpd} \in \{0,1\}$: 1 if order i is assigned to plant j , carrier k , port p on day d ;
0 otherwise

Objective Function:

- Minimize $Z = \sum_i \sum_j \sum_k \sum_p \sum_d (WC_{ij} + FC_{ikpd}) \cdot x_{ijkpd}$
→ Minimize total cost (sum of warehouse and freight costs)

5. Model Formulation

Constraints:

- 1. *Assignment Constraint:*

$$\sum_j \sum_k \sum_p \sum_d x_{ijkpd} = 1, \forall i \in I$$

→ Each order i can be assigned exactly once (to one plant-carrier-
port-date combination)

- 2. *Product Availability:*

$$x_{ijkpd} \leq \mathit{Prod}_{ij}, \forall i, j, k, p, d$$

→ Order i can only be assigned to plant j if that plant stocks the
required product

5. Model Formulation

Constraints:

- 3. *Plant-Port Network Connectivity:*

$$x_{ijkpd} \leq Net_{jp}, \forall i,j,k,p,d$$

→ Orders can only use existing physical connections between plant j and port p

- 4. *Daily Plant Capacity:*

$$\sum_i \sum_k \sum_p x_{ijkpd} \leq Cap_j, \forall j \in J, \forall d \in D$$

→ Total orders assigned to plant j on day d cannot exceed its daily processing capacity

5. Model Formulation

Constraints:

- 5. *Temporal Shipping Window:*

$$x_{ijkpd} = 0 \text{ if } d < ES_i \text{ or } d > LS_i, \forall i, j, k, p, d$$

→ Order i must ship within its allowed date range ES_i, LS_i

- 6. *Carrier-Route-Service Compatibility:*

$$x_{ijkpd} \leq Route_{kp,SL_i}, \forall i, j, k, p, d$$

→ Order i can only use carrier k on port p if that carrier offers the required service level on that route

5. Model Formulation

Constraints:

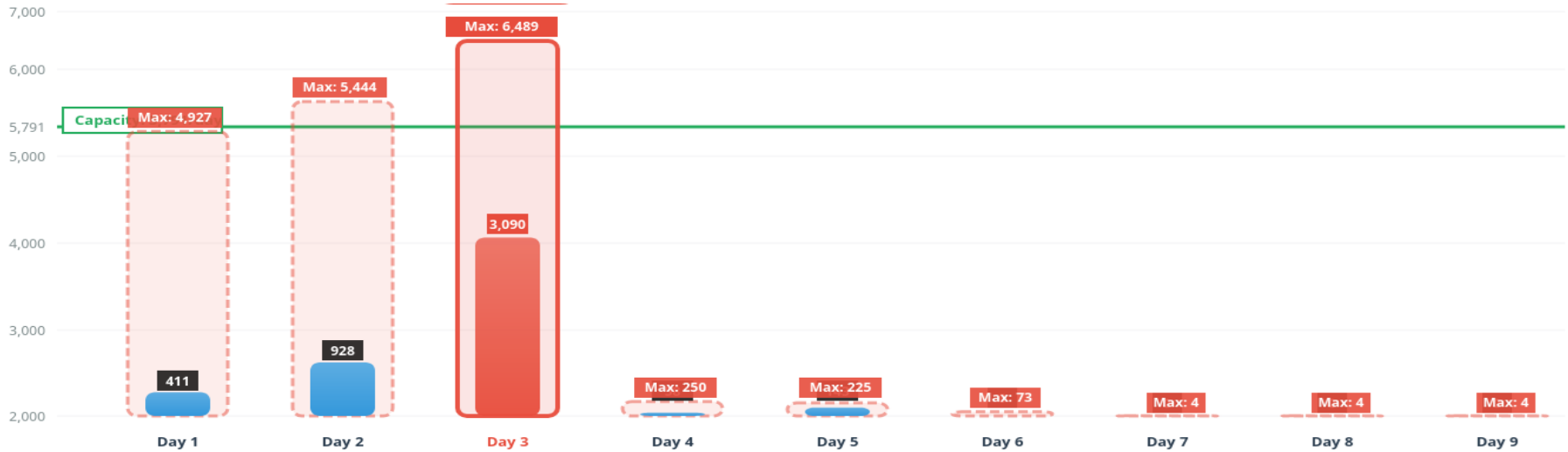
- *7. Binary Variable Definition:*

$$x_{ijkpd} \in \{0,1\}, \forall i,j,k,p,d$$

→ All assignment decisions are binary (assigned or not assigned)

6. Outlook & Questions

- The model yields an infeasible solution
- Combination of constraints creates a bottleneck



6. Outlook & Questions

- Potential Solution 1: Relax the time window constraint with a penalty
- Potential Solution 2: Relax the plant capacity constraint with a penalty system
- Open to suggestions

Thank you for your attention!