Journal of Social Research
P-ISSN: 2827-9832
E-ISSN: 2828-335x
Vol. 5, No. 01, December 2025
http://ijsr.internationaljournallabs.com/index.php/ijsr

A Facility Location Model with Partial Demand Satisfaction: Minimizing Total Cost In Logistics Networks

Ibnu Habib[1]*, Anisa Aprilia[2], Ryry Rizky Asri[3]
[1,2]Universitas Logistik dan Bisnis Internasional, Indonesia
[3]Universitas Pasundan, Indonesia
Email: ibnuhabib@ulbi.ac.id*, anisaaprillia@ulbi.ac.id, ryryrizki@unpas.ac.id

ABSTRACT

Facility location optimization plays a pivotal role across both public and private sectores, with critical applications in telecommunication, urban planning, industrial layout, and most notably for logistics and supply chain management. The main objective of a Facility Location Problem (FLP) is to determine the optimal placement of a set of facilities (Regional Distribution Centers) within a defined geographical space based on the spatial distribution of customer demand points. This strategic decision directly influences operational efficiency, service levels, and overall system cost. In the model presented, key factors such as the proximity of facilities to demand nodes, the volume of products required, transportation expenses, and dissatisfaction cost (i.e., penalties for unmet demand) are explicitly incorporated into the optimization framework. The goal is not only to identify the best facility locations but also to decide which transportation links to activate and how much flow to allocate across them, thereby minimizing total system cost while satisfying demand requirements as effectively as possible. The computational results demonstrate crucial insight. Dissatisfaction costs increase, reflecting higher penalties for failing to meet customer demand. The model responds by fully satisfying all destinations, even if it entails higher dissatisfaction expenditures and reduces the total cost.

Keywords: Facility Location Problem, Transportation Cost, Dissatisfaction Cost, Flow Allocation, Regional Distribution Center

INTRODUCTION

Facility location decisions play a key role in both public and private sectors. These decisions affect many areas, including telecommunications, urban planning, logistics, and supply chain management (Alegoz & Yapicioglu, 2022; Fang & Partovi, 2020; Shih, 2015; Sundarakani et al., 2020). The main goal of the Facility Location Problem (FLP) is to find the best places to build facilities such as warehouses, distribution centers, and service points so that customer demand is met efficiently and at the lowest possible cost (Adeleke & Olukanni, 2020; Espejo et al., 2023; Gao et al., 2021; Zhu et al., 2022).

In real-world applications, companies and governments must consider multiple interrelated factors when selecting facility locations. These include the geographical distance between facilities and customers, the volume and distribution of demand, production or service capacities, transportation costs, and the often-overlooked cost of failing to meet customer needs, known as dissatisfaction or penalty cost (Erturan-Ogut & Kula, 2023; Suman et al., 2021; Wang et al., 2021). Neglecting these factors can lead to inflated operational expenses, diminished service levels, and inefficient resource utilization. For instance, empirical studies indicate that logistics costs can constitute 10–15% of a product's total landed cost in many industries, and suboptimal facility placement can inflate these costs by up to 20–30% (World Bank, 2021). Furthermore, sectoral comparisons reveal that in e-commerce, where delivery speed is paramount, a 10% reduction in average delivery distance through better facility placement can decrease last-mile costs by approximately 5–8% (McKinsey & Company, 2023).

Recent research in facility location modeling has evolved beyond simple cost minimization to incorporate greater realism and complexity. For example, Alizadeh et al. (2019) integrated uncertainty in casualty numbers and transport capacity when locating emergency medical sites post-disaster. Efiyanti & Idayani (2025) applied integer programming to optimize public health center locations in Bandar Lampung, Indonesia, by considering travel time and population density. Pajić et al. (2024) employed multi-criteria decision-making for warehouse site selection based on infrastructure, labor availability, and delivery time. Additionally, Ciacco et al. (2026) developed an Integer Linear Programming model for the Two-level Facility Location Problem (TLFLP) to optimize the placement of Central and Regional Distribution Centers, enhancing logistics network efficiency. Transportation costs, a dominant factor, are influenced by fuel consumption, driver wages, vehicle depreciation, and maintenance—all linearly correlated with travel time and distance (Jafari et al., 2025).

The research introduces a pivotal advancement in FLP modeling through the incorporation of partial demand satisfaction, where unmet demand is penalized rather than treated as an infeasibility. This approach mirrors practical scenarios where fulfilling every unit of demand—especially from remote or low-margin customers—may be economically unjustifiable. The penalty, or dissatisfaction cost, represents tangible consequences such as lost sales, contractual penalties, or intangible losses like brand goodwill. Zhang & Kalcsics (2025) highlight the challenge of calibrating these penalty parameters to achieve desired service levels without incurring prohibitive costs. Despite its practical relevance, there remains a gap in the literature concerning the implementation of such penalty mechanisms in industry-applied models, particularly within the context of logistics networks for physical goods. Many academic models treat penalties as abstract parameters, lacking connection to real-world cost structures or managerial decision-making processes. Furthermore, there is a scarcity of empirical data and practical case studies that statistically demonstrate how specific location decisions and the strategic use of dissatisfaction costs directly influence total logistics costs and operational performance across different sectors.

This study addresses these gaps by developing and analyzing a facility location optimization model that explicitly integrates transportation and dissatisfaction costs within a logistics network framework. The model determines optimal locations for Regional Distribution Centers, activates transportation links, and allocates product flows—all while allowing for the strategic non-fulfillment of demand when economically rational. The mathematical formulation directly links each cost factor (transportation and dissatisfaction) to the decision variables (flow allocation). The core trade-off is as follows: when the cost of transporting a unit to a distant destination exceeds the penalty for not satisfying that demand, the model will allocate zero flow to that link, incurring the penalty instead. This mechanism can lead to a decrease in total system cost by avoiding prohibitively expensive deliveries, but it may also increase operational costs related to customer relationship management and long-term brand equity, which are encapsulated within the penalty parameter.

This paper aims to bridge theory and practice by utilizing realistic data from a home products manufacturer. It provides a practical example of how penalty costs are quantified and integrated into the objective function, offering readers a clear visualization of their implementation. Furthermore, through sensitivity analysis on key parameters (production capacities, demand levels, transportation, and dissatisfaction costs), the study empirically demonstrates how variations in these factors influence the optimal network configuration and total cost.

The aims of this research are threefold: (1) to formulate a facility location model that balances transportation and dissatisfaction costs under capacity constraints; (2) to analyze the model's behavior and sensitivity using real-world data, providing empirical insights into cost trade-offs; and (3) to offer a decision-support framework that helps logistics managers make informed, cost-effective strategic decisions regarding facility placement and demand fulfillment policies. The benefits of this study include providing practitioners with an adaptable model for optimizing their distribution networks, contributing to the academic literature on partial-demand FLPs with empirical validation, and highlighting the significant cost implications and strategic leverage points within logistics network design in an era of volatile demand and high customer expectations.

METHOD

This paper presents an optimization model for facility location that balances transportation cost and dissatisfaction cost. The model determines the best locations for Regional Distribution Centers and decides how much products to send on each route to the destinations. It also explores what occasions when some customers demand is left unsatisfied especially when the penalty for unmet demand is lower than the cost of delivery.

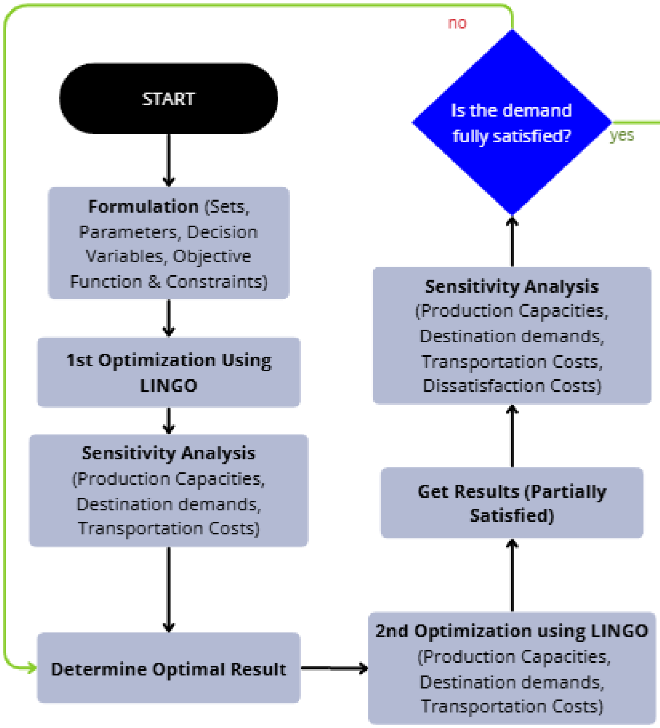

Figure 1. Facility Location Problem
Source: Author's illustration

Facility Location problem

The facility location problem studied in this report aims at establishing which links to use, and what amount of flow to send on each link, for the fulfilling of customer demands. Practical applications could be in the private and public sectors such as telecommunications, urban planning, layout problems, logistics, and energy, this problem deals with strategic and medium-term decision. In this exercise, real data from a house products producer company is used.

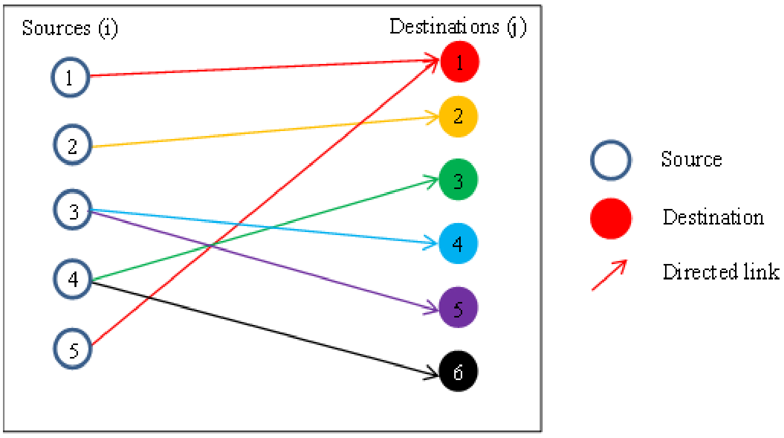

Figure 2. Network of Sources (i) and Destinations (j)
Source: Author's illustration

Formalization

1. **Sets**

The sets for the following facility location optimization problem are:

- i = 1,…, |V1| is the given set of facilities (the notation | V1 | denotes the cardinality of the set).
- j = 1,…, |V2| is the given set of destinations (the notation | V2 | denotes the cardinality of the set).

2. **Parameters**

The parameters for the following facility location optimization problem are:

- a_i, i=1,…, |V1| is the i_{th} facility production capacity.
- b_j, i=1,…, |V2| is the j_{th} destination demand.
- c_{ij}, i=1,…, |V1|, j=1,…,|V2| is the cost of transportation for the link between the i_{th} facility and the j_{th}destiation.

3. **Decision variables**

Decision variables are to be decided with respect to the objective of the optimization problem, in this case the objective is to reduce the cost of transportation and when necessary, dissatisfaction, to the minimum.

The decision variable for the following facility location optimization problems is:

- x_{ij} i=1,…, |V1| , j=1,…, |V2| is the flow associated to the link between the i_{th} facility and the j_{th}destiation.

4. **Objective functions and constraints**

The objective functions aim to minimize the overall cost related to the transportation, taking into account the facility production capacities and destination's demand.

Thus, the objective functions are:

- $min = \sum_{i=1} \sum_{j=1} c_{ij} x_{ij}$ Ex.1
(1.1)

- $min \quad \{\sum_{i=1}^{m} \sum_{j=1}^{n} c_{i,j} x_{i,j} + \sum_{j=1}^{n} d_j \, max(b_j - \sum_{i=1}^{m} x_{i,j} \, , 0)$ Ex.2
(1.2)

The objective function **(1.1)** is subjected to the following constraints:

- $\sum_{i=1} x_{ij} \; = \; b_j$ **(1.3)**

- $\sum_{j=1} x_{ij} \leq a_i$ **(1.4)**

- $\forall_{ij}\, x_{ij} \geq 0$ **(1.5)**

Constraint (1.3) guarantees that each destination's demand is fully satisfied.
Constraint (1.4) guarantees that the total outflow from each facility does not exceed the related production capacity.
Constraints (1.5) guarantees that the flow can only be outgoing from each facility.
The objective function **(1.2)** is subjected to the following constraints:

- $\sum_{j=1} x_{ij} \leq a_i$ **(1.6)**

- $\forall_{ij}\, x_{ij} \geq 0$ **(1.7)**

Optimal results (Ex1)
Data
In this section, the useful data for the first optimization problem are reported. The time span considered is 1 month.
Firstly, the demand of each destination "j" is defined as b_j(pcs/month):

Table 1. Demand per Destination (j)

Destinations (j)	**1**	**2**	**3**	**4**	**5**	**6**
Demand (b_j)	7194	5544	672	156	192	203

Source: Data from the home products manufacturer

While for each source "i" the maximum production capacity is set as a_i(pcs/month):

Table 2. Production Capacity per Source (i)
Source: Data from the home products manufacturer.

Sources (i)	**1**	**2**	**3**	**4**	**5**
Prod. Capacity (a_i)	2000	3000	5000	7000	2000

And lastly for each link (i,j) connecting each source to each destination, the cost of transportation is c_{ij}(€/pcs):

Table 3. Transportation Cost per Link (i,j)

c_{ij}	**1**	**2**	**3**	**4**	**5**	**6**
1	0.08	0,078	0,076	0.08	0,078	0,081
2	0,076	0,081	0,078	0,079	0,076	0.08
3	0.08	0,078	0,079	0.08	0,078	0,079
4	0,081	0,076	0,076	0,078	0,081	0,076
5	0,078	0.08	0,081	0,076	0.08	0,078

Source: Data from the home products manufacturer

Scope of the optimization problem is to establish which links to use and the amount of flow to send on each of those, to ultimately reduce the total cost (***Tot.C***) to the minimum while exactly meeting the total demand.

X(i,j) is the matrix reporting the values of the optimum flows (x_{ij}) for each link (i,j). This matrix is initialized to the null matrix since we consider no flow present at the start of the optimization problem:

Table 4. Initial Flow Matrix (Initialized as Zero)

X(i , j)	1	2	3	4	5	6
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0

Source: Prepared by the author for initial modeling

The flows (x_{ij}) are the only decision variables of this problem.

RESULTS AND DISCUSSION

To solve the two optimization problems, software LINGO 9.0 is used.
In the following table the optimal values of flow for the first optimization problem are shown.

Table 5. Optimal Flow for the First Problem (Ex1)

X(i , j)	1	2	3	4	5	6
1	2000	0	0	0	0	0
2	3000	0	0	0	0	0
3	194	0	0	0	192	0
4	0	5544	672	156	0	203
5	2000	0	0	0	0	0

Source: Optimization results from LINGO 9.0.

And the resulting total cost of transportation to be sustained by the seller is ***Tot.C = 1074.51€.*** The following figure (*figure 3.*) is a graphical representation of the flows resulting from solving the optimization problem.

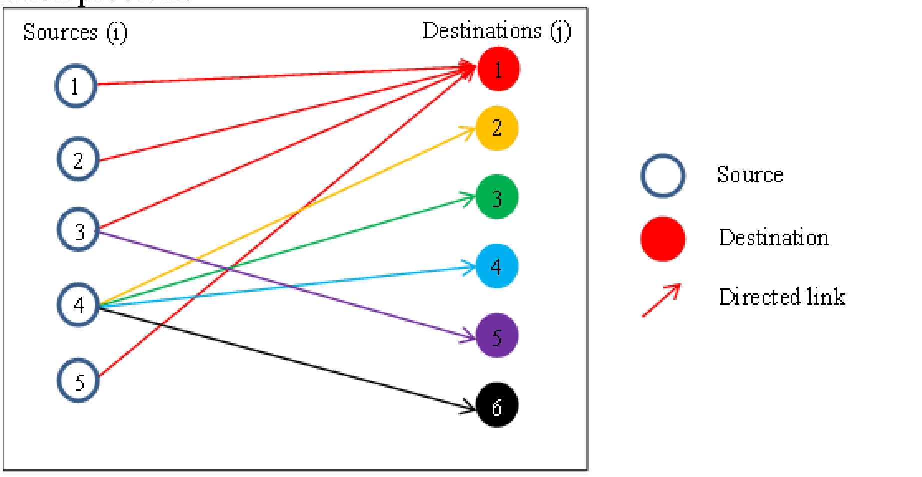

Figure 3. Optimal Flow from the First Problem (Ex1)
Source: Optimization results from LINGO 9.0 based on company data.

Results interpretation

From table 5. It is obvious that not all the possible links are used as it could be predicted. Depending on the cost of transportation and the demand it results less convenient to use certain links, therefore the flow is split to reduce overall cost as much as possible; still satisfying the demand of each destination fully.

Sources are selected depending on their maximum capacity and on the cost of transportation, from the cheapest on to the most expensive one. In example for the destination 1 the three cheapest sources 1 & 2 & 5 are fully exploited before asking the remaining products to the following cheapest source 3.

Destination 1: with demand $\boldsymbol{b_1}$ is satisfied by sources 1 & 2 & 3 & 5 . Since the total amount of product requested is higher than any maximum capacity of any source, it is necessary to have a combination of flows from different sources.
Destination 2: with demand $\boldsymbol{b_2}$ is satisfied by source 4
Destination 3: with demand $\boldsymbol{b_3}$ is satisfied by source 4
Destination 4: with demand $\boldsymbol{b_4}$ is satisfied by source 4
Destination 5: with demand $\boldsymbol{b_5}$ is satisfied by source 3
Destination 6: with demand $\boldsymbol{b_6}$ is satisfied by source 4
Source 4 is often exploited since it has very low cost of transportation for most of the destinations.

Sensitivity analysis
The sensitivity analysis is aimed at defining the response of the system to changes in its parameters. The parameters involved in this system are:
- Production capacities (a_i)
- Destination's Demands (b_j)
- Transportation costs (c_{ij})

Let's perform the sensitivity analysis for each of the above mentioned.

1. **Production capacities $\boldsymbol{a_i}$**

We can try to set the production capacity, of those sources related to the cheapest transportation cost, exactly equal to the demand of the corresponding destinations. This simulates a condition in which we have no limitation of production capacities, with the possibility of fixing, as default transportation links for each destination, those which are the cheapest.
- Source 2 has the cheapest transportation cost to destination 1 ($c_{ij} = 0{,}76\ €/pcs$) so we set $a_2 = b_1 = 7194\ pcs/month$ and so on:

Table 6. Modified Production Capacities (Sensitivity Analysis)

Sources (i)	**1**	**2**	**3**	**4**	**5**
Prod. Capacity (a_i)	672	7386	0	5747	156

Source: Prepared by the author for scenario analysis

Note that sources 2 and 4 are set to meet the demand of respectively destination 1 & 5 and 2 & 6.
What we expect is that we'll use only the least expensive links therefore having a reduction of the tot cost.

Table 7. Optimal Flow with Modified Capacities (Ex1)

X(i , j)	**1**	**2**	**3**	**4**	**5**	**6**
1	0	0	672	0	0	0
2	7194	0	0	0	192	0
3	0	0	0	0	0	0
4	0	5544	0	0	0	203
5	0	0	0	156	0	0

Source: Optimization results from LINGO 9.0 based on modified data

As expected, each destination is served by a single source having the cheapest transportation cost for that destination.
Source 3 is related to high transportation costs for every destination, thus resulting in a zero exploitation of it.
The total cost is reduced to ***Tot.C = 1061.04€ .***

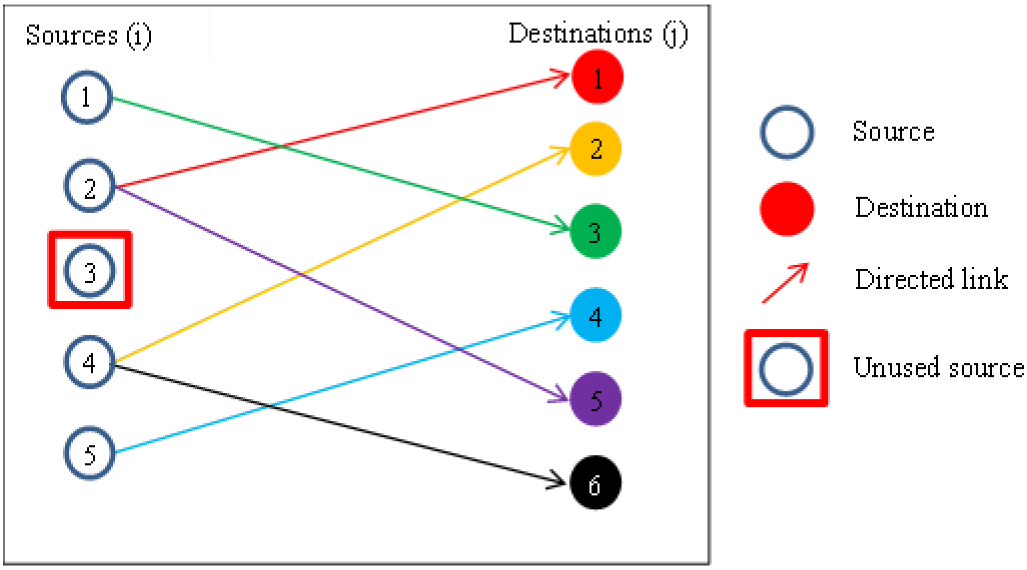

Figure 4. Optimal Flow with Modified Capacities (Ex1)

Source: Optimization results from LINGO 9.0 based on modified data

2. Destination demand b_j

We can try to increase the demand of the different destinations up to the saturation of the total production capacity.

– Total production capacity is $\sum_{i=1}^{n=5} a_i = 19.000 \frac{\text{pcs}}{\text{month}} (n = 5\ sources)$:

Table 8. Modified Demand (Sensitivity Analysis)

Destinations (j)	**1**	**2**	**3**	**4**	**5**	**6**
Demand (b_j)	6582	2542	256	864	6853	1903

Source: Prepared by the author for scenario analysis

Table 9. Optimal Flow with Modified Demand (Ex1)

X(i , j)	**1**	**2**	**3**	**4**	**5**	**6**
1	147	0	0	0	1853	0
2	3000	0	0	0	0	0
3	0	0	0	0	5000	0
4	1435	2542	256	864	0	1903
5	2000	0	0	0	0	0

Source: Optimization results from LINGO 9.0 based on modified data

The total cost is reduced to ***Tot.C = 1471.20€*** **.**

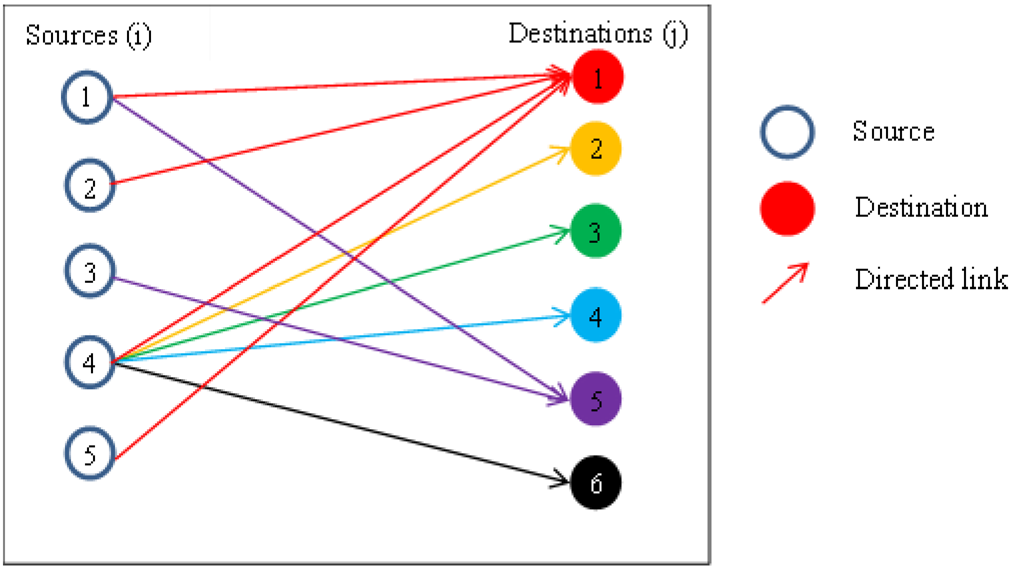

Figure 5. Optimal Flow with Modified Demand (Ex1)
Source: Optimization results from LINGO 9.0 based on modified data

3. Transportation costs (c_{ij})

This parameter is the most interesting and the most realistic. In the first example destination 1 was served by all sources but the 4th, being it the most expensive. A good analysis can be done setting the cost of transportation from source 4 and destination 1, $c_{41} = 0.70$ which is cheaper than any other link. We can expect the full production capacity of source 4 to be exploited for serving destination 1 e the remaining demand to be satisfied by the following cheapest source → the 2nd.

Table 10. Modified Transportation Costs (Sensitivity Analysis)

c_{ij}	1	2	3	4	5	6
1	0,08	0,078	0,076	0,08	0,078	0,081
2	0,076	0,081	0,078	0,079	0,076	0,08
3	0,08	0,078	0,079	0,08	0,078	0,079
4	0,07	0,076	0,076	0,078	0,081	0,076
5	0,078	0,08	0,081	0,076	0,08	0,078

Source: Prepared by the author for scenario analysis.

The resulting flows table:

Table 11. Optimal Flow with Modified Transportation Costs (Ex1)

X(i , j)	1	2	3	4	5	6
1	0	544	672	0	0	0
2	194	0	0	0	192	0
3	0	5000	0	0	0	0
4	7000	0	0	0	0	0
5	0	0	0	156	0	203

Source: Optimization results from LINGO 9.0 based on modified data

The total cost is reduced to ***Tot.C = 1030.53€ .***

The network flow graph:

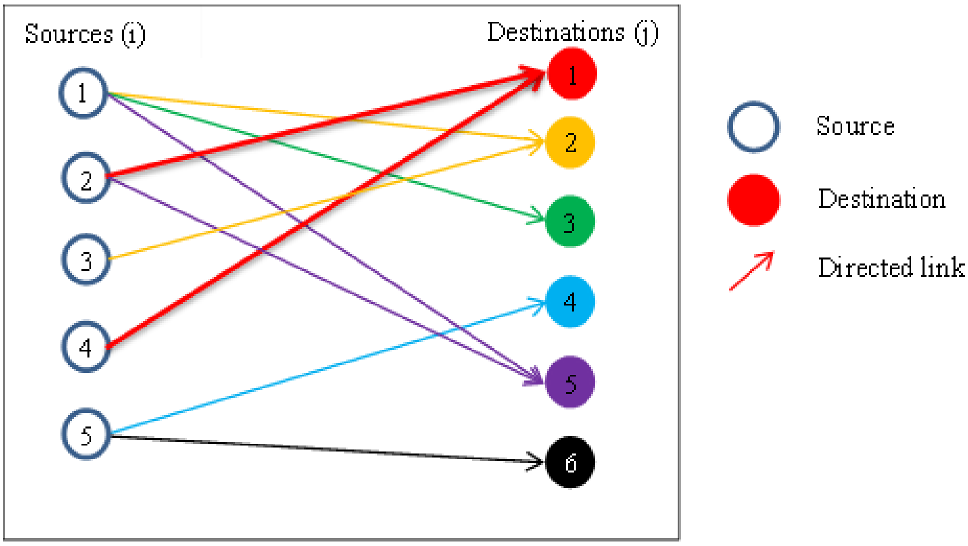

Figure 6. Optimal Flow with Modified Transportation Costs (Ex1)
Source: Optimization results from LINGO 9.0 based on modified data.

As expected the full production capacity of source 4 is exploited for serving destination 1 e the remaining demand is satisfied by the following cheapest source → the 2nd.

Optimal results (Ex2)

1. Data

In this section, the useful data for the second optimization problem are reported. The time span considered is 1 month.

For each destination "j":

the demand is defined as b_j(pcs/month):

Table 12. Demand per Destination (j) for the Second Problem

Destinations (j)	**1**	**2**	**3**	**4**	**5**	**6**
Demand (b_j)	7194	5544	672	156	192	203

Source: Data from the home products manufacturer

the cost of dissatisfaction, the cost of not satisfying the demand of the customer, is dependent on the amount of pieces not sent, d_j(€/pcs):

Table 13. Dissatisfaction Cost per Destination (j)
Source: Prepared by the author based on company data and assumptions

Destinations (j)	**1**	**2**	**3**	**4**	**5**	**6**
Dissatisfaction d_j(€/pcs)	0,08	0,078	0,077	0,077	0,083	0,080

While for each source "i" the maximum production capacity is set as a_i(pcs/month):

Table 14. Production Capacity per Source (i) for the Second Problem

Sources (i)	**1**	**2**	**3**	**4**	**5**
Prod. Capacity (a_i)	2000	3000	5000	7000	2000

Source: Data from the home products manufacturer

For each link (i,j) connecting each source to each destination, the cost of transportation is c_{ij}(€/pcs):

Table 15. Transportation Cost per Link (i,j) for the Second Problem

c_{ij}	1	2	3	4	5	6
1	0.08	0,078	0,076	0.08	0,078	0,081
2	0,076	0,081	0,078	0,079	0,076	0.08
3	0.08	0,078	0,079	0.08	0,078	0,079
4	0,077	0,076	0,076	0,078	0,081	0,076
5	0,078	0.08	0,081	0,076	0.08	0,078

Source: Data from the home products manufacturer

Scope of the optimization problem is to establish which links to use and the amount of flow to send on each of those, to ultimately reduce the total cost (***Tot.C***) to the minimum considering the existing dissatisfaction costs.

X(i,j) is the matrix reporting the values of the optimum flows (x_{ij}) for each link (i,j). This matrix is initialized to the null matrix since we consider no flow present at the start of the optimization problem:

Table 16. Initial Flow Matrix for the Second Problem

X(i , j)	1	2	3	4	5	6
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0

Source: Prepared by the author for initial modeling

The flows (x_{ij}) are the only decision variables of this problem.

Results

As previously said to solve the two optimization problems, software LINGO 9.0 is used.

In the following table the resulting optimal values of flow for the second optimization problem are shown:

Table 17. Optimal Flow for the Second Problem (Ex2)

X(i , j)	1	2	3	4	5	6
1	0	1	672	0	96	0
2	3000	0	0	0	0	0
3	0	1	0	0	96	0
4	2350	4447	0	0	0	203
5	1844	0	0	156	0	0

Source: Optimization results from LINGO 9.0.

Here below are reported the sustained costs of dissatisfaction K_j:

Table 18. Dissatisfaction Cost per Destination (j) from Optimal Solution

Destinations (j)	1	2	3	4	5	6
Tot. dissatisfaction cost K_j (€)	0	85,41	0	0	0	0

Source: Optimization results from LINGO 9.0

And the resulting total cost of transportation to be sustained by the seller is ***Tot.C = 1069.65€.***

The following figure (*figure 6.*) is a graphical representation of the flows resulting from the optimization problem.

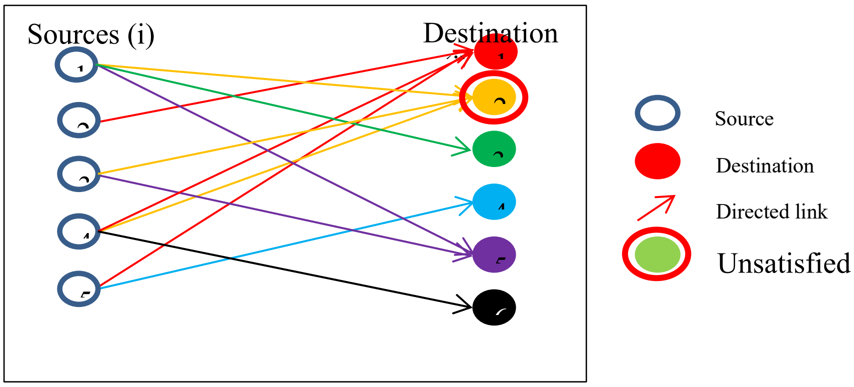

Figure 7. Optimal Flow from the Second Problem (Ex2)
Source: Optimization results from LINGO 9.0 based on company data

Results interpretation

From figure 6. As with the previous problem, depending on the cost of transportation and the demand it results less convenient to use certain links, therefore the flow is split to reduce overall cost as much as possible. Furthermore, we cannot satisfy completely the demand of some destinations, since the total cost, comprehensive of dissatisfaction and transport expenses, would be cheaper than in the case in which we fulfill the demand.

Sources are selected depending on their maximum capacity and on the cost of transportation, from the cheapest on to the most expensive one. In example for the destination 1 the cheapest source, the 2nd, is fully exploited before asking the remaining products to the following cheapest sources 4 & 5.

The latter is not the case of destination 2, due to the fact that its cost of dissatisfaction is lower or equal to most of the transportation costs, it is convenient to satisfy only partially its demand. Therefore, the resulting unsatisfied demand amount is $1095pcs$ which leads to total cost of dissatisfaction $K_j = 85{,}41€$.

Destination 1: with demand $\boldsymbol{b_1}$ is satisfied by sources 2 & 4 & 5 .
Destination 2: with demand $\boldsymbol{b_2}$ is partially satisfied by source 1 & 3 & 4 .
Destination 3: with demand $\boldsymbol{b_3}$ is satisfied by source 1 .
Destination 4: with demand $\boldsymbol{b_4}$ is satisfied by source 5 .
Destination 5: with demand $\boldsymbol{b_5}$ is satisfied by source 1 & 3 .
Destination 6: with demand $\boldsymbol{b_6}$ is satisfied by source 4 .
Source 4 is often exploited since it has very low cost of transportation for most of the destinations.

Sensitivity analysis

The sensitivity analysis is aimed at defining the response of the system to changes in its parameters. The parameters involved in this system are:

- Production capacities (a_i)
- Destination's Demands (b_j)
- Transportation costs (c_{ij})
- Dissatisfaction costs (d_j)

Let's perform the sensitivity analysis for each of the above mentioned.

i. Production capacities $\boldsymbol{a_i}$

Again we try to set the production capacity of those sources related to the cheapest transportation cost, exactly equal to the demand of the corresponding destinations. This simulates a condition in which we have no limitation of production capacities, with the possibility of fixing, as default transportation links for each destination, those which are the cheapest.

– Source 2 has the cheapest transportation cost to destination 1 ($c_{ij} = 0{,}76\ €/pcs$) so we set $a_2 = b_1 = 7194\ pcs/month$ but also for destination 5 therefore $a_2 = b_1 + b_5 = 7386\ pcs/month$ and so on:

Table 19. Modified Production Capacities (Sensitivity Analysis, Ex2)

Sources (i)	1	2	3	4	5
Prod. Capacity (a_i)	672	7386	0	5747	156

Source: Prepared by the author for scenario analysis

Note that source 4 is set to meet the demand of destinations 2 & 6.
What we expect is that we'll use only the least expensive links therefore having a reduction of the tot cost.

Table 20. Optimal Flow with Modified Capacities (Ex2)

X(i , j)	1	2	3	4	5	6
1	0	0	672	0	0	0
2	7194	0	0	0	192	0
3	0	0	0	0	0	0
4	0	5544	0	0	0	203
5	0	0	0	156	0	0

Source: Optimization results from LINGO 9.0 based on modified data

Table 21. Dissatisfaction Cost with Modified Capacities

Destinations (j)	1	2	3	4	5	6
Tot. dissatisfaction cost K_j (€)	0	0	0	0	0	0

Source: Optimization results from LINGO 9.0 based on modified data

The total cost is reduced to ***Tot.C = 1061.04€.***

As expected, each destination is served by a single source having the cheapest transportation cost for that particular destination and all demands are fully satisfied.

Source 3 is related to high transportation costs for every destination, thus resulting in a zero exploitation of it.

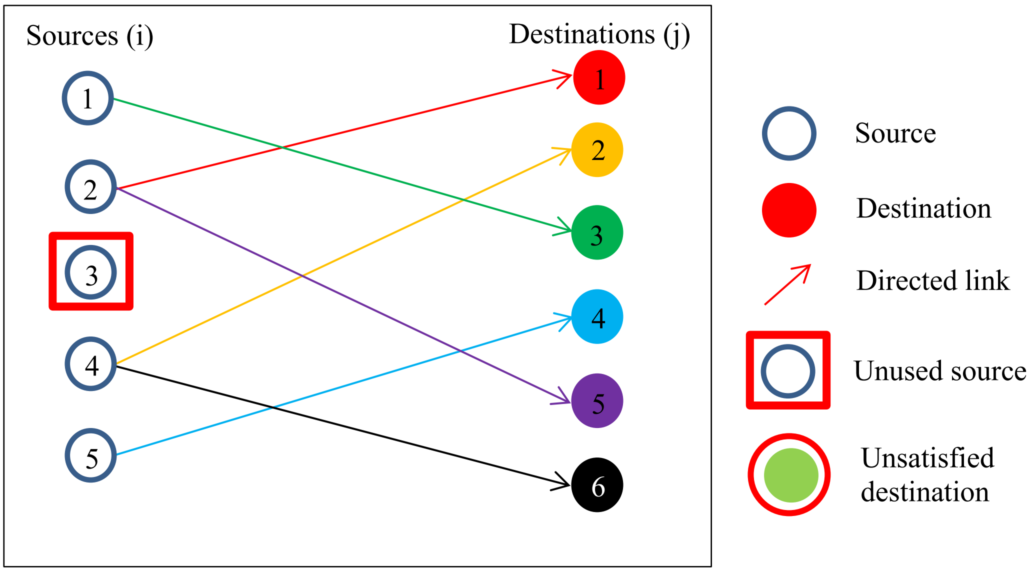

Figure 8. Optimal Flow with Modified Capacities (Ex2)
Source: Optimization results from LINGO 9.0 based on modified data

ii. Destination demand b_j

We can try to increase the demand of the different destinations up to the saturation of the total production capacity.

– Total production capacity is $\sum_{i=1}^{n=5} a_i = 19.000 \frac{\text{pcs}}{\text{month}} (n = 5\ sources)$:

Table 22. Modified Demand (Sensitivity Analysis, Ex2)

Destinations (j)	**1**	**2**	**3**	**4**	**5**	**6**
Demand (b_j)	6582	2542	256	864	6853	1903

Source: Prepared by the author for scenario analysis

Table 23. Optimal Flow with Modified Demand (Ex2)

X(i , j)	**1**	**2**	**3**	**4**	**5**	**6**
1	0	0	256	0	1744	0
2	2891	0	0	0	109	0
3	0	0	0	0	5000	0
4	2555	2542	0	0	0	1903
5	1136	0	0	864	0	0

Source: Optimization results from LINGO 9.0 based on modified data

Table 24. Dissatisfaction Cost with Modified Demand

Destinations (j)	**1**	**2**	**3**	**4**	**5**	**6**
Tot. issatisfaction cost K_j (€)	0	0	0	0	0	0

Source: Optimization results from LINGO 9.0 based on modified data

The total cost is reduced to ***Tot.C = 1462.31€***

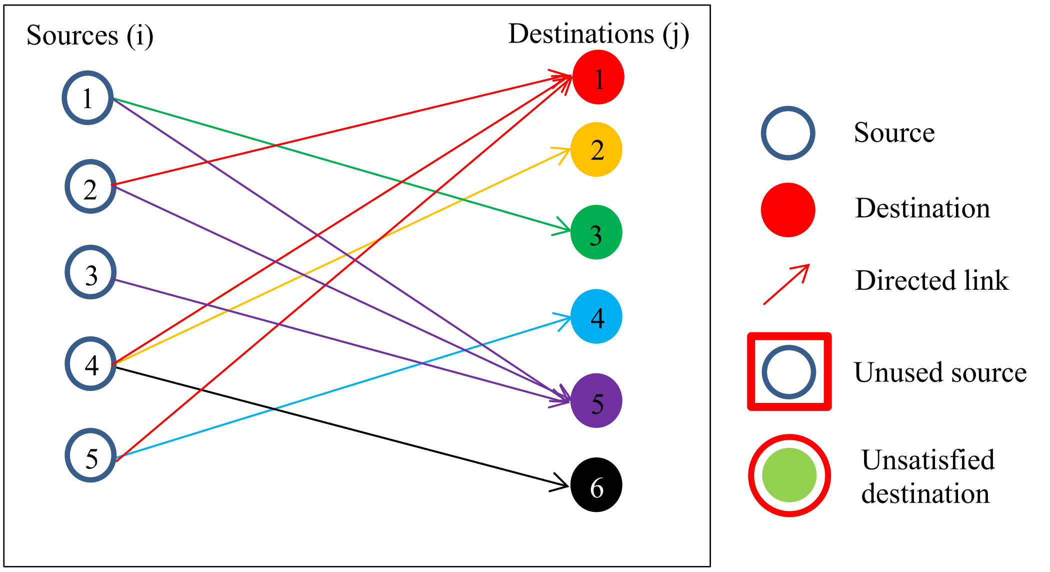

Figure 9. Optimal Flow with Modified Demand (Ex2)
Source: Optimization results from LINGO 9.0 based on modified data.

It is interesting to notice that now with an higher demand it results more convenient to fully satisfy each destination, even the 2nd which before was not satisfied completely.

iii. Transportation costs (c_{ij})

From the original solution of the problem, destination 3 is served by only source 1, being it the cheapest along with the 4th, in terms of transport costs. A good analysis can be done increasing the cost of transportation from source 1 and destination 3, $c_{13} = 0.77$. We can expect a reduction in the exploitation of source 1, together with an increase in use of other sources like the 4th (the cheapest in this case) or even the dissatisfaction of the demand.

Table 25. Modified Transportation Costs (Sensitivity Analysis, Ex2)

c_{ij}	1	2	3	4	5	6
1	0,08	0,078	0,077	0,08	0,078	0,081
2	0,076	0,081	0,078	0,079	0,076	0,08
3	0,08	0,078	0,079	0,08	0,078	0,079
4	0,077	0,076	0,076	0,078	0,081	0,076
5	0,078	0,08	0,081	0,076	0,08	0,078

Source: Prepared by the author for scenario analysis

The resulting flows table:

Table 26. Optimal Flow with Modified Transportation Costs (Ex2)

X(i , j)	1	2	3	4	5	6
1	0	1	1	0	96	0
2	3000	0	0	0	0	0
3	0	1	0	0	96	0
4	2350	4447	0	0	0	203
5	1844	0	0	156	0	0

Source: Optimization results from LINGO 9.0 based on modified data

Table 27. Dissatisfaction Cost with Modified Transportation Costs

Destinations (j)	**1**	**2**	**3**	**4**	**5**	**6**
Tot. dissatisfaction cost K_j (€)	0	85,41	51,67	0	0	0

Source: Optimization results from LINGO 9.0 based on modified data

The total cost is reduced to $\boldsymbol{Tot.C = 1070.32€}$ **.**

The network flow graph:

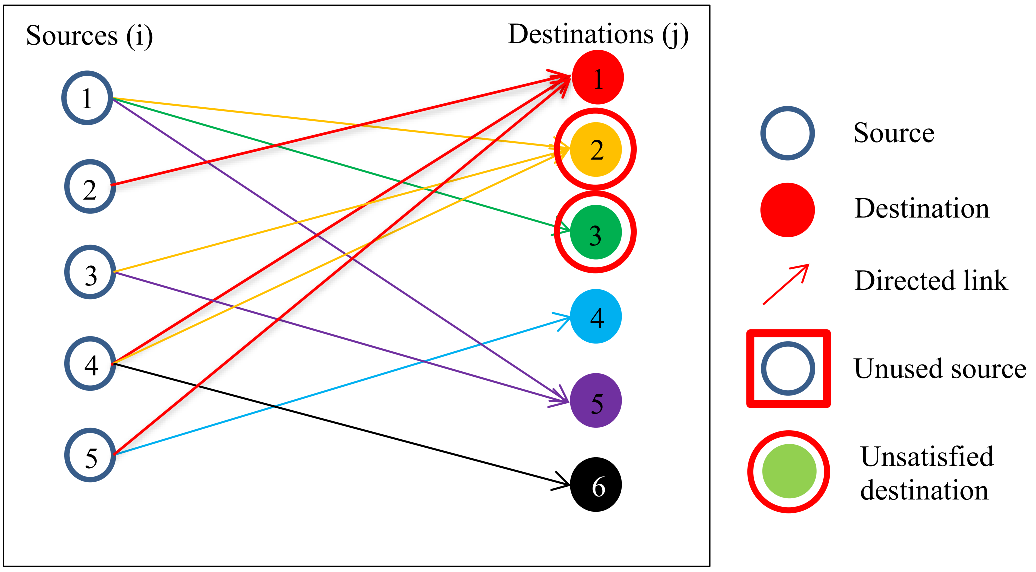

Figure 10.
Optimal Flow with Modified Transportation Costs (Ex2)
Source: Optimization results from LINGO 9.0 based on modified data

As expected, the flow from source 1 to destination 3 has been reduced and the best choice has been to not satisfy the rest of the demand, leading to an added dissatisfaction cost $\boldsymbol{K_3 = 51,67}$ **€.**

iv. Dissatisfaction costs (d_{ij})

Peculiarity of the second problem is the presence of dissatisfaction costs which establish the worthiness of satisfying the customer compared to a possible reduction of total costs. As previously set the current result leads to a dissatisfaction of the 2nd destination's demand. We can increase the dissatisfaction cost related to such destination, in order to drive the solution of the problem to a full satisfaction of its demand.

Table 28. Modified Dissatisfaction Costs (Sensitivity Analysis)

Destinations (j)	**1**	**2**	**3**	**4**	**5**	**6**
Dissatisfaction d_j(€/pcs)	0,08	0,08	0,077	0,077	0,083	0,080

Source: Prepared by the author for scenario analysis

The resulting flows table:

Table 29. Optimal Flow with Modified Dissatisfaction Costs

X(i , j)	**1**	**2**	**3**	**4**	**5**	**6**
1	0	0	672	0	96	0
2	3000	0	0	0	0	0

3	0	1097	0	0	96	0
4	2350	4447	0	0	0	203
5	1844	0	0	156	0	0

Source: Optimization results from LINGO 9.0 based on modified data

Table 30. Dissatisfaction Cost with Modified Dissatisfaction Costs

Destinations (j)	**1**	**2**	**3**	**4**	**5**	**6**
Tot. dissatisfaction cost K_j (€)	0	0	0	0	0	0

Source: Optimization results from LINGO 9.0 based on modified data

The total cost is ***Tot.C = 1069.65 €.***

Notice how the total cost did not change, this means that for $d_2 = 0{,}078\ €/pcs$ the total cost doesn't change, leaving to the seller the choice of satisfying or not the demand of destination 2 based on other parameters and considerations.

The network flow graph:

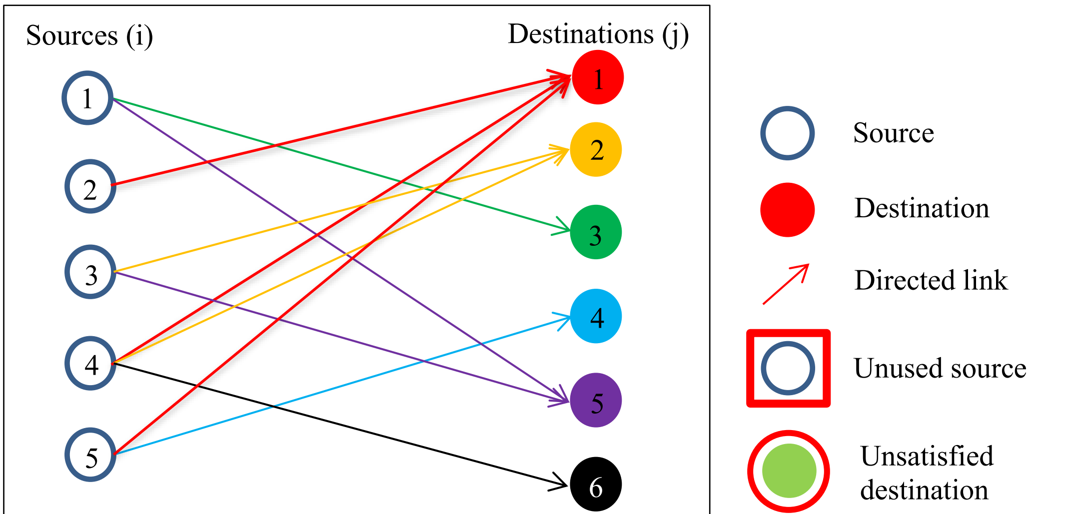

Figure 11.

Optimal Flow with Modified Dissatisfaction Costs (Ex2)
Source: Optimization results from LINGO 9.0 based on modified data

As expected the demand of destination 2 is fully satisfied due to the increased dissatisfaction cost.

CONCLUSION

This study examines facility location in supply chain design by integrating transportation and dissatisfaction costs into an optimization model, revealing how strategic facility placement and flow allocation decisions impact total operational expenses. In the full-demand satisfaction scenario, the model favors cost-effective routing through high-capacity, low-cost hubs like source 4, which excel due to competitive transport rates across destinations, while respecting production constraints. The partial satisfaction scenario introduces realism by allowing unmet demand when economically viable, with sensitivity analyses showing the system's adaptability: higher dissatisfaction penalties shift toward fuller fulfillment, and variations in capacities, demand levels, or transport costs maintain efficient network configurations. Overall, the work advocates dynamic models embracing trade-offs between delivery performance, resource limits, and service shortfalls to provide prescriptive guidance on high-leverage parameters amid volatile supply chains and rising customer expectations. For future research, extending the model to stochastic demand patterns and multi-modal transport options, incorporating real-time data from IoT-enabled logistics, could enhance robustness in volatile environments.

REFERENCES

Adeleke, O. J., & Olukanni, D. O. (2020). Facility location problems: Models, techniques, and applications in waste management. *Recycling, 5*(2). https://doi.org/10.3390/recycling5020010

Alegoz, M., & Yapicioglu, H. (2022). Integrating supplier selection, lot sizing and facility location decisions under a TBL approach: a case study. *Soft Computing, 26*(10). https://doi.org/10.1007/s00500-022-06866-7

Alizadeh, M., Amiri-Aref, M., Mustafee, N., & Matilal, S. (2019). A robust stochastic Casualty Collection Points location problem. *European Journal of Operational Research, 279*(3), 965–983. https://doi.org/10.1016/j.ejor.2019.06.018

Ciacco, A., Guerriero, F., & Saccomanno, F. P. (2026). Quantum annealing for the two-level facility location problem. *Future Generation Computer Systems, 174.* https://doi.org/10.1016/j.future.2025.107961

Efiyanti, R., & Idayani, D. (2025). Optimization of Public Health Centers Location in Bandar Lampung Using Integer Linear Programming. *G-Tech: Jurnal Teknologi Terapan, 9*(3), 1367–1375. https://doi.org/10.70609/g-tech.v9i3.7302

Erturan-Ogut, E. E., & Kula, U. (2023). Selecting the right location for sports facilities using analytical hierarchy process. *Journal of Facilities Management, 21*(5). https://doi.org/10.1108/JFM-09-2021-0103

Espejo, I., Páez, R., Puerto, J., & Rodríguez-Chía, A. M. (2023). Facility location problems on graphs with non-convex neighborhoods. *Computers and Operations Research, 159.* https://doi.org/10.1016/j.cor.2023.106356

Fang, J., & Partovi, F. Y. (2020). A HITS-based model for facility location decision. *Expert Systems with Applications, 159.* https://doi.org/10.1016/j.eswa.2020.113616

Gao, X., Park, C., Chen, X., Xie, E., Huang, G., & Zhang, D. (2021). Globally optimal facility locations for continuous-space facility location problems. *Applied Sciences (Switzerland), 11*(16). https://doi.org/10.3390/app11167321

Jafari, M. J., Parodi, L., Ferro, G., Minciardi, R., Paolucci, M., & Robba, M. (2025). Mixed-Fleet Goods-Distribution Route Optimization Minimizing Transportation Cost, Emissions, and Energy Consumption. *Energies, 18*(19), 5147. https://doi.org/10.3390/en18195147

Pajić, V., Andrejić, M., Jolović, M., & Kilibarda, M. (2024). Strategic Warehouse Location Selection in Business Logistics: A Novel Approach Using IMF SWARA–MARCOS—A Case Study of a Serbian Logistics Service Provider. *Mathematics, 12*(5). https://doi.org/10.3390/math12050776

Shih, H. (2015). Facility Location Decisions Based on Driving Distances on Spherical Surface. *American Journal of Operations Research, 05*(05). https://doi.org/10.4236/ajor.2015.55037

Suman, M. N. H., MD Sarfaraj, N., Chyon, F. A., & Fahim, M. R. I. (2021). Facility location selection for the furniture industry of Bangladesh: Comparative AHP and FAHP analysis. *International Journal of Engineering Business Management, 13.* https://doi.org/10.1177/18479790211030851

Sundarakani, B., Pereira, V., & Ishizaka, A. (2020). Robust facility location decisions for resilient sustainable supply chain performance in the face of disruptions. *International Journal of Logistics Management, 32*(2). https://doi.org/10.1108/IJLM-12-2019-0333

Wang, Y., Sun, Y., Guan, X., & Guo, Y. (2021). Two-Echelon Location-Routing Problem with Time Windows and Transportation Resource Sharing. *Journal of Advanced Transportation, 2021.* https://doi.org/10.1155/2021/8280686

Zhang, H., & Kalcsics, J. (2025). Capacitated facility location problem under uncertainty with service level constraints. *European Journal of Operational Research.* https://doi.org/10.1016/j.ejor.2025.08.056

Zhu, T., Boyles, S. D., & Unnikrishnan, A. (2022). Two-stage robust facility location problem with drones. *Transportation Research Part C: Emerging Technologies, 137.* https://doi.org/10.1016/j.trc.2022.103563