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Selecting Optimal Overseas Warehouse Location in Global Supply Chain: An Application of Binary Integer Programming

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Abstract

Overseas warehouses are crucial nodes in today's worldwide supply chain. They offer timely delivery of products to remote customers at a low cost and with few shipping issues. A foreign warehouse is a cross-border solution that may be used to solve cross-border B2B and B2C transactions. Strategically positioned warehouses allow organizations to effortlessly cross borders across multiple countries, regardless of where company headquarters and production or assembly units are situated. We argued that selecting an overseas warehouse site has always come down to determining where the majority of a company's foreign clients are located such that when a customer places an order, it is fulfilled by the distribution warehouse closest to that client. In this study, a warehouse site optimization framework was developed using Binary Integer Programming to help decision-makers choose the best region, or sites, to build an overseas warehouse facility to meet expected customer demands. The proposed model is focused on determining the appropriate placement of the warehouse from a set of potential locations in order to decrease the travel distance between warehouse facilities and overseas customers. The overseas customers are assumed to be served by the warehouse that is closest to them geographically. When the number of to be overseas customers served is large, they might be organized into clusters. This pre-processing is based on the assumption that the warehouse charged with servicing the overseas customers of a certain cluster would care for all of them in that cluster. We presented four distinct case situations with varying characteristics. The k-means approach is used within the context of Binary Integer Programming to divide C overseas customers into G distinct and non-overlapping subgroups. Warehouse site influences transportation costs, and when new supply routes are introduced or a current supply chain is re-engineered, a thorough warehouse placement analysis is required. The proposed model would hope to help choose the best location for warehouses as well as other immovable infrastructure in the global supply chain.

Keywords: *Binary Integer Programming, Global supply chain, Overseas warehouse*

Introduction

Foreign warehouses are storage infrastructures built abroad. Foreign warehouses are domestic entities that transfer goods to target market nations in bulk, maintain warehouses, and store goods locally, after which the one-stop administration and control service of processing, packaging, and delivery is carried out straightforwardly from the regional warehouses in a timely fashion, based on the local customer

orders [1]. The foreign warehouse model entails sellers storing goods in warehouses formed in the home countries of foreign buyers, and then carrying out sorting, packaging, and distribution effectively from a local warehouse constructed overseas.

Depending on their position in the global supply chain, both raw materials and finished goods may need the same or differing kinds of storage facilities. One company's final product is another company's raw material, and their placement in the global supply chain is arbitrary and dependent on the viewpoint of those operating in the similar product supply chain [2]. The numbers of supply chain stages varied widely depending on the kind of material or product being transported. The same holds true for warehouses; the number of warehouses needed depends on the materials or product in question, the logistics involved in getting them from A to B, the distribution network chosen, and the associated costs.

There are two main types of overseas warehouses.

1. Owned and managed foreign warehouses

The self-operated foreign warehouses are constructed and maintained by export cross-border e-commerce businesses; it is a logistics form that only offers logistics operations such as warehousing and shipping for the products sold by the company; in other words, the whole cross-border e-commerce logistics platform is managed by the exporting organization [3].

2. Third-party foreign public service warehouse.

The third-party foreign warehouse is a foreign warehouse constructed and managed by a third-party logistics enterprise capable of providing customs clearance and storage of goods, quality check for many exports cross-border e-commerce businesses. The logistics operation of taking orders, processing orders, multi-channel distribution, follow-up shipping, and other logistics services are controlled by the third party [4].

The significance of warehouses in global trade can not be ignored for few reasons. First, The placement of a single warehouse facility or numerous warehouse facilities, as well as the distribution of customer requirements to those locations, has a long-term influence on transportation costs, inventory costs, and service standards [5]. Thus, the single most critical logistics network choice is the proper geographical arrangement of a warehouse as well as distribution hub.

Second, they make shopping more enjoyable for the consumers. Delivery time is among the first factors a consumer looks for. It is also a major cause of cart abandonment. Direct local distribution from a foreign warehouse reduces shipping times significantly. Leveraging local logistics, businesses can typically monitor the delivery report of products online, allowing them to trace the whole package; The overseas warehouse's initial step is to employ the classic international trade logistics technique and import using the standard customs clearance procedure, which considerably minimizes the customs clearance obstacle [6]. Local shipping and distribution shorten the transfer procedure, lowering the incidence of package losses and damage. The foreign warehouse has a wide range of items in store, making it simple to process returns and replacements. Consumers will have a positive purchasing experience as a result of these features.

Third, a foreign warehouse may assist firms making lower logistical expenses. Postal shipments and global special line logistics incur weight, volume, and value constraints on the objects to be carried, resulting in many big products and commodities being delivered exclusively by international rapid delivery [7]. Overseas warehouses have not only overcome the limitations of size, dimension, and value of commodities, but they are also less expensive than international freight carriers.

With the growth of the foreign warehouse, the size, criteria, and distribution of foreign warehouses have changed. There are various issues, such as incorrect inventory forecasting, which may result in

unsalable commodities. If there is a gap in goods monitoring, there will be a loss; and foreign warehouse providers themselves to perform local services as well as team administration is also a major issue, which will damage the seller's efficiency [8].

There are wide range of options of foreign warehouses. They cannot succeed via numbers, but only through quality. And the real demands of businesses serve as the beginning point for quality assurance. If a firm merely construct a warehouse and fail to maintain it properly, it is basically shipping local inventory offshore.

If consumers return products for different reasons, they may send them straight to offshore storage, avoiding the expense, delay, abandonment, and other losses associated with repeated clearance at home and abroad [9]. The dilemma of return and replacing items through foreign direct delivery has long troubled merchants, but the challenge has been avoided with the establishment of foreign warehouses. The ease of returning and exchanging items not only enhances after-sales support, but also the customer's buying experience. It will be very beneficial in cultivating repeat consumers and increasing the repurchase ratio.

If it is peak transportation period, not only will prices rise across the board, but there will also be regular warehouse explosions, which is the most challenging challenge for cross-border vendors [10]. Many businesses may circumvent this difficulty for the time being by using foreign warehouses.

There are also some drawbacks of an international warehouse. First, selecting an overseas warehouse necessitates a significant capital expenditure, such as capital for products preparation, transportation, storage, and so on, resulting in a protracted time of capital recovery, uncomfortable capital turnover of the firm, and a broken capital chain [11].

When selecting an international warehouse, firms must pay a specific amount of foreign storage costs. Fees fluctuate across countries. Cross-border retailers must assess the cost of an offshore warehouse and compare it to the cost of their present shipping method before making a decision.

The seller must have a particular quantity of inventory items, as a prerequisite for storage in foreign warehouses, which amplifies the risk and is not ideal for inexperienced sellers or merchants offering unique tailored products [12].

It is heavily influenced by service providers' operational capabilities and has low controllability. Uncontrollable elements such as local legislation, social issues, and environmental conditions have an impact on foreign warehouses. If the provider of foreign warehouses has issues with a specific connection, it is probable that items will be delayed, warehouse inspections will occur, and commodities may be confiscated [13].

To create the demand profile, companies need the locations of demand (client addresses) as well as the volume assigned to each location (sales by customer). Investing in additional warehouse centres is a long-term investment, and so utilizing past demand or a demand sample may not represent business's anticipated future [14].

It is preferable to create a long-term profile that incorporates the business's projected development in terms of area expansion, changes in demand profiles, and adjustments in order volumes.

The significance of a rigorous warehouse site selection procedure is undeniable in terms of global supply chain. Businesses may begin the location choice process for a new warehouse facility for a variety of reasons, including cost reduction, capacity expansion to expedite business growth, entry into new markets, taking advantages of new labor pools, standardization following an acquisition or merger and dealing with regional and global developments [15]. The construction of a new warehouse facility necessitates substantial expenditures (or leases). Because the investments are made over a lengthy period of time, the effect of the new site should likewise be favorable for a long time. In other

words, if the improper site is chosen, the bad consequences will last for a long time (e.g. greater expenses, difficulties in locating qualified workers, customs obstacles, and delivery problems [16]).

There are some specifics of distribution center site selection. In general, we can observe that location is chosen based on three sorts of considerations. Charges - All significant monetary considerations such as location, real estate, labor, logistical costs, taxes, and so on.

Business environment quality - Variables that cannot be easily converted into currency but have a direct impact on the success of the new operation. Consider workforce availability and flexibility, accessibility (through multiple modes of transportation), supplier availability, and customs rules.

Risk - All external market risk variables that a firm cannot control but may have a significant effect on future operations, such as price volatility, exchange rate volatility, transparency risk, natural catastrophe risk, and so on.

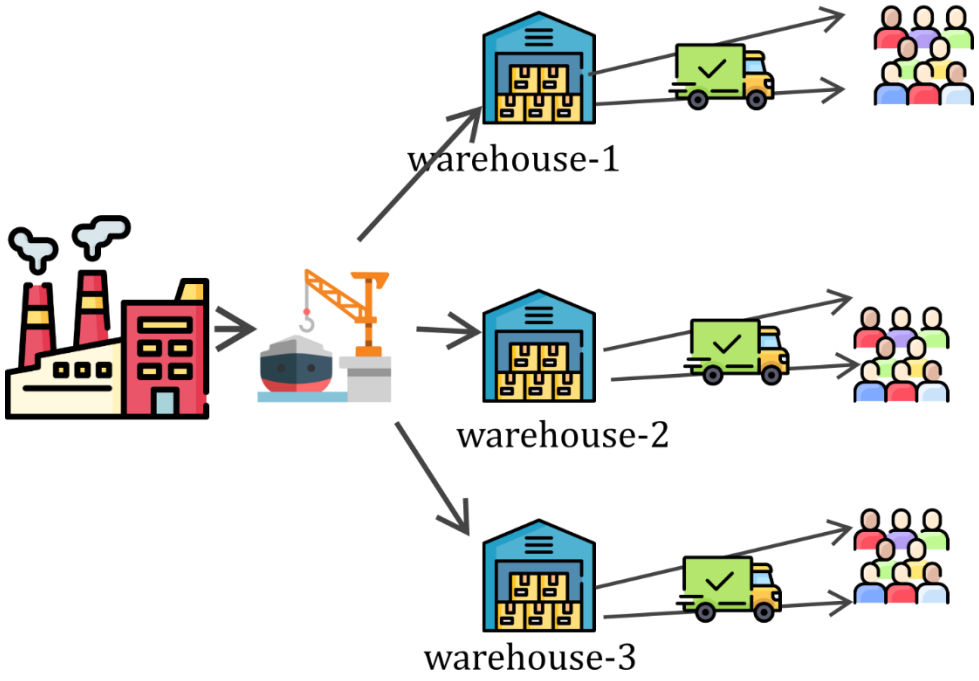

Figure 1. Overseas warehouse. Source: Author

Literature review

Business, economics, geography, and mathematics literature has paid a great attention in finding the most suitable location for manufacturing facilities [17]. Geographers, with their attention on locative and spatial variations leading to natural phenomena, have also had a part in complementing these location views and finding optimum places to site industrial activities location. Although business and economics plays the key role in providing location theories by referring to its theories, geographers have also had a share in finding optimal locations to position industrial activities.

Shuyan & Lisi, (2013) argued that The order cycle is too lengthy to be efficient under present logistics and distribution methods, which occur with high costs, uncontrolled risks, and cumbersome procedures [18]. These obstacles have stifled the growth of cross-border e-commerce. In this scenario, e-commerce

overseas warehousing increasingly emerges. They further claimed that an important topic that has to be considered in the sphere of cross-border e-commerce is how to overcome the paradox of low-cost and rapid delivery, reap the benefits of overseas warehouse development, and effectively open up abroad markets.

Rath & Gutjahr (2014) made use of a three-objective optimization model, which includes a humanitarian goal function, a medium-term economic objective function, and a short-term economic objective function [19]. In order to find the Pareto frontier, they used a technique called the epsilon constraint approach, and present an exact solution approach as well as a "math-heuristic" strategy that builds on a MILP conception with a heuristically created constraint pool in order to tackle the issue of single-objective constrained optimization which will allow to find the optimal solution.

Michel & Van Hentenryck (2004) proposes a straightforward tabu-search strategy that is both resilient and effective in solving the UWLP, often known as the uncapacitated warehouse locating problem [20]. The method was tested on both the industry-standard benchmarks provided by the OR Library and on real-world problems that provide significant difficulties for mathematical programming strategies. The instances used as benchmarks have a dimension of 2000 by 2000 pixels each. The method, despite the fact that it is conceptually and procedurally simple, is capable of finding optimum solutions to all criteria in a very short amount of time and with a very high frequency.

Given a certain number of local warehouses and their current locations, the focus of the work by Drezner et al. (2003) is on determining where a central warehouse should be situated for maximum efficiency [21]. We analyze whether the solution that is decided by a standard model that seeks to reduce overall transportation costs is the same as the solution that is derived by a model that additionally considers the costs of inventory and service. To investigate this matter, we devise straightforward models. According to the findings of several numerical analyses, it is possible to get to subpar location solutions if one models locations without taking inventory costs into account.

Utilizing a variety of techniques to fuzzy multi-attribute group decision-making, Kahraman et al. (2003) attempted to find a solution to the issue of facility placement using those approaches [22]. The article presents four distinct methods of fuzzy multi-attribute group decision-making. One of them is essentially called a fuzzy theory of collective decision-making, and it was presented by Blin. The second kind of assessment is the fuzzy synthetic one. The Yager's weighted objectives technique comes in at number three, and the fuzzy analytic hierarchy approach rounds out the list. Although all four strategies have the same end goal of deciding which of many potential facility locations is the best option, they were developed independently of one another theoretically and have unique connections to the field of multi-attribute collective decision. These methods are then expanded upon in order to pick the most optimal facility site option by taking quantitative and qualitative variables into consideration.

Model

The Facility Location Problem, often known as the FLP, is a well-known example of a classic optimization problem [23]. Its purpose is to find the optimal location for a manufacturing plant or storage facility by taking into account regional needs, facility costs, and travel distances. The notion of warehouse site selection was developed by situating a warehouse so that the distance covered between the warehouse and the clients is reduced. In most cases, the goal of these challenges is to maximize the profit that the company makes on the basis of the given client demand and location. FLP may be further subdivided into capacitated issues and uncapacitated problems, with the distinction between the two being based on whether or not the facilities in consideration have a maximum capacity.

Binary Integer Programming

An integer programming issue is an integer programming in which all of the variables are expected to be integers. The issue is referred to as a mixed integer programming if there are certain variables that are required to be integers while other variables are not [24]. Often, the situation arises in which the integer quantities are only allowed to take on the values 0 or 1, respectively. These kinds of issues are referred to be 0-1 programming or binary integer programming issues.

When modeling distribution networks, one must make choices on tradeoffs between the costs of managing warehouses and the costs of transporting goods to various locations. If an international business needs to determine which of warehouses to choose in order to satisfy the needs of many clients for a certain product. The choices that need to be taken include which warehouses to run and how much product should be sent from each warehouse to each individual consumer [25].

There are five parts that make up a mathematical optimization model, and they are as follows:

Sets

Specifications.

Decision factors.

Objective Function

Constarints/Restrictions.

Our standard for Binary Integer Programming (BIP) may be formulated as follows:

Sets and Indices

$c \in C$: Set of customers.

$l \in L$: A list of possible locations for a warehouse.

Pairings $= \{(c, l) \in C \times L : dist_{c,l} \leq threshold\}$: Collection of all the potential pairings.

Parameters

Threshold $\in \mathbb{R}^+$: The maximum distance that may exist between a cluster and a warehouse before a match is considered invalid.

max_warehouse $\in \mathbb{N}$: The maximum number of warehouse facilities that may be built.

$weight_c \in \mathbb{N}$: Count of the people living in cluster c.

$dist_{c,l} \in \mathbb{R}^+$: Distance from cluster C to the warehouse location.

Decision Factors

$select_l \in \{0,1\}$: The value 1 is returned if warehouse site i is selected; otherwise, the value 0 is returned.

$assign_{c,l} \in \{0,1\}$: The value 1 is returned if the cluster c is assigned to the warehouse location i; otherwise, the value 0 is returned.

Objective Function

Overall proximity: Minimize the total distance traveled by foot or other means between clusters and the warehouse facilities to which they are assigned:

$$Min\ P = \sum_{(c,l)\in Pairing} weight_c . dist_{c,l} . assign_{c,l}$$

Constraints

Limitation on the number of warehouses that may be built: There will be a restriction on the total number of businesses that can be established:

$$\sum_{l} select_l \leq \max\ \_facilities$$

• Cluster c is accessible for assignment, but it can only be allotted to site l if we chose to go ahead and build it:

$$assign_{c,l} \leq select_l \quad \forall (c,l) \in Pairings$$

• Cluster ii must be assigned to a single warehouse facility since it is the closest to that facility:

$$\sum_{\boldsymbol{l}:(\boldsymbol{c},\boldsymbol{l})\in \boldsymbol{Pairings}} assign_{\boldsymbol{c},\boldsymbol{l}} = \mathbf{1} \quad \forall \boldsymbol{c} \in \boldsymbol{C}$$

Use cases

Candidates for the placement of the facility depicted by the most visible dots. Some places have black lines extending outward in the direction of each cluster which is predicted to be serviced by that warehouse. These lines originate from the chosen locations.

Case a: 2 countries:

	Parameters	Numbers
1.	Number of countries	2
2.	Number of total customers	20,000
3.	Number of candidates overseas warehouses	8
4.	The maximum number of overseas warehouses that may be established	5
5.	Number of clusters	90

Outputs:

First customer location: (0.33164437091949245, -0.2809884943538464)

First cluster center: [0.36587632 -0.25258193]

Weights for first 10 clusters: [612, 1229, 795, 437, 595, 578, 401, 656, 429, 783]

Number of viable pairings: 962 .

Optimal solution found (tolerance 1.00e-04)

Best objective 8.918366903087e+03,

Best bound 8.918366903087e+03,

gap 0.0000%

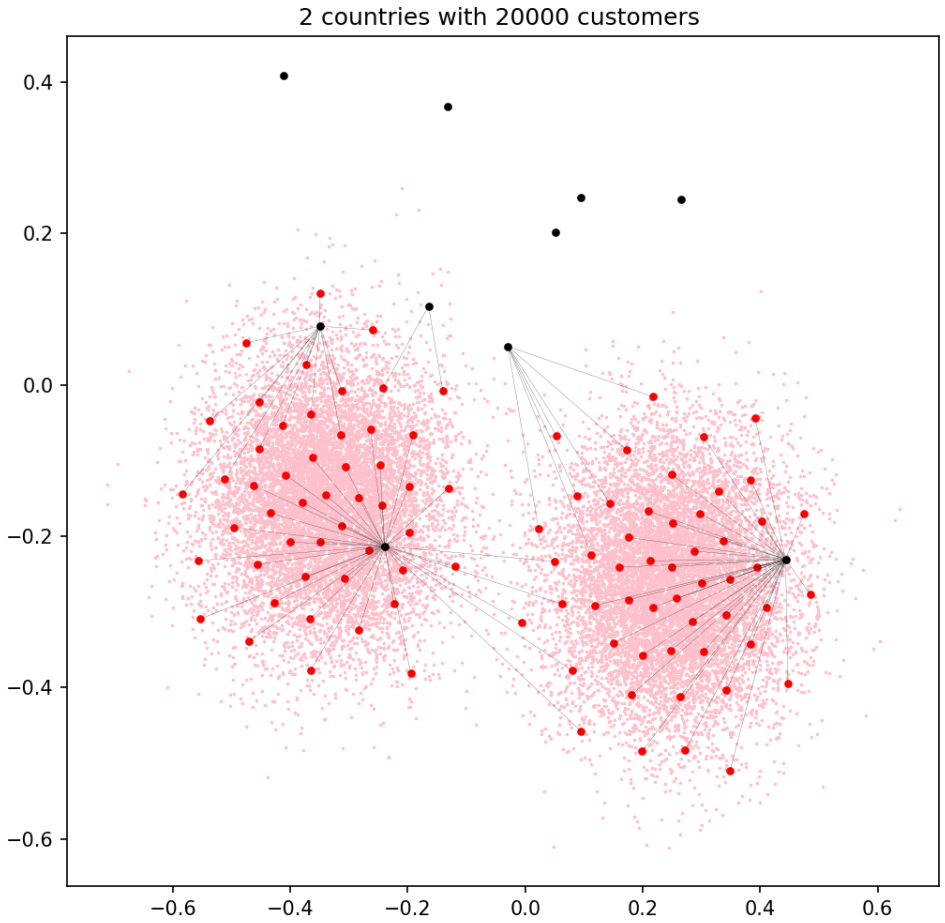

Figure 2. Case a: warehouse in 2 countries. Source: Author

Case b: 3 countries:

	Parameters	Numbers
6.	Number of countries	3
7.	Number of total customers	30,000
8.	Number of candidates overseas warehouses	10
9.	The maximum number of overseas warehouses that may be established	6
10.	Number of clusters	90

Outputs:

First customer location: (0.3216443709192345245, -0.2709884545538464)

First cluster center: [0.46587632 -0.35258193]

Weights for first 10 clusters: [622, 1229, 785, 437, 595, 578, 411, 656, 429, 783]

Number of viable pairings: 1123 .

Optimal solution found (tolerance 1.00e-04)

Best objective 8.918366903087e+03,

Best bound 8.918366903087e+03,

gap 0.0000%

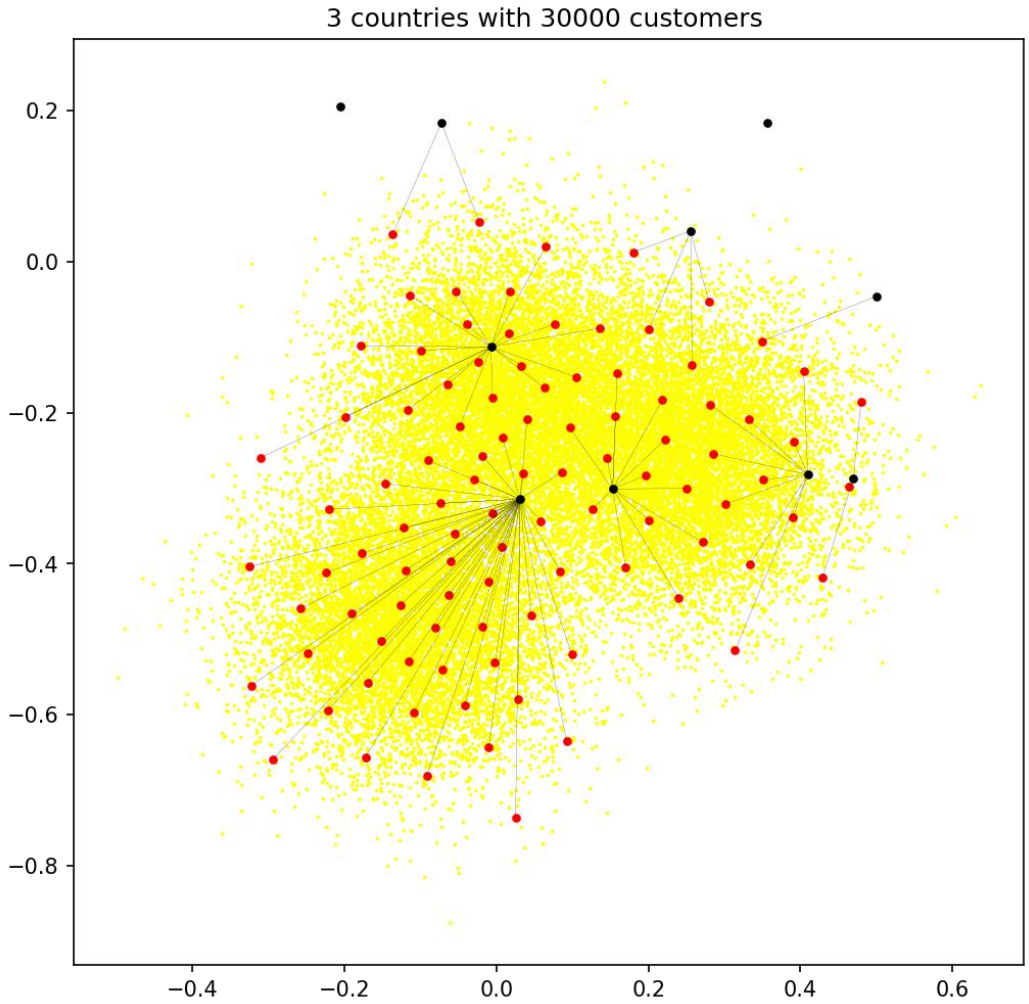

Figure 3. Case b: warehouse in 3 countries. Source: Author

Case c: 4 countries:

	Parameters	Numbers
11.	Number of countries	4
12.	Number of total customers	40,000
13.	Number of candidates overseas warehouses	10

14.	The maximum number of overseas warehouses that may be established	8
15.	Number of clusters	90

Outputs:

First customer location: (0.3216443709192345245, -0.2709884545538464)

First cluster center: [0.46587632 -0.35258193]

Weights for first 10 clusters: [622, 1229, 785, 437, 595, 578, 411, 656, 429, 783]

Number of viable pairings: 1273 .

Optimal solution found (tolerance 1.00e-04)

Best objective 8.818366953087e+04,

Best bound 9.918366903087e+04,

gap 0.0000%

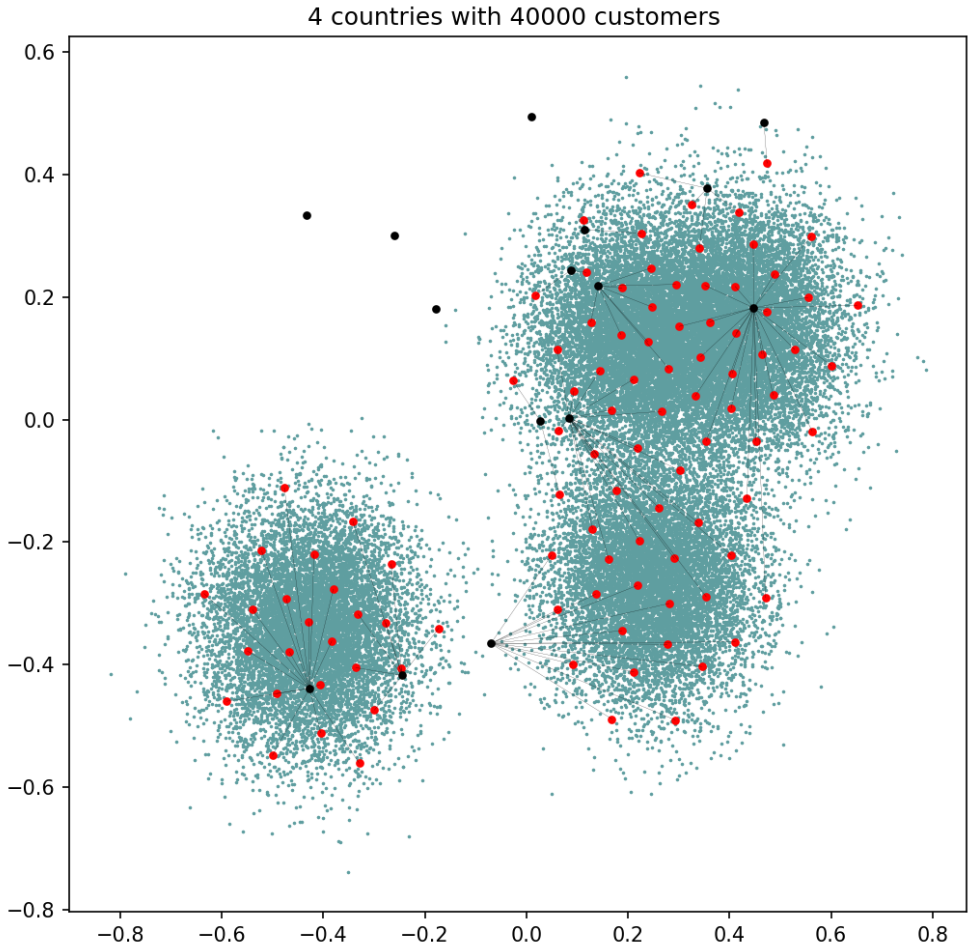

Figure 4. Case c: warehouse in 4 countries. Source: Author

Case d: 5 countries:

	Parameters	Numbers
16.	Number of countries	5

17.	Number of total customers	50,000
18.	Number of candidates overseas warehouses	20
19.	The maximum number of overseas warehouses that may be established	10
20.	Number of clusters	100

Outputs:

First customer location: (0.33164437091949245, -0.2809884943538464)

First cluster center: [0.38319271 -0.14277969]

Weights for first 10 clusters: [920, 646, 805, 845, 581, 377, 326, 105, 722, 659]

Number of viable pairings: 1729 .

Optimal solution found (tolerance 1.00e-04)

Best objective 8.818366953087e+04,

Best bound 9.918366903087e+04,

gap 0.0000%

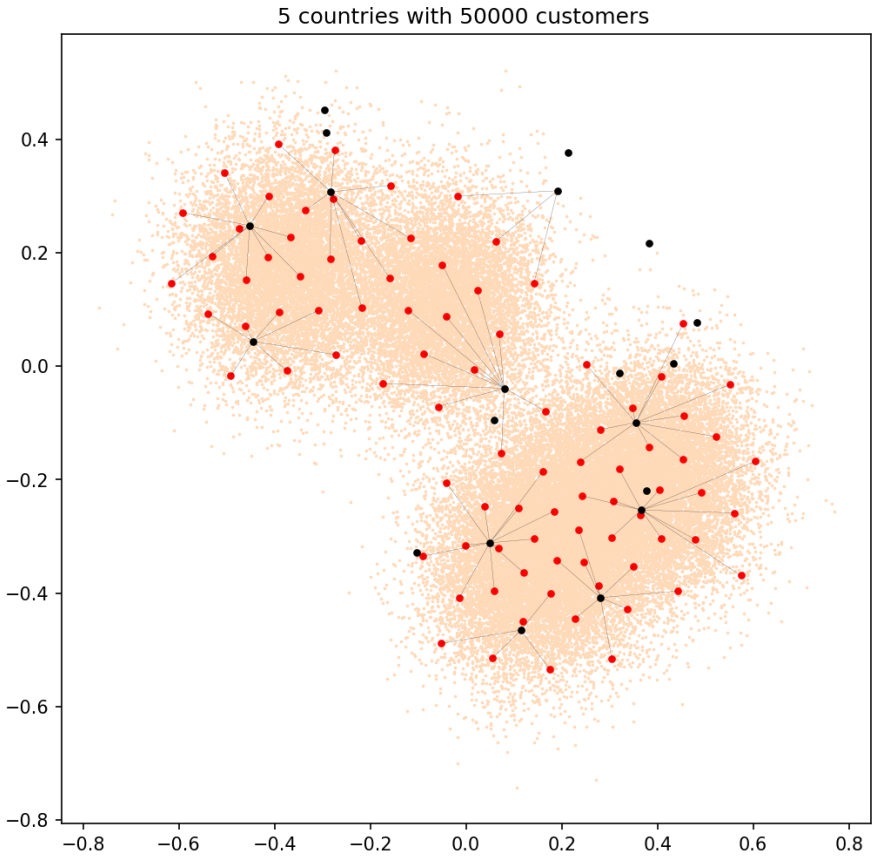

Figure 5. Case d: warehouse in 5 countries. Source: Author

Conclusion

Because transportation costs are generally proportional to distance and vary more than warehouse expenses throughout the globe, choosing the best location for a warehouse may greatly cut operational costs. Having numerous overseas warehouses is advantageous to both a business and its clients. Shipping will be quicker, less costly, and more ecologically friendly if the items are warehoused in many locations and sent from the one closest to the consumer. Furthermore, if an international business targets a large number of people in a certain region, it may simply establish it warehouse there. This allows the business to provide service its consumers more easily and quickly. This would not only increase client loyalty but will also assist the business obtain more prospective consumers. The business can better understand its consumers. As a consequence, clients who are unfamiliar with goods and services will find the company more intelligible, reputable, and appealing. When determining where to build a new warehouse, it is also crucial to consider future development and fluctuations in demand

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