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Smart solutions for importing automotive components from Europe to Mexico

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Abstract: This study presents a strategic approach to optimizing the importation of automotive components from Europe to Mexico, aimed at enhancing operational efficiency, reducing costs, and ensuring timely deliveries. Using the Analytic Hierarchy Process (AHP) as a structured decision-making tool, the research evaluates and selects the optimal port of departure based on criteria such as cost, transit time, and port capacity. The Weber Location Problem (WLP) is also applied to determine the ideal consolidation center (CC) location to streamline cargo collection from multiple European suppliers. Through a Mexican automotive company case study, the research highlights the importance of integrating Full Container Load (FCL) and Less Container Load (LCL) operations to improve traceability, reduce handling errors, and optimize supply chain performance. The findings emphasize the critical role of port selection and cargo consolidation in mitigating risks associated with supply chain disruptions. The proposed methodology provides importers practical tools to strengthen their logistics strategies, offering valuable insights for enhancing global automotive supply chain competitiveness. This work contributes to maritime logistics and supply chain management, guiding importers, shipping companies, and policymakers in improving port efficiency and cross-border operations.

1 Introduction

Being efficient in importation is crucial for several reasons. Here are some key points highlighting the importance of importation efficiency: *Cost Reduction:* efficient importation processes help minimize costs associated with shipping, customs duties, and handling. Lower costs can lead to reduced consumer prices and improved business profit margins. *Timely Delivery*: importation efficiency ensures that goods are delivered promptly. It is essential for maintaining inventory levels, meeting customer demand, and ensuring that businesses can operate smoothly without delays. *Competitive Advantage:* companies that import goods efficiently are better positioned to compete in the market. They can respond more quickly to changes in consumer demand, adjust pricing strategies, and maintain a strong market presence against competitors, including parallel importers. *Quality Control:* efficient importation processes often include better quality control measures. It ensures that the products received meet the required standards and specifications, which is particularly important in industries like pharmaceuticals and electronics. *Regulatory Compliance:* efficient importation helps businesses navigate complex customs regulations and compliance requirements. It reduces the risk of delays, fines, or legal issues arising from non-compliance. *Supply Chain Optimization*, an efficient importation process, contributes to overall supply chain optimization. It allows businesses to manage logistics better, reduce lead times, and improve coordination with suppliers and distributors. *Market Responsiveness*: in a rapidly changing market environment, importation efficiency enables businesses to respond more to trends and consumer preferences. This agility can lead to better customer satisfaction and loyalty. *Sustainability*: efficient importation can also contribute to sustainability efforts by optimizing transportation routes and reducing waste. It can lead to lower carbon footprints and more environmentally friendly practices [1].

The study [2] empirically demonstrates that efficiency in importation processes, driven by key factors such as international price, product quality, product availability, customs clearance knowledge, and a company’s logistics capability, significantly reduces costs and improves profit margins. Through a survey of major food processing companies in Northern Mexico and multiple linear regression analysis, the research finds that these variables collectively explain 66.4% of the variation in import volume. The findings highlight that price competitiveness and product quality are primary drivers, enabling companies to reduce procurement costs and enhance product differentiation, ultimately leading to increased competitiveness and profitability in the market.

For example, the context of the [3] is rooted in the complexities of the global soybean market, the strategic role of China as a primary importer, and the competitive dynamics that shape trade relationships among the leading soybean-producing countries. This study provides valuable insights that can help exporters, policymakers, and industry stakeholders make informed decisions, enhance competitiveness, and adapt to the evolving dynamics of the global soybean market.

The study [4] evaluates the efficiency of customs operations in 29 countries from the APEC region and other leading trading nations. Using the Data Envelopment Analysis (DEA) Network model reveals that efficient customs procedures are crucial for facilitating international trade. Countries with streamlined customs processes, such as China, Germany, and Singapore, demonstrate higher efficiency, resulting in faster cargo clearance, reduced operational costs, and improved regulatory compliance. The research emphasizes that modernizing customs infrastructure and adopting digital solutions, like electronic declarations, significantly enhance the punctuality and reliability of import processes. These improvements reduce the risk of delays and help businesses avoid penalties associated with non-compliance, fostering more competitive and resilient supply chains.

Overall, the study [5] aims to fill a gap in the literature on import retail e-commerce by providing a detailed analysis of competitive strategies and their implications for sellers operating in this dynamic market. The three major competitive strategies identified in the study are product optimization, cost leadership, and reputation priority. It also underscores the need for imported retail e-commerce sellers to be strategic and adaptive in their approaches to enhance their competitiveness in a rapidly changing market environment.

In [6], it explores developing and implementing effective marketing strategies to enhance industrial import substitution in Russia, emphasizing the necessity for Russian enterprises to adapt to a volatile competitive environment and focus on achieving competitive stability. In conclusion, the paper presents a comprehensive analysis of the marketing and operational strategies necessary for successful industrial import substitution, offering practical tools and methodologies for enhancing competitiveness in the Russian industrial sector.

The research [7] delves into the global forage trade from 1997 to 2020, focusing on the market power of forage exporters in key importing nations like Japan, China, and South Korea. By employing an extended G-K model, the authors uncover important dynamics in pricing power and market structure, highlighting the significant roles played by the United States and Australia in this sector. Some key benefits are an enhanced understanding of market dynamics, strategic planning for exporters, informed policy development, and sustainability.

The study [8] emphasizes that efficient import management is a key factor for companies in the automotive sector in Tungurahua, Ecuador, to enhance their competitiveness and adapt swiftly to international market demands. It demonstrates that firms that streamline their import processes can reduce costs, improve production planning, and ensure timely input delivery, strengthening their ability to respond to changing consumer preferences. Moreover, optimizing imports contributes to supply chain efficiency by improving inventory control, enabling better supplier relationships, and fostering innovation through access to quality materials and technologies from global markets. These advantages collectively position companies to compete more effectively both locally and internationally.

Therefore, an importation strategy is crucial for several reasons, regardless of sector. An effective importation strategy helps ensure a stable and reliable supply of essential goods. By diversifying sources and establishing relationships with multiple suppliers, countries can mitigate risks associated with supply disruptions due to geopolitical issues, natural disasters, or market fluctuations. In addition, an importation strategy enables countries to respond quickly to changes in market demand. By monitoring trends and adjusting import volumes accordingly, countries can avoid shortages or surpluses that could disrupt local markets.

1.1 Context problem

This project is focused on companies in the automotive sector in Mexico, which require processes for importing goods (production material, spare parts, auxiliary maintenance material, and machinery) from Europe. The case study is of a Mexican company that needs to establish the logistics chain for present and future projects.

The Mexican company already has a list of suppliers, and every week, an exclusive consolidated container must be sent with cargo collected from different suppliers. The company uses the LCL (Less Container Load) and FCL (Full Container Load) operations. LCL is required to collect all the goods from different European suppliers that do not fill an entire container by themselves, which is why a collection and consolidation service is needed. FCL is used to transport the necessary machinery to install production lines for which full containers of different types are required: 20 and 40 feet, dry cargo, high cube, flat rack, and open top, as well as for production materials and spare parts.

Currently, the company is responsible for collecting the components weekly from each of its European suppliers under the (Free Carrier) FCA incoterm at the plant and sending them by any available parcel service to the ports of Hamburg and/or Bremen, depending on the availability of containers. Causing more excellent staff wear in product traceability and not necessarily consolidating the containers. There are times when up to 20 partial containers have been received, generating high costs for the importing company even if the product has been lost between the parcel and the ports and delays in finding this product for shipment or restocking and shipping in the worst case.

This work aims to create an import strategy for Mexico from Europe through the Weber Location Problem (WLP) to select a Consolidation Centre (CC). Through the Analytic Hierarchy Process (AHP) method, select the port of departure that meets the time, costs, and capacity criteria to have more control over the consolidation and shipment of the products.

In Figure 1, there are 42 European suppliers of the Mexican company. These have blue markers, and in Figure 2, the ports of Bremerhaven and Hamburg have red markers.

Figure 1 European suppliers

Figure 2 Ports of Bremerhaven and Hamburgo

2 Literature review

This study applied an AHP method to select the best port. Then, it used the Weber Problem to allocate the CC that optimized the importer's time and cost and had more control over the product traceability.

On the one hand, the AHP is a structured decision-making framework used to analyze complex problems by breaking them down into smaller, more manageable parts. Thomas Saaty developed it in the 1970s, and it is beneficial in situations where multiple criteria must be considered. AHP is valued for its flexibility and ability to incorporate qualitative and quantitative factors, making it suitable for various applications, including construction management, project selection, resource allocation, and risk assessment [9].

The AHP involves several key steps to facilitate decision-making. The authors outline the following six phases in the AHP method: 1) Define the Problem, 2) Determine the Criteria and Sub-Criteria, 3) Identify the Alternatives, 4) Structure the Hierarchy, 5) Perform Pairwise Comparisons, and 6) Calculate Weights and Rank Alternatives [10].

[11] employs the AHP to investigate the criteria influencing transshipment port selection by global container carriers. Four primary criteria and twelve sub-criteria were identified through a comprehensive literature review and expert Delphi surveys. The study reveals that global carriers and port service providers share similar views on the importance of these attributes. However, their rankings differ, indicating potential areas for service providers to adapt to user priorities. The findings underscore the significance of understanding these criteria for enhancing competitive strategies in the transshipment market, ultimately aiding in effective decision-making for port operators and authorities.

Also, [12] presents an AHP model to analyze port choice in regions with multiple container ports, emphasizing its significance in international trade transportation. The model aims to simulate shipping carriers' decision-making behaviors and identify the importance of various factors influencing port selection. By applying the AHP model to five shipping companies, the research reveals the weight of each factor affecting port choices. The findings are intended to assist port managers and government agencies in developing effective operational strategies and policies to enhance port competitiveness and attract more container traffic. The study underscores the critical role of optimal port selection in reducing transportation costs.

Many studies have applied the AHP model to identify critical criteria influencing transshipment port selection by global carriers. In [13], expert surveys reveal that critical factors include handling costs, primary infrastructure conditions, and proximity to navigation routes. The findings highlight the need for ports to focus on cost reduction and infrastructure investment to enhance competitiveness. Additionally, understanding carrier preferences and addressing perception gaps between port users and operators can improve service alignment. These insights provide strategic implications for enhancing transshipment market strategies in a competitive global environment.

The study [14] introduces a decision support system (DSS) that utilizes the Analytic Hierarchy Process (AHP) to rank alternatives and support multi-criteria decision-making in port selection for maritime operators. The research emphasizes that AHP is valuable for integrating qualitative and quantitative factors, such as port efficiency, costs, infrastructure, and transit times. By systematically evaluating these criteria, AHP helps operators identify the most cost-effective and efficient route, which is crucial for ensuring business sustainability and competitiveness in the highly demanding maritime transportation.

In [13], this article applies the analytical hierarchy process (AHP) technique to analyze transshipment port selection by global carriers. It identifies primary criteria and sub-criteria influencing port choice, offering a comprehensive understanding of carriers' decision-making priorities. The study provides valuable insights into how port service providers can better align their offerings with user preferences, enhancing ports' competitiveness and attracting more significant container traffic in the global shipping market.

On the other hand, the Weber problem, introduced by Alfred Weber in his 1909 work on industrial location, generalizes the Fermat problem by considering not just the distances but also the weights of the points representing demand or supply and the costs associated with transportation. When all weights are equal, and the distances are Euclidean, the Weber problem reduces to the Fermat problem. The objective is to minimize the total weighted distance to a set of points. The Weber problem is more focused on practical applications in economics and logistics, particularly in determining optimal locations for facilities based on transportation costs and the distribution of resources [15].

The Weber Problem in logistics and service networks under congestion conditions. It analyzes how the optimal location of a facility can maximize resource utilization and minimize travel times, considering capacity constraints and demand distribution. The findings offer an updated perspective on the practical application of the Weber Problem in optimizing modern supply chains [16].

[17] This paper examines the Facility Weber Problem with Setup Costs, an advanced version of the classic Weber problem, which considers both transportation costs and the fixed setup costs associated with opening multiple facilities. The authors propose a mathematical model and develop solution methods that optimize facility location under capacity constraints. The research demonstrates that including setup costs significantly impacts the placement of facilities, leading to more realistic and cost-effective decisions. This approach is especially valuable for logistics and supply chain management, as it helps businesses minimize total costs when establishing distribution centers, warehouses, or production sites in competitive, resource-sensitive environments.

However, in the literature, many techniques can solve location problems. [18] Explores the strategic positioning of critical ports across Asia, Europe, and Oceania using a mixed-integer linear programming model; they analyzed a realistic shipping network and discovered significant hub ports, including Rotterdam and Zeebrugge in Europe, Sokhna and Salalah in Western Asia, Colombo and Cochin in Southern Asia, and Singapore and Jakarta in Southeastern Asia and Australia. This approach allowed the authors to develop a hierarchical hub location problem that distinguishes between different types of ports, specifically international hub ports, regional hub ports, main ports, and feeder ports. The model was tested through numerical experiments based on a realistic Asia-Europe-Oceania liner shipping network to evaluate its effectiveness and determine optimal port locations.

[19] presents an exciting mixed integer programming model focused on selecting a hub port along the East Coast of South America. The study evaluates a set of 11 ports to effectively meet the regional demand for container shipping, aiming to optimize logistics and enhance maritime economics. The mixed integer programming model for selecting a hub port considers several critical factors, including total system costs, port costs, shipping costs, traffic flows, and feeder ports. One of the benefits is cost efficiency, which minimizes total system costs. The model helps identify the most cost-effective hub port, lowering shipping and operational expenses for shipping companies and port authorities.

Another research delves into the complexities of port choice and hinterland dynamics, explicitly analyzing the shipment of French AOC wines to the US. By addressing the common confusion surrounding the origins of containerized shipments, the authors propose innovative solutions and introduce new variables that enhance our understanding of logistical decisions. Using a conditional logit model, they reveal vital factors influencing port selection, emphasizing the significance of inland distance. Some critical benefits highlighted in the research are the improved accuracy in shipment origin identification, the enhanced understanding of port choice factors, insights into forwarder behavior, and maritime connectivity as a competitive advantage [20].

3 Methodology

3.1 AHP method

This research will use the power method of Palacios of 2007 and the Saaty scale of 1994 [21].

The criteria used in this project are:

1. Sending costs, costs of maneuvers in the terminal, depending on the incoterm, freight costs / Terminal Handling Charges (THC) at Origin.
2. Transit time.
3. Port terminal with enough capacity. Today, the Port of Hamburg is managed by the Hamburg Port Authority, created in 2005 in a merger between the various authorities that managed responsibilities related to the port. The port handles an annual throughput of 126 million tonnes and a container throughput capacity of 8.5 million TEU, making it the largest port in the country. The Port of Bremerhaven handled almost 54.7 million tonnes of containerized cargo at over 5.4 million TEU. The Port of Bremerhaven can handle nearly 5.5 million TEU and 55 million tonnes of containerized cargo annually.

Were:

- ✓ Cost is 3 times more important than time.
- ✓ Cost is 7 times more important than capacity.
- ✓ Time is 4 times more important than capacity.

The respective weights were calculated after the experts selected this list of judgments. Thus, the positive reciprocal matrix is the following (1):

$$
\begin{array}{c c}
 & \begin{array}{ccc} \textit{Criterion 1} & \textit{Criterion 2} & \textit{Criterion 3} \end{array} \\
\begin{array}{c} \textit{Criterion 1} \\ \textit{Criterion 2} \\ \textit{Criterion 3} \end{array} &
\begin{pmatrix} 1 & 3 & 7 \\ 1/3 & 1 & 4 \\ 1/7 & 1/4 & 1 \end{pmatrix}
\end{array} \tag{1}
$$

The alternatives were considered by three shipping companies that can be found in both ports. Thus, there are six alternatives (2). The records of these alternatives were treated with the correct interpretation of the data in terms of priorities; that is, the method looks for the maximum argument, so the data, such as the lead time, was corrected for its correct interpretation since the maximum argument was not beneficial for the selection, on the contrary, we looked for the minimization of the transfer times, and later these data were normalized. The Consistency Radius (CR) was calculated, resulting in 3.7%, so the judgment matrix is considered unbiased.

$$
\begin{array}{c c}
 & \begin{array}{ccc} \textit{Criterion 1} & \textit{Criterion 2} & \textit{Criterion 3} \end{array} \\
\begin{array}{c} \textit{Alternative 1} \\ \textit{Alternative 2} \\ \textit{Alternative 3} \\ \textit{Alternative 4} \\ \textit{Alternative 5} \\ \textit{Alternative 6} \end{array} &
\begin{pmatrix} 0.163 & 0.250 & 0.111 \\ 0.158 & 0.227 & 0.222 \\ 0.157 & 0.250 & 0.111 \\ 0.163 & 0.253 & 0.222 \\ 0.177 & 0.250 & 0.111 \\ 0.177 & 0.246 & 0.222 \end{pmatrix}
\end{array} \tag{2}
$$

The global priority for each decision alternative is summarized in the column vector resulting from the priority matrix's product with the priority vector of the criteria; it was proven that the matrices are conformable; that is, they can be multiplied. Finally, a matrix of six by one or solution vector was obtained, in which the final weights of each one of the alternatives were to be selected (3).

$$\underset{\textit{Alternatives/Criteria}}{\begin{pmatrix} 0.163 & 0.169 & 0.111 \\ 0.158 & 0.153 & 0.222 \\ 0.157 & 0.169 & 0.111 \\ 0.163 & 0.171 & 0.222 \\ 0.177 & 0.169 & 0.111 \\ 0.177 & 0.167 & 0.222 \end{pmatrix}} \times \underset{\textit{Criteria Weights}}{\begin{pmatrix} 0.690 \\ 0.263 \\ 0.079 \\ \\ \\ \\ \end{pmatrix}} = \underset{\textit{Results}}{\begin{pmatrix} 0.1664 \\ 0.1673 \\ 0.1622 \\ 0.1756 \\ 0.1760 \\ 0.1842 \end{pmatrix}} \quad (3)$$

Once the results were found, the Weber method was applied to find the best location for the CC.

3.2 Weber problem

The main objective of the Fermat-Weber location problem is to find a point in $\mathbb{R}^N$ that minimizes the sum of weighted Euclidean distances to a given set of *m* points. In practical terms, these fixed points often represent locations such as customers or demands, while the determined point denotes the location of a new facility. The problem can be mathematically formulated by minimizing the function, which reduces the sum of weighted Euclidean distances to a given set of *m* points. In practical terms, these fixed points often represent locations such as customers or demands, while the determined point denotes the location of a new facility. The problem can be mathematically formulated as minimizing the function (4):

$$W(x) = \sum_{i=1}^{m} w_i \, ||x - a_i|| \quad (4)$$

Where w_i is a positive weighting constant that converts the distance between the new facility and demand point i into a cost, and a_i represents the known position of the *i-th* demand point.

Weiszfeld's algorithm is an iterative method for solving the Fermat-Weber location problem. The algorithm is based on the first-order necessary conditions for a stationary point of the objective function, which leads to a mapping. The convergence of Weiszfeld's algorithm is conditional on specific criteria like:

1. Non-collinearity: If the given points $a_1,\ldots,a_m$ are not collinear, the algorithm will converge to the unique optimal solution for all but a denumerable set of starting points x^0.
2. Avoiding Fixed Points: The algorithm's convergence is guaranteed as long as none of the iterates in the sequence generated by the algorithm coincides with one of the fixed points a_i. If an iterate does coincide with a fixed point, the algorithm may not converge to the optimal solution.
3. Dimension of Convex Hull: The authors conclude that Weiszfeld's algorithm converges to the unique optimal solution for all but a denumerable set of starting points if the convex hull of the given points is of dimension *N*.

In summary, Weiszfeld's algorithm is a powerful tool for solving the Fermat-Weber location problem. Still, its effectiveness depends on the geometric arrangement of the given points and the choice of starting point [22].

The problem was programmed in Lingo software, and the coordinates of 42 suppliers were considered.

4 Results and discussion

The AHP method is beneficial in selecting carriers-ports for several reasons: a) it can provide a systematic framework for breaking down complex decision-making processes into manageable components, allowing decision-makers to evaluate multiple criteria and sub-criteria effectively. B) It enables identifying and quantifying the importance weights of various factors influencing port choices, such as port charges, operational efficiency, and hinterland economy. This helps in understanding which factors are most critical for shipping companies. C) It allows for including qualitative and quantitative data, incorporating the insights and preferences of top decision-makers from shipping companies, and enhancing the decision-making process's relevance and accuracy. D) The method facilitates direct comparisons between different ports based on the established criteria, making it easier to identify the most favorable options for carriers. E) AHP can be adapted to various contexts and accommodate changes in criteria or preferences over time, making it a flexible tool for port selection.

Applying the AHP method made it possible to see that alternative six was the best for sending the products, and this carrier belongs to the port of Hamburg. The worst option for sending the products is alternative three, which leaves from the port of Bremerhaven. With this solution, we can see shipping options and select the best for the importing company. The idea is only to choose one carrier and one port to negotiate better prices, without forgetting that there are alternatives for any incident. In this case, the

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second option with which you can also start negotiations is alternative five, the same as shown in Table 1.

Table 1 List of AHP results

Port	Alternatives	Results
Hamburg	Alternative 6	0.2052494
Bremerhaven	Alternative 5	0.19732552
Hamburg	Alternative 4	0.19714262
Bremerhaven	Alternative 1	0.18765689
Hamburg	Alternative 2	0.18669939
Bremerhaven	Alternative 3	0.1834489

We can see that alternative five corresponds to the port of Bremerhaven, so we will have to view alternative four if we want to use the same port.

Once the port of Hamburg was chosen as the best choice, not so much for capacity, but for the carrier's costs and delivery times, the Weber problem wa365egion365ded and solved. Both ports were added, and 42 clients were considered. The problem wa365egion365ded as a non-linear programming problem, and the solution to locate the new CC was the following coordinate 50.82786, 8.981236 (50°'9'40"3"N 8°'8'52"5" E) corresponding to RXHJ+4FX Kirchhain, Germany. In Figure 3, you can see the proposed CC with the green marker. The idea of having a CC is to have greater control of the processes and traceability and negotiate costs with the parcel.

Figure 3 Results of the Consolidation Centre (CC)

Location-allocation models are essential tools in logistics and supply chain management, helping organizations optimize the placement of facilities and allocation of resources to meet demand efficiently. These models consider transportation costs, customer proximity, and service levels, ensuring facilities are strategically positioned to minimize costs and improve service quality. Using location-allocation models, companies can reduce operational expenses, improve delivery times, and enhance customer satisfaction. These models are also valuable for handling fluctuating demand, accommodating growth, and mitigating risks associated with location-based disruptions. Ultimately, location-allocation models enable data-driven decision-making, leading to more resilient and cost-effective supply chain networks, especially in complex, dynamic environments where efficiency and customer satisfaction are critical for maintaining competitive advantage.

This research has many benefits for the importers and suppliers, among them are:

1. Strategic Insights for Importers: Companies importing any components can use this strategy to reduce costs and have more planned and controlled operations.
2. Strategic Insights for Exporters: Exporting companies of any components can use this strategy as a competitive advantage to be selected as a leading supplier, since if among their services they offer to handle all customs procedures and send the package to the CC, they would reduce the amount of paperwork on the part of the buyer, generating confidence in a quality shipment.
3. Market Diversification: The findings emphasize diversifying component supply sources. By recognizing the quality of the European supplier's components, importers can reduce reliance on any single market and mitigate associated risks.
4. Policy Formulation: Policymakers can use the insights from the study to develop strategies to improve the automotive industry's competitiveness in Mexico. By having a CC, it is possible to negotiate discounts with the shipping company on all incoming component packages and have reduced shipping costs. Likewise, the most convenient shipping policies can be established regarding shipping cost and time by having a single port of departure.
5. Collaboration between Importing and Exporting Countries: The findings highlight a common interest among the different suppliers of the countries analyzed. This collaboration can lead to joint marketing efforts and shared strategies to lead the sector.
6. Cost Leadership: This strategy focuses on achieving cost advantages through various means, such as optimizing logistics and reducing waiting costs, rather than relying solely on low-price suppliers. A well-planned importation strategy allows countries to negotiate better prices and terms with suppliers. By understanding market dynamics and demand trends, importers can make informed decisions that help control costs and improve profitability.
7. Sustainability Considerations: An importation strategy can incorporate sustainability goals, such as sourcing

from environmentally responsible suppliers or reducing the carbon footprint associated with transportation.

8. Strategic Port Development: Identifying key hub ports can inform the important strategic decisions regarding port development and investment for the government. Shipping companies and port authorities can focus on enhancing infrastructure and services at these critical locations to serve global trade better.
9. Feeder Allocation: The study highlights the importance of feeder ports. It can optimize the flow of containers from smaller suppliers, improving overall network efficiency and reducing transit times.
10. Improved Decision-Making: The proposal provides a structured approach to decision-making, allowing port managers and policymakers to make informed choices based on quantitative data and analysis. It can lead to more strategic investments and resource allocation.
11. Enhanced Service Quality: By focusing on port and shipping costs, the model encourages ports to improve their service offerings, enhancing customer satisfaction and attracting more shipping lines.
12. Regional Economic Growth: The proposal can improve regional economic development by optimizing logistics and enhancing container transportation efficiency. Improved port operations can facilitate trade, create jobs, and stimulate local economies.
13. Improved Accuracy in Shipment Origin Identification: The proposal recognizes shipment origins and allows for a more accurate estimation of where and when goods are actually coming from, rather than relying solely on the addresses provided in shipping documents. It can lead to better logistical planning and decision-making.

5 Conclusions

This research presents a robust methodology for optimizing the importation of automotive components, focusing on port selection and the strategic location of a consolidation center (CC). The proposed approach, which integrates the Analytic Hierarchy Process (AHP) and the Weber Location Problem (WLP), demonstrates its applicability not only to the automotive industry in Mexico but also to import operations in other countries and sectors. The methodology can be adapted to different geographical and market contexts, such as China or other regions with diverse suppliers, by adjusting the input data and criteria according to local conditions.

The findings underline the critical role of selecting an optimal port and establishing a consolidation center to improve traceability, reduce transportation costs, and enhance delivery times. These elements collectively contribute to greater supply chain visibility and operational control, enabling companies to mitigate risks associated with supply disruptions and minimize product losses during transit. The study also emphasizes the importance of negotiating long-term contracts with carriers and optimizing FCL (Full Container Load) and LCL (Less Container Load) operations to achieve cost leadership and ensure flexibility in shipping schedules.

The practical implications of this work extend beyond cost reduction; the proposed strategy supports long-term business planning by fostering resilient and sustainable logistics operations. By consolidating cargo from multiple suppliers into a single shipment, importers can leverage economies of scale, reduce handling errors, and enhance product quality assurance. This approach improves efficiency and contributes to environmental sustainability by optimizing transport routes and reducing the carbon footprint associated with fragmented shipments.

Furthermore, the research highlights the strategic value of collaboration between importers, suppliers, and shipping companies. Establishing strong partnerships and aligning logistics processes can improve service levels, predictable lead times, and better negotiation power regarding freight rates and port fees.

From a policy perspective, the study offers insights that can inform government authorities and port operators in developing infrastructure and policies that support import efficiency, particularly in sectors with complex supply chains like the automotive industry. Strengthening port capabilities and promoting consolidation services can enhance the competitiveness of logistics hubs and attract more international trade.

In summary, improving importation efficiency is essential for reducing costs, ensuring timely delivery, maintaining quality, complying with customs regulations, and increasing market responsiveness. These factors collectively enhance a company’s competitiveness and long-term success in the global marketplace.

6 Future research

While this study focuses on automotive components, the proposed methodology can be extended to other industries with complex supply chains, such as electronics, pharmaceuticals, or consumer goods. Future research could explore the adaptation of this approach to different product categories and regions, as well as the integration of digital technologies like blockchain, IoT, and real-time tracking systems to enhance traceability and operational control further. Additionally, investigating the impact of trade policies, port congestion, and geopolitical factors on port selection and consolidation strategies could provide valuable insights for supply chain resilience.

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