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The Importance of the Facility Location Techniques to Assist Companies in Decision-Making for the Installation of Logistics Hub

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Abstract

The Facility Location Problem (FLP) is fundamental for companies seeking to optimize their logistics operations and gain a competitive advantage. In this context, the selection of locations for factories, warehouses, distribution centers and logistics centers is one of the main approaches used to reduce logistics costs. This study performed a literature review on FLP and explored how FLP techniques can be applied to solve location problems for logistics hubs. Furthermore, the research sought works related to the main methods of multi-criteria analysis for decision making. The research was carried out by searching two databases, Google Scholar and Scopus. Although the literature presents several methods for solving FLP, the P-median method was well accepted for applying FLP in the selection of locations for logistics centers, as well as the help of multi-criteria methods to, together with FLP, bring greater accuracy in making decisions. The objective of this study was achieved by highlighting the importance of FLP techniques and how they can help companies in making decisions to install logistics hubs, considering multimodal integration, distance and cost optimization. This work was exploratory and theoretical in nature, using a quantitative approach to generate data and support discussions on the topic.

Keywords

Facility Location Problem, Logistic, Logistics Corridors, Multi-Criteria Method

1. Introduction

The selection of locations for the installation of factories, warehouses, distribution centers, logistics hubs (considering multimodal), among others, is of paramount importance for companies seeking to optimize their logistics operations and, consequently, achieve a competitive advantage (Matos & Thomé, 2020; Carniel, da Silva, & Mestria, 2021). This location selection is known as the Facility Location Problem (FLP), as stated by Scaburi, Ferreira and Steiner (2023), and has been widely studied in the literature for solutions in operations and logistics (Unnu & Pazour, 2022).

The main function of logistics is the management of financial, material, people and information flows from the point of origin to the point of consumption in the supply chain (Appiah, 2021), which involves all activities inherent to the aforementioned flows. For successful logistics management, it is necessary to use techniques that help managers make decisions, such as the Facilities Location Problem technique, ensuring crucial information for more efficient management.

The p-Median FLP technique has optimization at its core as an improvement in decision-making regarding the location of facilities, seeking to minimize the distances between demand points and supply points, involving the positioning of supply points closer to demand points, with the aim of minimizing operating costs (Matos & Thomé, 2020; Carniel, da Silva, & Mestria, 2021; Unnu & Pazour, 2022; Scaburi, Ferreira, & Steiner, 2023).

Other studies on the location of facilities have been developed, such as: a study on the location of terminals for charging electric bus batteries (Liu & Song, 2017); similarly (Guo, Yang, & Lu, 2018) developed a study on the location of terminals for charging electric vehicles; another study (Tsao, Thanh, Lu, & Yu, 2018), was carried out to assist in decision-making regarding the selection of production technologies and materials and in determining the number and location of production and distribution centers and the quantity of product to be transported between facilities.

The study by (Fischetti, Ljubić, & Sinnl, 2017) used the literature review model for locating facilities with operational research to identify ways of reducing operating costs; (Ni, Shu, & Song, 2018) studied decision-making with regard to the simultaneous optimization of locations for facilities with supplies to facilitate rapid response in the event of humanitarian aid in earthquakes; (Schiffer, Schneider, Walther, & Laporte, 2019) reviewed the literature on vehicle routing problems and location routing problems with intermediate stops and classified the publications into different categories, both from an application-based perspective and from a methodological perspective.

The principle of logistics is to reduce costs and increase the availability of products. To do this, it is necessary to strategically position distribution centers so that customers are served according to their needs (Fischetti, Ljubić, & Sinnl, 2017; Tsao, Thanh, Lu, & Yu, 2018). In their decision-making process, modern organizations seek to optimize their resources, which involves strategically locating supply points to meet the demands of their products in the most efficient way.

In this sense, decision-making is not an easy task, as it involves several criteria, such as location, possibility of multimodal integration, proximity to main consumption points, among others. All of this can be understood as a multi-criteria analysis for decision making, as it involves solve choice problems, which are complex (Diaz-Balteiro, González-Pachón, & Romero, 2017; Bystrzanowska & Tobiszewski, 2018).

The selection of locations for installation, such as a logistics hub, is a complex issue that involves a set of factors, such as cost, travel time, modal types, infrastructure, market accessibility for goods and services, environmental impacts of facilities, among others (Hiassat, Diabat, & Rahwan, 2017; Prataviera, Norrman, & Melacini, 2022). Existing approaches to solve FLP problems can be divided into two main groups: deterministic approaches and stochastic approaches (Shavarani, Nejad, Rismanchian, & Izbirak, 2018; Deutsch & Golany, 2018).

Deterministic approaches involve the mathematical modeling of the problem and the application of optimization techniques to find the optimal solution for the problem. On the other hand, stochastic approaches tend to consider the uncertainty associated with input data and use simulation methods to evaluate the effectiveness of different location options (Habibi, Asadi, Sadjadi, & Barzinpour, 2017).

The methods for solving FLP are varied, such as coverage, p-centers, p-dispersion, p-median, and others. One of the most used methods in the literature surveyed in this work was the P-Median method, as stated by (Hiassat, Diabat, & Rahwan, 2017; Shavarani, Nejad, Rismanchian, & Izbirak, 2018; Deutsch & Golany, 2018; Chauhan, Unnikrishnan, & Figliozzi, 2019), based on (Hakimi, 1964) who studied this method for locating a police station in a road system.

The use of the P-Median FLP method considers decisions regarding facilities, including various installations, factories, warehouses, logistics hubs, among others. The integration of different modes of transportation is an important factor to be considered in the selection of locations for the installation of a logistics hub, involving multimodal terminals, distribution centers, railways, highways, electricity, costs of cargo handling and storage, and their environmental impacts. Such integration aims to reduce transportation costs and seek logistical efficiency. For example, in some situations, it may be more efficient to transport products by railways instead of highways, especially in terms of the quantity transported at once (Fazayeli, Eydi, & Kamalabadi, 2018).

The objective of this work is to speculate on how FLP techniques can be applied to solve location problems for logistics hubs. To achieve this, a literature review was conducted on existing FLP studies, which address the main approaches currently used for location selection with the purpose of reducing logistics costs.

2. Materials and Methods

The approach of this research is quantitative, because using the following descriptors: "facility AND location AND problem"; "p-median AND logistic AND hub OR facility AND location" (Scopus search platform, used in this section); "facility location problem", (Google Scholar search platform used in section 1); "multicriteria logistical decision analysis method" (Dimensions search platform, used in this section), it was possible to generate data to be explored in the article.

In terms of its nature, this research is theoretical in nature in order to generate discussion and further study of the subject (Gil, 2002). The stages in carrying out this article are shown in **Figure 1** below.

The research was carried out, as mentioned previously, in three databases, Google Scholar, Scopus and Dimensions, covering the period from 2017 to 2023. From reading the works selected in the Google Scholar database, it was possible to observe the recurrence in use of studies by (Hakimi, 1964) with the work entitled "Optimal locations of switching centers and the absolute centers and medians of a graph". (Hakimi, 1964) employed the P-Median FLP technique to install a police station on a highway system. When researching the work (Hakimi, 1964), it already had 3412 citations, highlighting the importance of the topic, although the year of this publication is 1964, this study supported several literature

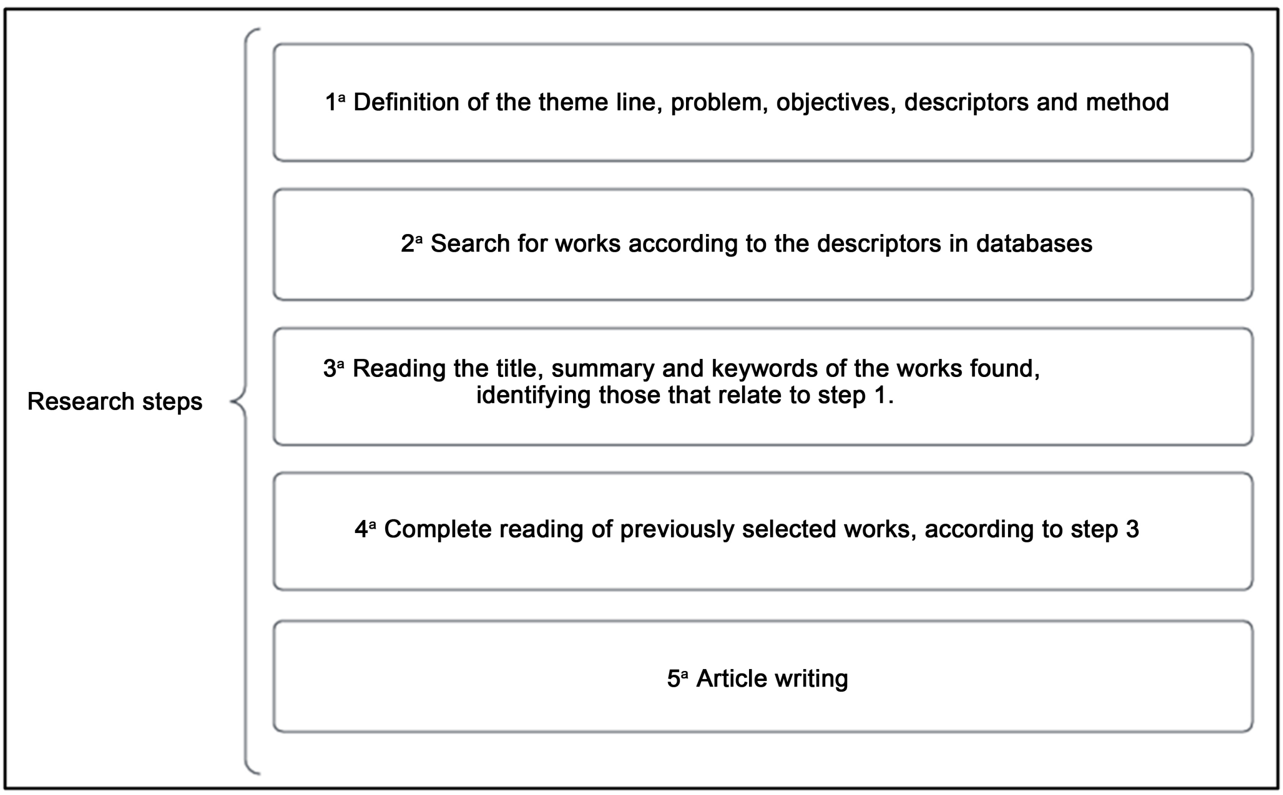

Figure 1. Research steps. Source: Authors (2023).

reviews.

From the research stages, it was possible to construct the article. To do this, a second search for papers was carried out on the Scopus platform—this data is included in the next section—and another search was carried out for papers related to the main multi-criteria analysis methods for decision-making.

In the Scopus database we found 916 articles, from which the 20 most cited ones were selected. Another filter was then applied based on their relevance to logistics location problems, resulting in a final selection of 16 articles as shown in **Table 1** below.

These papers are relevant to the study, as their content contains information aimed at achieving the objective of the work. After this, a search was carried out for papers related to the main methods of multi-criteria analysis for decision-making and which were in line with the article, and we chose five methods, which are shown in **Table 2** below.

Multi-criteria analysis methods for decision-making represent a strategic approach to dealing with complex decisions, where multiple factors and criteria must be analyzed. In logistics, these methods can be used to better position the supply chain, aiming to minimize operating costs, as well as helping to analyze the best locations for intermodal hubs, among others.

In this way, these methods allow for structured analysis and weighted considerations in different hierarchies in the decision-making process (Bystrzanowska & Tobiszewski, 2018; Karl, 2022; Tian, Lu, Zhang, Zhan, Dulebenets, Aleksandrov, & Ivanov, 2023). Furthermore, after carrying out the steps contained in this section, it was possible to understand the relevance of the subject and the results are contained in Section 3.

3. Results

Based on the data collected in the research, the relevance of the topic and the peculiarities involved in deciding the best location for a logistics hub through FLP became apparent. Despite the literature presenting various methods for solving FLP, this study found a higher incidence of research focused on the use of P-Median (**Table 3**) as a way to optimize the resources involved in facility location decisions. This was confirmed through the use of the descriptors "facility AND location AND problem" and "p-median AND logistics AND hub OR location" utilized for this research. The method can be described mathematically as follows: $y_i = \begin{cases} 1, & \text{if the facility is open at location } i \\ 0, & \text{otherwise} \end{cases}$

The constraints (1), which take into consideration (4), ensure that each customer j is served by only one facility, while constraints (2) guarantee that each customer j can only be assigned to one open facility at location i. Constraint (3) indicates that exactly p facilities are opened, and constraint (4) represents the type of variables.

Thus, it can be conjectured that when making a decision on where to locate a multimodal integrated logistics hub, the use of this approach can be suggested to

Table 1. Most cited articles considering the scopus database, first descriptor.

Article Title	Authors	Citation
Robust planning of dynamic wireless charging infrastructure for battery electric buses	Liu & Song, 2017	125
The battery charging station location problem: Impact of users' range anxiety and distance convenience	Guo, Yang, & Lu, 2018	112
Designing sustainable supply chain networks under uncertain environments: Fuzzy multi-objective programming	Tsao, Thanh, Lu, & Yu, 2018	104
Redesigning benders decomposition for large-scale facility location	Ni, Shu, & Song, 2018	102
Location and Emergency Inventory Pre-Positioning for Disaster Response Operations: Min-Max Robust Model and a Case Study of Yushu Earthquake Open Access	Ni, Shu, & Song, 2018	99
Hybrid manufacturing—integrating traditional manufacturers with additive manufacturing (AM) supply chain	Strong, Kay, Conner, Wakefield, & Manogharan, 2018	86
Vehicle routing and location routing with intermediate stops: A review Open Access	Schiffer, Schneider, Walther, & Laporte, 2019	84
Location selection of intra-city distribution hubs in the metro-integrated logistics system	Zhao, Li, Li, Sun, Hu, Mao, & Xue, 2018	64
Analyzing the location of city logistics centers in Istanbul by integrating Geographic Information Systems with Binary Particle Swarm Optimization algorithm	Çakmak, Önden, Acar, & Eldemir, 2021	16
Optimization in waste landfilling partitioning in Paraná State, Brazil	De Barros Franco, Steiner, & Assef, 2021	15
A simulated annealing algorithm for solving two-echelon vehicle routing problem with locker facilities	Redi, Jewpanya, Kurniawan, Persada, Nadlifatin, & Dewi, 2020	11
Hybrid manufacturing—Locating AM hubs using a two-stage facility location approach	Strong, Kay, Conner, Wakefield, & Manogharan, 2019	7
Selection of recycling centre locations by using the interval type-2 fuzzy sets and two-objective genetic algorithm	Tadić, Đorđević, Aleksić, & Nestić, 2019	6
Identifying ambient service location problems and its application using a humanized computing model	Chen, Chu, & Sangaiah, 2019	2
A stochastic distribution center location model for earthquake relief supplies based on monte carlo simulation	Tong, Zhang, Zhu, Liu, & Yan, 2017	2
Location Selection for Regional Logistics Center Based on Particle Swarm Optimization	Huang, Wang, & Chen, 2022	1

Source: Authors (2023).

reach the optimal model in terms of reducing operational logistics costs.

Another important factor in decision making also found in the research is the use of multi-criteria methods which consider distances, operating costs, demand, capacity and other relevant factors, placing each criterion as a preponderant factor for the most efficient location decision. By seeking to minimize the total

Table 2. Main multi-criteria analysis methods for decision making (base Dimensions).

Main multi-criteria analysis methods for decision making	Description	Authors
Analytical Hierarchy Process (AHP)	Methodology aimed at solving choice problems, applied to various situations where complex structures exist.	Diaz-Balteiro, González-Pachón, & Romero, 2017; Bystrzanowska & Tobiszewski, 2018; Pimenta, Beltrão, Gemaque, & Tavares, 2019; Deveci, Simic, & Torkayesh, 2021; Tian, Lu, Zhang, Zhan, Dulebenets, Aleksandrov, & Ivanov, 2023
Analytical Network Process (ANP)	Decision-making method that adapts to a non-independent recursive hierarchy is a new practical decision-making method based on AHP.	Diaz-Balteiro, González-Pachón, & Romero, 2017; Pimenta, Beltrão, Gemaque, & Tavares, 2019; Tian, Lu, Zhang, Zhan, Dulebenets, Aleksandrov, & Ivanov, 2023
Best-Worst Method (BWM)	It can be used to compare the performance of multiple alternatives when they are evaluated under different criteria.	Deveci, Simic, & Torkayesh, 2021; Pamucar, Deveci, Canıtez, Paksoy, & Lukovac, 2021; Karl, 2022; Tian, Lu, Zhang, Zhan, Dulebenets, Aleksandrov, & Ivanov, 2023
Multi-Criteria Group Decision Making (MCGDM)	The main advantage is the shift from single to multiple decision makers.	Karl, 2022; Tian, Lu, Zhang, Zhan, Dulebenets, Aleksandrov, & Ivanov, 2023
Technique for ordering preference by similarity with ideal solution (TOPSIS)	Classification method that approaches the ideal solution, the main advantage is that it can be applied for multi-objective decision making with continuous solutions.	Deveci, Simic, & Torkayesh, 2021; Karl, 2022; Tian, Lu, Zhang, Zhan, Dulebenets, Aleksandrov, & Ivanov, 2023

Source: Authors (2023).

Table 3. P-Median model.

The objective function minimizes the total cost.	$\sum\sum c_{ij}x_{ij}$ $i \in I,\ \ j \in J$
Constraint (1)	$\sum x_{ij} = 1,\ \ \forall j \in J$ $i \in I$
Constraint (2)	$x_{ij} \le \gamma_i,\ \ \forall i \in I,\ \ \forall j \in J$
Constraint (3)	$\sum \gamma_i = p$ $i \in I$
Constraint (4)	$x \in B^{\lvert I\rvert\lvert J\rvert}, y \in B^{\lvert I\rvert}$

cost, location and multi-criteria techniques provide managers with crucial information for deciding where to locate an integrated multimodal logistics center, as they consider a variety of criteria that reflect the operational complexities involved.

Furthermore, the results of this study corroborate the relevance of the topic and, together with multi-criteria analysis methods, become a valuable tool for decision-making, contributing to operational efficiency (internal and external), resulting in a reduction in order fulfillment times and cost optimization in logistics contexts.

4. Conclusion

The P-Median method, according to the analyzed studies, proved to be well accepted for FLP applications, but this does not invalidate other methods. The objective of the work was achieved as, during the search for relevant studies, the importance of the topic "The Importance of the Facility Location Techniques to Assist Companies in Decision-making for the Installation of Logistics Hubs" became evident. Specifically, the importance of FLP in helping companies make decisions on where to install a logistics hub, the possibilities of multimodal integration, distances between production and distribution points, and cost optimization.

Each method can be used according to the application needs, and thus, this work sought evidence from the literature regarding studies on facility location decisions, which encompass resource optimization in the logistics field. It also showed that multi-criteria analysis methods provide an important basis, as they use several criteria to assist managers in decision-making, seeking to minimize operational costs.

Furthermore, further studies can be conducted to explore computational simulation methods applied to the selection of locations for various facilities. Additionally, studies can be carried out to demonstrate the effectiveness of probabilistic methods combined with the use of simulation software in the selection of factory locations, among other areas.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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