Optimal Location of a Central Warehouse for a Retail Painting Company: Practical Case in Mexico

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Abstract

The present paper is a case study based on a retail painting company (SME: small and medium-sized enterprise) located in Mexico that built a Central Warehouse to save money by improving its inventory management. The Fermat-Weber facility location problem was studied and applied to obtain the optimal location for the mentioned warehouse. The proposal was validated throughout the ROI methodology to ensure necessary financial results achieving a cost reduction and investment return within the first year of operation of the new warehouse. It is paramount important for current SMEs to apply exact methodologies to improve their cash flow and promote their existence among other companies in such a competitive business environment. The authors' primary purpose is to use an existent model in a real case that can be replicated by any retail SME obtaining cost improvements.

Keywords
Central Warehouse, Facility Location Problem (FLP), SMEs, Retail Logistics, Return on Investment (ROI)

1. Introduction
In general, warehouses are created to cover different roles in the supply chain, such as the safeguarding of raw materials, product in process, or finished goods. They can have different functions, including consolidation centers, distribution centers for order processing, and other activities, and are operated by the company or subcontracted by third-party suppliers (Richards, 2014). They must be designed to meet the specific requirements of the supply chain of which they are a part (Rushton, et al., 2014)

Some operations are common to most warehouses, and these tend to apply whether the warehouse is manual with the reasonably necessary equipment or highly automated with sophisticated storage and handling systems (Rushton, et al., 2014).

Small warehouses are different from large ones in different ways. The most relevant to this context is that small warehouses are usually managed at the (stock keeping unit) SKU level, and their density is high; capital investments are low, they do not invest in warehouse management, and there is little or no automation (Limère & Çelik, 2011).
The company's supply chain under study is a SME dedicated to purchasing and selling coatings and light building materials that operate with five peripheral warehouses located in each group's branch. However, to reduce the working capital and be more efficient at the service level, a central warehouse is sought. It will play the main warehouse's role to supply the peripheral warehouses, which are defined as a location shared by a central warehouse, used for direct distribution of materials to customers. Its main intention is to ensure higher quality in customer service (Ghiani, et al., 2004).

Understanding then, a central warehouse as the primary location for the supply of peripheral warehouses both owned and rented (Drezner, et al., 2003).

This case study is elaborated with a strategic approach that seeks to locate a central warehouse to consolidate the inventory operations of an SME. Moreover, thus, achieve the reduction of logistics costs. Logistics models are used that optimize the use of resources to achieve this objective. A feasibility study of the improvement proposal is also carried out to intend that the methodologies developed can be replicated by other SMEs.

2. Literature Review

The Fermat-Weber problem dates to the 17th century, and since then, multiple authors have conducted studies on it. This problem consists of finding a point that minimizes the weighted distances to a given number of issues. The question initially formulated by the French mathematician Pierre de Fermat was "given three points on a plane, find a fourth point such that the sum of the distances to the three given points is the minimum possible."

Under this question, in the 20th century, the German economist Alfred Weber incorporated weightings and increased the number of points to more than three facilities, calling it the Fermat-Weber problem (Beck & Sabach, 2014). In fact, in a traditional configuration, decision-makers choose a subset of locations within a list of candidates to open facilities and allocate demand to them while minimizing the cost of opening and meet demand. In this sense, the market demand is critical in determining the locations for opening new facilities (Basciftci, et al., 2020).
At present, facilities' location is a strategic decision of the organization’s management as it represents an investment from which profits are expected (Farahani, et al., 2009).

There are many applications for (Facility Location Problems) FLP models. Their extensive study in recent decades shows the importance of these models and their application in not only business but also social contexts, as is the case of urban solid waste management, where the inadequate location of garbage collection centers can lead to low collection systems contributing to health problems and environmental impact (Adeleke & Olukanni, 2020). FLP is recognized for establishing distribution centers within the business context to meet specific demands within given points (Zhang, et al., 2014). The study of FLP is so extensive that it has been extended to more than 50 derived problems (Brandeau & Chiu, 1989).
As mentioned earlier in this section, FLP is so versatile that it can be viewed from social, economic, or even environmental aspects, and these three dimensions can be studied as a whole or separately (Anvari & Turkay, 2017). The FLP models can be classified within the structure described in Table 1 (Klose & Drexl, 2005).

Table 1: FLP classifications

Type	Classification
1	The shape or topography of the set of potential plants yields in the plane, network location models, and discrete location.
2	Objectives may be either minisum or minimax type.
3	Models without capacity constraints do not restrict demand allocation.
4	Single-stage models focus on distribution systems covering only one stage explicitly.
5	Single-product models are characterized by the fact that demand, cost, and capacity for several products can be aggregated to a single homogeneous product.
6	Frequently, location models base on the assumption that demand is inelastic; demand is independent of spatial decisions.
7	Location models are based on the assumption that demand is inelastic. The demand is independent of spatial decisions. If demand is elastic, the relationship between, e.g., distance and demand, has to be explicitly considered.

Warehouses are a crucial aspect in modern supply chains and play an essential role in the success or failure of businesses since they are locations that generate added value to the warehouse, but also, when poorly managed, can represent a source of costs rather than benefits to the company (Frazelle, 2002).

It is essential to focus this study's attention on the central warehouse's optimal location to allow each of the branches to request the material from it.

The first exact solution method was developed three centuries after discovering the original SWP (Single-source Weber Problem) model in 1972 (Kuenne & Soland, 1972). Several authors began to analyze problems with optimal solutions involving two to three supply centers in subsequent years.

As the number of supply sources and customers to be served increased, the complexity of the models required to find a solution also grew, so multiple heuristic models were developed to solve this problem. Among these models, the Cooper Algorithm stands out, which maintained the art state for many years (Drezner, et al., 2015).

The Fermat-Weber methodology is adapted, which considers Euclidean distances that minimize the distances traveled for the re-supply of goods and considers each point of sale's demand weighting. One of the benefits sought is reducing inventories representing a waste of resources, as mentioned above.

This study's main objective is to locate a central warehouse that supplies five branches with different demands. Minimizing the distance traveled for its supply to transform the dynamics of the current supply chain where each point of sale pushes its inventories to the market, to a mechanism with pull effect where each store is supplied from the central warehouse to fulfill the forecasted demand.

3. Methods

The research is carried out in different stages (Figure 2): a) definition of the problem, where to describe the current conditions of the company and improvement areas, b) data collection, the information for the main SKUs of the article Forecasting Demand for a Retail Painting Company, developed within the same company (Briseño, et al., 2019)] and it is considered information provided by the company regarding the rest of the products based on historical sales of the last three years since 2017, c) minimize the distance for distribution between the central warehouse and the peripheral warehouses, at this stage the Fermat-Weber tool is used to choose the optimal location, and finally, d) interpretation of the results obtained with the analyzed proposals.

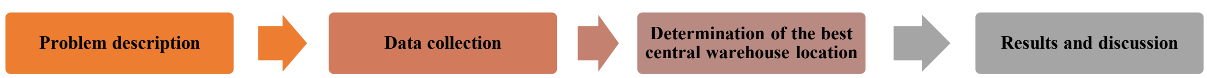

Figure 1: Research methodology

4. Problem Description

Currently, the distribution system used for supply begins with truck shipments from the manufacturer's (Distribution Center) DC to the branches for direct sales to customers, where deliveries from the stores to the final consumers are made in different ways, such as in-store purchase and pick up, store purchase with home delivery and remote-order with pick up or remote-order with home delivery by motorcycle or truck depending on the volume of investment.

According to the company's internal records, it is known that the time of service to a customer from the reception of the order to the availability of the goods is up to 15 minutes, depending on the number of materials included in the order. However, a recurrent problem is observed when the product for an order is not available in the same branch, where the collection of the development happens in more than one warehouse, increasing the time of service up to 60 minutes, on average. In addition to the impact on customer service, this situation generates additional logistics costs that can be interpreted as waste per the Lean Philosophy definition (Daine, et al., 2011).

Derived from the existence of materials in different warehouses, regular customers opt for remote purchase orders with home delivery to avoid waiting, representing 20% of current sales, with an upward trend since in 2017 when this service represented only 5%, the service increase has risen the distribution cost of the company.

It is worth mentioning that each operation within the warehouse incurs a cost, which for the practical case is shown in Table 2, is classified into five categories. The safety stock (SS) was obtained from the analysis made by consolidating all branches' demand with their variation and a 95% service level. The general safety stock difference is obtained from the subtraction of 5 SSs (2,029.13 USD each) maintained in 12 months, minus one security inventory (2,029.13 USD) to be kept in the central warehouse CW.

Table 2: Current warehousing costs (yearly basis)

Class	Frequency	Unitary cost (USD)	Total cost (USD)
Obsolete inventory	60	1,000.00	60,000.00
Operational cost	36	270.83	9,750.00
Opportunity cost	36	104.17	3,750.00
SS surplus (current-CW SS)	5-1	2,029.13	8,116.50
Freight costs	52	208.33	10,833.33
			92,449.83

4.1. Details of the current situation in the company

The present case's importance is to propose a more robust inventory and distribution management system that allows maintaining the service level desired by the consumers and the company itself. Although having independent inventories per branch allows a higher service level, this represents a more significant investment for the company, increasing its cash flow. As indicated by (Stanimirovic & Ciric, 2011) and (Werner, 2018), SMEs face difficulties managing credit to conduct business, which denotes the need for proper cash flow management when considering that the company in the case study belongs to this category. Additionally, there is a precedent that cash flow, bad debts, and debtor management are serious problems SMEs face to manage their credit. It represents a high possibility that businesses of this size will fail due to poor business credit management (Werner, 2018).

It is essential to highlight that currently, the company, in the search to give independence to each branch, is managed with an ERP software (Enterprise Resource Planning) that is not interconnected, which can represent a problem during the order preparation since instead of redistributing the inventory of the cluster, sometimes materials are bought for a branch that has a high demand for a specific material. In contrast, in another, they represent obsolete products. It is naturally associated with the different needs of the markets that each one serves. However, a general visualization could minimize the economic impact of this type of decision.

The company's interest is to create a central warehouse that allows the branches' supply, consolidating the inventory in the central location. A proposal will be generated for the main warehouse and the branches' conversion in logistical terms from primary to peripheral warehouses, with a regular supply plan.

The company currently does not intend to expand the existing transport fleet to distribute goods from the central warehouse to the peripheral warehouses, composed of 2 units with a limited capacity of 1 and 2 tons, respectively. These transports have established activities, such as home delivery, carried out during the working day. Given this restriction, we wish to consider that the re-supply of the peripheral warehouses is carried out after the branches' opening. It takes advantage because the vehicles are kept in the central warehouse so that the day's first trip will be considered goods distributed to the branches.

The warehouse's purpose is to receive the goods from suppliers and then distribute the goods to the peripheral warehouses that represent each of the branches, where the sales process will be completed. Figure 1 illustrates the proposed operation:

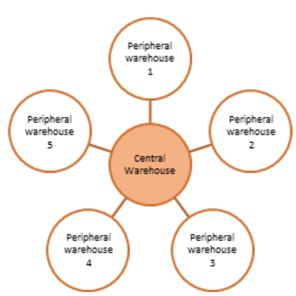

Figure 2: New warehouse configuration

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5. Data Collection

The information necessary for the proper development of this improvement proposal required the analysis of historical sales for the last three-yearly periods to analyze and understand the behavior of demand and to be able to generate a sales projection based on the observed trend, as well as to consider the company's particular growth objectives.

Once the expected demand is known, the sales mix of each of the products grouped by SKU and type of packaging is calculated. It to estimate the space required to store the materials to be distributed to the peripheral warehouses. This step is decisive in calculating costs incurred by the improvement and determining the project's financial viability.

Once this information has been determined, an estimate can be made of the number of racks required for the warehouse's operation, considering two main types: dedicated floor space, identified with one storage level, and those that believe fixed-height racks with four stowage levels. The final result is 51 racks (considered a rounding to multiples of 0.25, representing a location within each shelf), equivalent to 140 positions. This information will be vital in determining the space required for the operation of the warehouse.

$$\boldsymbol{SS} = (\boldsymbol{\sigma})(\boldsymbol{z})\sqrt{\boldsymbol{L}} \quad (1)$$

Where:

SS = Safety stock,
$\boldsymbol{\sigma}$ *= Demand standard deviation within the sampled values,*
L = Lead time of each product

$$\#\,\boldsymbol{racks} = \frac{\boldsymbol{Safety\ stock+weekly\ demand}}{\boldsymbol{Units\ per\ rack}} \quad (2)$$

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Table 3: Demand figures for space determination

Type of package	Safety Stock (pc)	Weekly demand (pc)	Total demand (pc)	Rack levels	Pieces per level	Remarks	# racks	Unit weight (kg)
Ac	113	696	809	4	18		11.5	5
Sp	55	131	186	4	72		0.75	0.5
Bu	7	0	7	1	7	Floor space	1.0	25
QL	33	33	66	4	100		0.25	0.4
20L	58	155	213	4	6		9	35
4L	94	367	461	4	18		6.5	6
Li	121	729	850	4	90		2.5	1.6
HL	57	98	155	4	150		0.5	0.8
EL	19	11	30	4	165		0.25	0.2
PA	35	44	600	1	50	Floor space	12.0	25
Dr	1	5	6	1	1.5	Floor space	4.0	250
MP	76	224	600	1	200	Floor space	3.0	2
Total		**2493**	**3983**				**51**	

Based on the packages' dimensions and the sales projection for each of them (Table 3), the required storage volume is determined. With this information, the warehouse's size is estimated. Furthermore, a cost projection incurred by the proposed warehouse's conditioning and operation is calculated without focusing on this study.

As a parallel study, the current security inventory cost for each of the branches was analyzed. It was compared with the value of the consolidated security inventory at a single point. The difference obtained was an initial indicator to determine if the proposal made would represent any benefit compared to the company's current operation. Similarly, the operating costs related to the logistics of its warehouses were obtained from the company to provide a point of comparison with the proposal developed.

Through this analysis, it was possible to find those materials that have remained in inventory for long periods, which generates operating and storage costs, directly impacting its cash flow results. This phase visualizes that there are slow-moving materials in one point of sale that can be of high rotation for another.

Finally, we obtained the operating costs for the supply of the branches and other costs associated with the center's operation to estimate the investment required for the implementation of the central warehouse and verify the feasibility of improvement.

5.1. Determination of the Best Central Warehouse Location

The Weber model (also known as the Fermat-Weber problem) was used to select the central warehouse location, defined as a basic theoretical location model with significant attention in the scientific literature due to its effectiveness (Wesolowsky, 1993).

Within the case study, an adaptation of the original Fermat-Weber model will be developed, which seeks to minimize the Euclidean distance between demand points *i* and center *j* located at $X_{ij} = (x_i, y_j)$, the objective function to be minimized:

$$\boldsymbol{Min}_{W,X}\left\{\sum_{i=1}^{n}\sum_{j=1}^{p} w_{ij} d_i(X_j)\right\} \quad (3)$$

Subject to:

$$\sum_{j=1}^{p} w_{ij} = w_i \;\; i = 1, \dots, n \quad (4)$$
$$w_{ij} \geq 0 \; i = 1, \dots, n; j = 1, \dots, p \quad (5)$$

It should be mentioned that other measurements, such as coordinates or weighted points, also play an essential role in the theory and practice of location problems (Stanimirovic & Ciric, 2011). The most popular method to solve the Weber problem is an iterative procedure initially proposed by Weiszfeld (Beck & Sabach, 2014).

With the above definitions, it is clear that the Weber model allows the use of different elements, so in the case study will be used Cartesian metrics to locate the points to be served by the central warehouse, this is achieved within a plane (x, y) to the branches and once the model is executed, it is also known the optimal location for the warehouse.

Since the original model does not consider each point's demand, adding an attraction factor "c" represents the proportion of volume expressly provided by the company. It implies that each of the coordinates (x, y) is affected by the volume required by the branches for whose demand will be dispatched from the proposed location. The following is a description of the model used, computed in the "Lingo" software for quick results.

It was decided to add a factor related to demand to establish the stores with higher sales, since these will have a greater flow of goods, so, to seek cost reduction, it will be necessary for the warehouse to be located closer to the most representative points of sale for the company.

It is important to mention due to the confidentiality policy of the company. Although the authors knew these, the actual locations could not be presented, so an alternative method was made using Google Maps initially and was converted to a map of Cartesian coordinates, assigning values within a grid to each point to be served. Similarly, it was made for the central warehouse, the distances calculated maintain proportionality, and once the location of the proposed warehouse is known, it is taken to the original map (delivered to the company).

$$\boldsymbol{Min} \sum_{i=1}^{n} \sqrt{(\boldsymbol{x} - \boldsymbol{c_i x_i})^2 + (\boldsymbol{y} - \boldsymbol{c_i y_i})^2} \quad (6)$$

Where:
x= Cartesian coordinate x for the location of the CW
y= Cartesian coordinate and for the site of the CW
c_i= Weighted distance value depending on demand

The matrix of coordinates (x, y) is considered in Table 4, where Cx and Cy calculations appear.

Table 4: Cartesian coordinates

Branch	Demand factor (%)	Weight percentage (10)	x	y	Cx	Cy
B1	0.15	1.5	23	5	34.5	7.5
B2	0.2	2	19	45	28.5	67.5
B3	0.16	1.6	18	54	27	81
B4	0.25	2.5	38	47	57	70.5
B5	0.24	2.4	7	88	10.5	132
	CW x, y		**30.24**	**70.91**		

Figure 3 shows the location on a Cartesian plane of the five branches (orange nodes), as well as the site obtained for the central warehouse (blue node), according to Weber's model with demand weights for each client served by the peripheral warehouse (or branch).

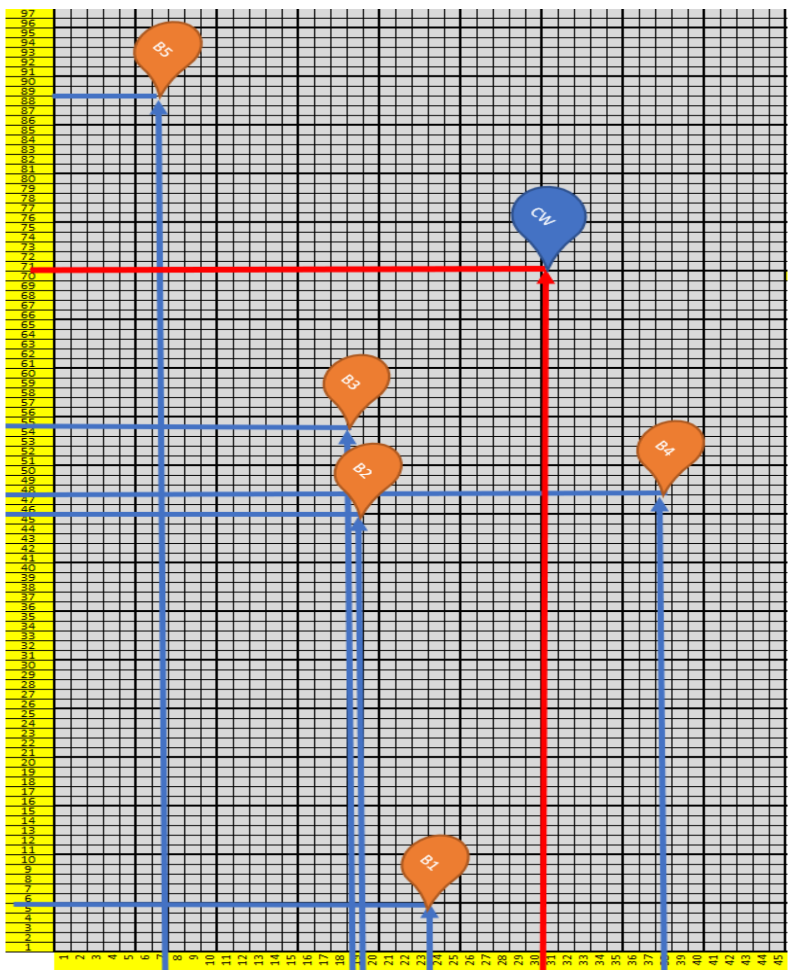

Figure 3: Cartesian coordinates with branches and central warehouse locations

Once the distances and frequencies of supply are known based on each peripheral warehouse's demand factor, the investment required for the operation of the pull system of each sales branch is estimated.

The costs incurred to implement the central warehouse in the location previously determined are detailed in Table 5, where they are reflected in USD throughout an annual period. It is shown in Table 2 the same analysis horizon used in the calculation of the current costs; it is essential to mention that in Table 5, the interest payment generated by a loan to cover the investment required for the improvement is included since currently, the company does not have the necessary capital.

The logistics costs under the organization's current supply chain configuration are US$92,449.83/year (Table 2), while with the proposal for a central warehouse, an operation of US$64,410.68/year is planned achieving savings of US$28,039.16/year (-30.32%). The initial inventory investment could be considered virtual for profitability analysis purposes, as the majority f the stock could be allocated from existent peripheral warehouses. However, its full value is used for the calculation to have an objective vision of the new facility.

On the other hand, the main driver for savings is eliminating obsolete inventory, representing an income for the company as it is reduced. Likewise, thanks to the centralization of operations, the current safety stock will be reduced by 80%. Similarly, another source of savings derived from the creation of the central warehouse is the reduction of freight payments, since currently, the sum amounts to 10,833.33 USD/year, due to the need for supply from the leading supplier, while having a local re-supply, the cost of freight is reduced to 638.18 USD/year.

Table 5: New central warehouse implementation costs

Class	Frequency	Unitary cost (USD)	Total cost (USD)
Inventory	1	21,527.08	21,527.08
Installations	31	241.67	7,491.67
Installations	113	14.58	1,647.92
Safety and security	1	416.67	416.67
Safety and security	1	833.33	833.33
Safety and security	1	833.33	833.33
Installations	1	1,250.00	1,250.00
Operational cost	12	833.33	10,000.00
Safety and security	1	416.67	416.67
Safety and security	1	2,083.33	2,083.33
Safety and security	3	75.00	225.00
Operational cost	1	416.67	416.67
Safety and security	4	41.67	166.67
Safety and security	8	20.83	166.67
Operational cost	12	62.50	750.00
Operational cost	36	270.83	9,750.00
Interests	1	10%	5,797.50
Operational cost	3,063	0.21	638.18
			64,410.68

6. Results and Discussion

Although the central warehouse's optimal location was determined to meet the needs of 5 branches, it is time to compare the costs associated with the current operation of the independent warehouses against the proposal developed.

The comparison is made using the financial measure of ROI (Return on investment), which answers the question: Is there a financial return on investing in a performance improvement program, process, or solution (Zamfir, et al., 2016). The ROI is calculated with equation 7:

$$\boldsymbol{ROI}_{\%} = \frac{\boldsymbol{Net\ benefit\ of\ the\ improvement}}{\boldsymbol{Cost\ of\ the\ improvement}} \boldsymbol{x100} \quad (7)$$

$$\boldsymbol{ROI}_{\%} = \frac{\boldsymbol{CW\ costs - current\ costs}}{\boldsymbol{CW\ costs}} \boldsymbol{x100} \quad (8)$$

Substituting in Equation 8:

$$\boldsymbol{ROI}_{\%} = \frac{\mathbf{92,449.83 - 64,410.68}}{\mathbf{64,410.68}}\boldsymbol{x}\mathbf{100} = \mathbf{44\%}$$

The 45% ROI (Equation 8) is interpreted for each dollar invested; the company will receive USD 0.44. Therefore, it is considered that the implementation of a central warehouse is feasible since there is a tangible improvement in economic and operational terms by simplifying the company's logistics functions.

Another possible conclusion on the results is the possibility of improving the company's cash flows through the establishment of the central warehouse, which will, in the first instance, represent an additional income to the company by establishing inventories adequate to the actual demand to meet the cost of the proposed investment. At the same time, the obsolete or slow-moving inventory will be converted into liquidity for the company, as a single occasion, given the opportunity to significantly increase the turnover of its stocks that will be reflected as an increase in profits by considerably reducing the investment stationed for long periods and costs associated with this activity.

By applying the Lean philosophy of an industry that involves a "pulling" methodology, it is considered that the proposed facility will allow branches to order material only when it is required for sale. By modifying the current practices in which we seek to push material that is lagging by having over the inventory of specific goods.

It is also necessary to emphasize the importance of measuring the proposed warehouse's operation by using performance indicators as a future proposal to identify improvements, and action plans are suggested for those aspects that require it.

7. Conclusion

As exemplified during the development of this case study, there are many methodologies for improving supply chain processes. However, SMEs' suitability is a branch of knowledge little studied in an approach such as the supply chain and specifically the warehouses as a tool for cost control.

Adapting existing methodologies to a real case within SMEs' context represents an opportunity to increase their competitiveness in today's markets, which are becoming increasingly professional, since knowing how companies create and manage a competitive advantage represents a fundamental element in strategic management.

One of the intentions set out before developing this case study was to provide a tool for other SMEs to improve their operational and strategic processes. This goal was achieved by proposing generic models that can be replicated with moderate adjustments according to each company's nature, processes, and specific needs.

The study shows that, although there are many case studies focused mainly on large supply chains, little is said about their application to smaller companies, whose impact can generate a significant economic benefit by implementing changes within the traditional operational form of these companies. These models can provide a high utility for the development of logistics projects, considering measuring their effectiveness based on the improvements' profitability, as was done in this case study where one was obtained with an ROI of 44%.

This study continues to be developed on great relevance when considering the economic context in which this work has been carried out. Since there are a large number of companies that meet these characteristics, generating 72% of employment and 52% of Mexico's GDP (Sánchez, 2020), so the implementation of a project like a case study can develop a more significant opportunity for success within the market not only to continue operating but increasing their chances of growth, which will generate new opportunities for expansion and employment generation.

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