Journal of Ecohumanism
2025
Volume: 4, No: 1, pp. 5185 – 5194
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v4i1.6453

Optimization of the Distribution Chain of the Meat Marketing Sector Through Facility Location Models

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Abstract

Understanding marketing as a structural and functional system that manages the product at the moment it leaves the establishment until it reaches the consumer, it is necessary to have the objective of having optimal marketing places that integrate distance, production, and marketing costs, as well as variables. as the optimal location. In this sense, we start from the integration of optimal location models Weber, p-median, vehicle routing, and travel agent, achieving that, for the marketing of meat in the city of Azogues, by correlation of distances it must be carried out in the Recinto Ferial Market, achieving savings of 14.5% and from a cost reduction analysis of 7.9%, an optimal distribution route obtained. With these results, it is achievable to see the advantage of the Facility Location model; however, applying a complementary Cooperative Game Theory with transferable utility is proposed, strengthening the work in associativity, achieving even fewer plus losses by 15.3%.

Keywords: *Optimization, Distribution Chain, Marketing, Meats, Facility Location.*
Subject classification codes: M11.

Introduction

To review state of the art we propose the search equation optimization AND distribution AND chain AND marketing AND facility AND location AND (LIMIT-TO (SUBAREA, "DECI") OR LIMIT-TO (SUBAREA, "BUSI") OR LIMIT-TO (SUBAREA, "ENGI") OR LIMIT-TO (SUBAREA, "SOCI")) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")) during the last five years.

Economic development has strengthened with the support of new digital technologies, which allow coordinated regional economic growth (Liu, y otros, 2024).

The production of Ecuador's meat processing and preservation industry contributed an average of 1.39% of the GDP (Tene Cabrera, Garzón Montealegre, Quezada Campoverde, & Carvajal Romero, 2023). Production for 2022 is 2,857 million dollars (Much Better Ecuador, 2022). In the province of Cañar, the meat processing and preservation industry contributed 115.24 million dollars in 2022, representing 8.1% of provincial production (BCE, 2023).

Business logistics is analyzed as the management of the supply chain, which covers all activities related to storage, product transformation, and distribution to final consumers (Aguilar-Escobar, Garrido-Vega, & Godino-Gallego, 2013) (Rojas Amaya, 2014) (Martínez Jurado & Moyano Fuentes, 2011). Its importance lies in the ability of a company to comply with the delivery of goods or services requested within an acceptable time frame, which provides benefits and reduces (Coyle, J., R., & B., 2020).

The foundation of logistics management is within Porter's value chain concept (Robayo Acuña, Cabrera, & Araujo-Ochoa, 2016). In the value chain input and output logistics are identified as primary components of the value chain, which is a management tool that allows an industry or sector to be analyzed through primary activities and support activities to identify the sources of value generation of the company in the

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production process of its goods or services, and thus find a way to establish a strategy that allows it to obtain an advantageous position with the competition (Coyle, J., R., & B., 2020) (Porter M. , 2004).

Logistics is executed in companies' strategic, tactical, and operational decision-making, thus managing costs and expenses.

Logistics is essential for every process, both in cost and expense management, given that it executes strategic decision-making without leaving aside each company's tactical and operational aspects.

Logistics costs are related to inventory and transportation costs, that is, from the point of departure to the end of arrival (Aguilar-Escobar, Garrido-Vega, & Godino-Gallego, 2013) (BCE, 2023) (Coyle, J., R., & B., 2020). For Escalante (2016) (BCE, 2023), the costs in the supply process are the resources consumed in purchasing and acquisition activities where taare incurred, and transportation and storage from supply sources are involved.

One of the functions within outbound logistics is distribution, which involves the transportation and physical handling of products since it should not only focus on the manufacturers who work in the organization; another is warehouses, retailers, wholesalers, and the adaptation of the product assortment to consumer demands. By focusing on each, the total value generated can be maximized, thus being different in the market and the industry (Serrano, 2019).

Customers changing needs cause a company to innovate, stay ahead of what its competition is doing, and be alert to its environment. Schumpeter coined the term destructive innovation: innovation destroys the previous status quo and replaces it with a new situation (Chiavenato, 2010). Porter explains innovation: A nation's competitiveness depends on its industry's ability to innovate and improve. Companies achieve competitive advantages through innovations (Porter M. E., 2015).

In Ecuador, SMEs are fundamental to the economy; they are a source of employment generation and a means to offer diverse products and services in smaller markets and develop new productive ideas. They are organizations that adapt to new technologies relatively quickly since their planning and organization do not require much capital (Delfín & Acosta, 2016). SMEs develop in an environment of continuous improvement, which allows them to achieve sustainable growth over time (Yance, Solís, Burgos, & Hermida, 2017).

The optimization of the distribution chain in the meat and prepared meat marketing sector is essential to improve operational efficiency and reduce logistics costs. In this context, applying facility location models is a valuable tool for designing strategies that maximize efficiency in supply chain management to identify the optimal locations for a set of facilities that offer services in order (Blanco et al., 2024). Among the most relevant methods are Weber's models, the Traveling Agent Problem, the P-median Problem, and the Vehicular Routing Problem, which address different spatial distribution and route optimization aspects.

Based on the facility location theory, Weber's model seeks to determine the optimal location of distribution centers by considering the demand of the points of sale and the costs associated with transportation. On the other hand, the Travel Agent Problem focuses on finding the most efficient route a vehicle should follow to visit a set of destinations, minimizing the total distance traveled.

Solving the P-median problem focuses on identifying the optimal locations for a predefined number of distribution centers, considering the demands of the outlets, and minimizing the weighted total distance between the centers and the destinations. Finally, the vehicular routing problem deals with planning the routes of distribution vehicles to meet customer demand efficiently and optimize the allocation of products to each car.

Together, these models offer a comprehensive approach to optimizing the distribution chain in the meat and prepared meat marketing sector, enabling informed decisions that result in more efficient distribution, lower logistics costs, and a significant improvement in supply chain management.

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Problem

A localization problem is a problem of allocating resources within a given space. In the general problem of facility location, one or more service facilities (Suppliers) serve a spatially distributed set of demands (Customers). The objective is to situate the services or suppliers to optimize a specific criterion; generally the attention to customers' needs, considering one or more criteria such as cost, time, or distance.

We see that public space is misused for the commercialization of products because markets do not have enough space or because they are not in places close to needs, which leads to a challenge of optimal location of one or several facilities. Decision-making about the location of commercialization facilities is a process that depends on four key research questions: (i) How many facilities are needed? (ii) What clients should each installation attend? (iii) Where are the facilities needed? and (iv) What size should the facilities be?

With all this context, the main objective of this work is to optimize the logistics cost structure in the distribution chain, as well as the location and competitiveness of the meat marketing sector in the city of Azogues.

Methodology

Within the methodological proposal, the starting point is a survey of the current state and characterization of the meat marketing chain in Azogues through a study with 52 closed questions, with a Likert and numerical scale. This is followed by a phase of linear programming application in optimization and facility location problems (Facility Location), proposing the Weber, P-Median, traveling agent, and vehicle routing models.

Within Weber's problem, the coordinates would have determined (x_i, y_i); for a number P of installations within the market. The objective is to minimize the sum of the distances between the facilities and the demand points n for $i = 1,2,3, \cdots n,$ and the intensity of the demand is given by h_i.

$$Minimize\ (X, Y) \quad \sum_{i=1}^{n} h_i \sqrt{(x_i - X)^2 + (y_i - Y)^2} \quad (1)$$

Within the P-median model, P facilities are located to minimize the weighted average distance between the demand points and the nearest facility. Mathematically, it is represented as follows:

$Minimize$:

$$\sum_{j \in J} \sum_{i \in I} C_{ij} X_{ij} \quad (2)$$

$Subject\ to$:

$$\sum_{j \in J} Y_j = p \quad (3)$$

$$\sum_{j \in J} X_{ij} = 1 \qquad \forall i \in N \quad (4)$$

$$X_{ij} \leq Y_j \qquad \forall i \in N, j \in J \quad (5)$$

$$X_{ij} \in \{0,1\}, Y_j \in \{0,1\} \forall i \in N, j \in J \quad (6)$$

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Where the equations:

Ensures that each client is assigned to a median

Ensures that exactly p locations are selected for medians

They ensure that clients are assigned to a median only if it is selected

Specifies that all decision variables are binary

In the traveling agent model, the optimal route of the product distribution chain in the markets is sought through

$Minimize$:

$$\sum_{i=1}^{n}\sum_{j=1}^{n} C_{ij}X_{ij}$$

$Suject\ to$:

$$\sum_{j=1}^{n} X_{ij} = 1, i = 1, \cdots, n$$

$$\sum_{i=1}^{n} X_{ij} = 1, j = 1, \cdots, n$$

$$The\ following\ constraint\ removes\ sub - tour:$$

$$u_i - u_j + nX_{ij} \leq n - 1, i, j = 2, \cdots, n$$

$$X_{ij} \in \{0,1\}$$

Finally, for the vehicle routing model, the concept of a transport fleet is proposed for the distribution of meat within the markets of the city of Azogues through:

$Minimize$:

$$\sum_{i \in V}\sum_{j \in V} C_{ij}X_{ij}$$

$Suject\ to$:

$$\sum_{i \in V} X_{ij} = 1 \quad \forall j \in V \setminus \{0\}$$

$$\sum_{j \in V} X_{ij} = 1 \quad \forall i \in V \setminus \{0\}$$

$$\sum_{i \in V} X_{i0} = K$$

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$$\sum_{j \in V} X_{0j} = K$$

$k: number\ of\ vehicles\ available$

The following constraint removes sub-tour:

$$\sum_{i \in S} \sum_{j \in S} X_{ij} \geq r(S) \qquad \forall S \in V \setminus \{0\}, S \neq 0$$

$r(S): Cutting\ capacity. Minimum\ number\ of\ vehicles\ that\ satisfy\ the\ demand\ in\ S$

$$X_{ij} \in \{0,1\} \quad \forall i, j \in V$$

Results

Within the information gathering, on average, it is found that the people who are dedicated to the marketing of meat have an average of 20 years in the business, with a maximum average billing value on a typical day of 264.33USD and when it is fair invoice 311.93USD, with a profit margin of 35.5% on many meat products (662.56lbs) per week, including beef, pork, chicken, and sausages.

Once the production channel was characterized using GPS and Google Maps, the four markets of the city of Azogues were located, and the coordinates were obtained in standard decimal degrees. Subsequently, a relationship was made using the central reference point, the center of the city, whose coordinates correspond to (0,0) [Table 1].

Table 1. Geographic Coordinates of the Marketing Centers of the City of Azogues

Place	Coord. X [°]	Coord. Y [°]	Coord. X [km]	Coord. Y [km]
Central Park	-2,7397675	-78,8474714	0	0
Recinto Ferial Market	-2,7413465	-78,8542703	-0,7565	-0,1733
Sucre Market	-2,7325408	-78,854067	-0,7322	0,8007
Mayorista Market	-2,7574255	-78,8460513	0,1544	-1,9534
San Francisco Market	-2,7438991	-78,8466508	0,0905	-0,4572

Algorithm 1. Weber

MODEL:

$$MIN = @SQRT((X - PX_1)^2 + (X - PY_1)^2) + @SQRT((X - PX_2)^2 + (X - PY_2)^2) + @SQRT((X - PX_3)^2 + (X - PY_3)^2) + @SQRT((X - PX_4)^2 + (X - PY_4)^2) + @SQRT((X - PX_5)^2 + (X - PY_5)^2);$$

DATA :

$(PX_1 \wedge PY_1) \in CP$; *!Central Park*

$(PX_2 \wedge PY_2) \in RFM$; *!Recinto Ferial Market*

$(PX_3 \wedge PY_3) \in SM$; *!Sucre Market*

$(PX_4 \wedge PY_4) \in MM$; *!Mayorista Market*

$(PX_5 \wedge PY_5) \in SFM$; *!San Francisco Market*

END DATA

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$@FREE\ (X);$
$@FREE\ (Y);$

END

With the processing of algorithm 1, with two non-linear variables and a time of 0.04s out of a total of 9 iterations, we obtain a central marketing point for meat products at the coordinates $(-0{,}377858, -0{,}3002386)$ [Figure 1].

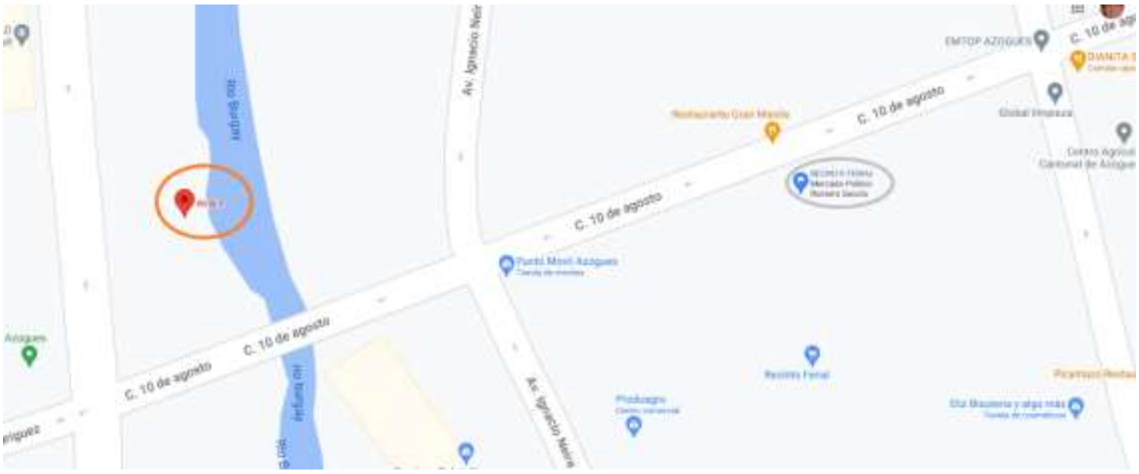

Figure 1. Weber's Solution for the Optimal Distance for the Marketing of Meat

Although we obtain the most optimal location with Weber, a new location must be made for marketing, so with the p-median method, the infrastructure of the four existing markets, the distances between them, and the demands are considered.

Table 2. Distances Between the Central Park of the City of Azogues and the Meat Marketing Places

Place	Central Park	Recinto Ferial Market [km]	Sucre Market [km]	Mayorista Market [km]	San Francisco Market [km]
Central Park	--	0,776	1,085	1,959	0,466
Recinto Ferial Market	0,776	--	0,974	1,999	0,893
Sucre Market	1,085	0,974	--	2,893	1,503
Mayorista Market	1,959	1,999	2,893	--	1,497
San Francisco Market	0,466	0,893	1,503	1,497	--

Table 3. Amount of Meat Production Offered in the Markets of the City of Azogues

Product	Recinto Ferial Market [kg]	Sucre Market [kg]	Mayorista Market [kg]	San Francisco Market [kg]
Beef	308	264	396	220
Pork meat	319	275	407	231
Chicken meat	330	286	418	242
Sausage	341	297	429	253
subtotal	1298	1122	1650	946

Algorithm 2. P- Mediana

MODEL:

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$$MIN = (\overline{RFM \wedge CP} \times dem(RFM) \times Y1RFM) + (\overline{RFM \wedge SM} \times dem(SM) \times Y2RFM)$$
$$+ (\overline{RFM \wedge MM} \times dem(MM) \times Y3RFM)$$
$$+ (\overline{RFM \wedge SFM} \times dem(SFM) \times Y4RFM)$$
$$+ (\overline{SM \wedge CP} \times dem(SM) \times Y1SM) + (\overline{SM \wedge RFM} \times dem(RFM) \times Y2SM)$$
$$+ (\overline{SM \wedge MM} \times dem(MM) \times Y3SM)$$
$$+ (\overline{SM \wedge SFM} \times dem(SFM) \times Y4SM)$$
$$+ +(\overline{MM \wedge CP} \times dem(MM) \times Y1MM)$$
$$+ (\overline{MM \wedge RFM} \times dem(RFM) \times Y2MM)$$
$$+ (\overline{MM \wedge SM} \times dem(SM) \times Y3MM)$$
$$+ (\overline{MM \wedge SFM} \times dem(SFM) \times Y4MM)$$
$$+ (\overline{SFM \wedge CP} \times dem(SFM) \times Y1SFM)$$
$$+ (\overline{SFM \wedge RFM} \times dem(RFM) \times Y2SFM)$$
$$+ (\overline{SFM \wedge SM} \times dem(SM) \times Y3SFM)$$
$$+ (\overline{SFM \wedge MM} \times dem(MM) \times Y4SFM);$$

$$Y1RFM + Y2RFM + Y3RFM + Y4RFM +$$
$$Y1SM + Y2SM + Y3SM + Y4SM +$$
$$Y1MM + Y2MM + Y3MM + Y4MM +$$
$$Y1SFM + Y2SFM + Y3SFM + Y4SFM = 1;$$

$$RFM + SM + MM + SFM = 1\,;$$
$$@BIN\ (Y1RFM); @BIN\ (Y2RFM); @BIN\ (Y3RFM); @BIN\ (Y4RFM);$$
$$@BIN\ (Y1SM); @BIN\ (Y2SM); @BIN\ (Y3SM); @BIN\ (Y4SM);$$
$$@BIN\ (Y1MM); @BIN\ (Y2MM); @BIN\ (Y3MM); @BIN\ (Y4MM);$$
$$@BIN\ (Y1SFM); @BIN\ (Y2SFM); @BIN\ (Y3SFM); @BIN\ (Y4SFM);$$

END

Based on the results of the Weber problem and those of the p-median, it is evident that it should marketed in the Recinto Ferial Market (RFM), with just 115m distance from the optimal location.

These two variables of Euclidean distance and quantity of products will affect the variable cost of users and producers, which is why the use of the traveling agent method is proposed, which allows for an optimal delivery route of the meat to the markets and thus reduces said values. The route between markets is toke as an additional variable [Table 4].

Table 4. Vehicle Tour Between Markets in the City of Azogues

	Recinto Ferial Market [km]	Sucre Market [km]	Mayorista Market [km]	San Francisco Market [km]
Recinto Ferial Market	0	1,6	2,1	0,9
Sucre Market	1,6	0	3,2	2,2
Mayorista Market	2,1	3,2	0	1,7
San Francisco Market	0,9	2,2	1,7	0

Algorithm 3. Travel Agent

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$$MIN = (\overline{RFM \wedge RFM} \times R11) + (\overline{RFM \wedge SM} \times R12) + (\overline{RFM \wedge MM} \times R13) + (\overline{RFM \wedge SFM} \times R14) + (\overline{SM \wedge RFM} \times R21) + (\overline{SM \wedge SM} \times R22) + (\overline{SM \wedge MM} \times R23) + (\overline{SM \wedge SFM} \times R24) + (\overline{MM \wedge RFM} \times R31) + (\overline{MM \wedge SM} \times R32) + (\overline{MM \wedge MM} \times R33) + (\overline{MM \wedge SFM} \times R34) + (\overline{SFM \wedge RFM} \times R41) + (\overline{SFM \wedge SM} \times R42) + (\overline{SFM \wedge MM} \times R43) + (\overline{SFM \wedge SFM} \times R44);$$

$R11 + R12 + R13 + R14 = 1;$
$R21 + R22 + R23 + R24 = 1;$
$R31 + R32 + R33 + R34 = 1;$
$R41 + R42 + R43 + R44 = 1;$

$R11 + R21 + R31 + R41 = 1;$
$R12 + R22 + R32 + R42 = 1;$
$R13 + R23 + R33 + R43 = 1;$
$R14 + R24 + R34 + R44 = 1;$

$R12 + R21 \leq 1; R13 + R31 \leq 1; R14 + R41 \leq 1;$
$R23 + R32 \leq 1; R24 + R42 \leq 1;$
$R34 + R43 \leq 1;$

$R11 + R22 + R33 + R44 \leq 0;$

$@BIN\ (R11); @BIN\ (R12); @BIN\ (R13); @BIN\ (R14);$
$@BIN\ (R21); @BIN\ (R22); @BIN\ (R23); @BIN\ (R24);$
$@BIN\ (R31); @BIN\ (R32); @BIN\ (R33); @BIN\ (R34);$
$@BIN\ (R41); @BIN\ (R42); @BIN\ (R43); @BIN\ (R44);$

END

By modeling the 16 possible combinations of the four markets in a processing time of 0.04s, we obtain that the transport should go from the Sucre Market to the Mayorista Market, followed by the San Francisco Market. Once this route is finished, the algorithm suggests that transportation leaves from the Recinto Ferial Market to the Sucre Market, thus reducing transportation costs by 7.9%.

Algoritmo 4. Vehicle Routing

$$MIN = (\overline{RFM \wedge RFM} \times R11) + (\overline{RFM \wedge SM} \times R12) + (\overline{RFM \wedge MM} \times R13) + (\overline{RFM \wedge SFM} \times R14) + (\overline{SM \wedge RFM} \times R21) + (\overline{SM \wedge SM} \times R22) + (\overline{SM \wedge MM} \times R23) + (\overline{SM \wedge SFM} \times R24) + (\overline{MM \wedge RFM} \times R31) + (\overline{MM \wedge SM} \times R32) + (\overline{MM \wedge MM} \times R33) + (\overline{MM \wedge SFM} \times R34) + (\overline{SFM \wedge RFM} \times R41) + (\overline{SFM \wedge SM} \times R42) + (\overline{SFM \wedge MM} \times R43) + (\overline{SFM \wedge SFM} \times R44);$$

$R11 + R12 + R13 + R14 = 1;$
$R21 + R22 + R23 + R24 = 1;$
$R31 + R32 + R33 + R34 = 1;$
$R41 + R42 + R43 + R44 = 1;$

$R11 + R21 + R31 + R41 = 1;$
$R12 + R22 + R32 + R42 = 1;$
$R13 + R23 + R33 + R43 = 1;$
$R14 + R24 + R34 + R44 = 1;$

$R12 + R21 \leq 1; R13 + R31 \leq 1; R14 + R41 \leq 1;$
$R23 + R32 \leq 1; R24 + R42 \leq 1;$
$R34 + R43 \leq 1;$

$R11 + R22 + R33 + R44 \leq 3;$! Number of vehicles to use;

$@BIN\ (R11); @BIN\ (R12); @BIN\ (R13); @BIN\ (R14);$
$@BIN\ (R21); @BIN\ (R22); @BIN\ (R23); @BIN\ (R24);$
$@BIN\ (R31); @BIN\ (R32); @BIN\ (R33); @BIN\ (R34);$
$@BIN\ (R41); @BIN\ (R42); @BIN\ (R43); @BIN\ (R44);$

END

Once the algorithm has been executed, the results indicate that only two vehicles should be used for the most efficient marketing of meat products, using the following route. You must leave from Sucre Market, go to San Francisco Market, then to the Recinto Ferial Market, and finally return to Sucre Market. Additionally, due to the variables of quantity and cost efficiency, it is mathematically recommended that a single independent vehicle be used in Mayorista market.

Conclusions

Based on applying optimal infrastructure location algorithms, optimal marketing locations are obtained for the distribution of meat considering the variables distance, route, distribution cost, supply and demand of products, and geographic location.

With the minimization of the Weber equation, the distances to a central marketing point are minimized; however, as it is a space without existing infrastructure, a platform that serves for marketing can be created or occupy a space that is 115m from the optimal place, being strengthened and validated through the p-median algorithm.

Applying the travel agent algorithm achieves a sequential route, but having to return to start again to finish the marketing to a place is necessary to work with other vehicles.

By modeling the traveling agent algorithm and proposing three vehicles, it obtained that mathematically, two cars are enough to achieve optimization parameters to distribute meat products.

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