Location Of a Coconut Processing Industry in The Context of The Agri-Food Chain

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Abstract

Location problems remain a practical necessity, despite their extensive theoretical development. The objective of the research is to identify the location of a coconut plant and its derivatives in the context of the Manabí agrifood chain. A procedure for locating a coconut derivatives processing industry was developed using a mathematical model. In the first stage: characterization of the variables of the value chain, it helps to determine the most feasible location of a coconut plant in the province of Manabí. The actors and links in the chain are identified. Along with the description of these. In the second stage: selection of the location method, each location method is analyzed with its risks and potential for decision-making on the location of the coconut derivatives processing plant in the province of Manabí. The methods selected for the location of the plant are applied and the one with the highest performance is chosen. The weighted method and center of gravity were selected. In the third stage, the model that best fits the one carried out

was determined, with the objective function of model optimization based on the selected variables, and the information that is counted. Along with the identification of restrictions of the variables of the value chain. The model that bests fits is the p median. Finally, the optimal location of the plant within the agri-food chain is identified. As a result of the application of the methodology, the location of the plant in the town of Sosote was obtained, an element that demonstrates the practical-methodological application of the research.

Keywords
Location, mathematical model, center of gravity, weighted factors.

1. Introduction
The location of facilities is a strategic decision within the agrifood chain (Z. Li, Zhao, & Han, 2022; Stadtler et al., 2015). Due to the importance that affects logistics costs and opportunities to offer a better level of customer service. For this reason, the investigations have been varied due to their objectives and decisions to be made.

For example, the study by (González-Solano, Escorcia-Caballero, & Patiño-Toledo, 2017) where the location of a consolidation center is determined with the goal of minimizing costs and risks in the chain. Other authors are based on the geographical coordinates of different actors but in this case for the identification of the location of the collection center and a route proposal (Martínez-Flores & Santana-Robles, 2017). This last study is applied in an agri-food chain. On the other hand, there are complex studies such as the one by (Díaz, Luna, Camacho-Vallejo, & Casas-Ramírez, 2017) that are based on hybrid heuristics to solve a location problem, in this case related to the maximum coverage of the order of customer preference and with existing facilities. In this context, another example is that of (Farahani, Rezapour, Drezner, Esfahani, & Amiri-Aref, 2015) where a heuristic algorithm is applied for the location of retail facilities and their capacity is taken into account, respectively.

At the same time, there are other studies aimed at locating health centers in a chain of services, with the goal of optimizing human resources (Rodríguez Sánchez, Gómez Figueroa, Diéguez Matellán, De León Rosales, & Rodríguez González, 2016). The authors (Gómez Figueroa, Diéguez Matellán, Rodríguez Sánchez, Sarmentero Bon, & Hernández Pérez, 2020), identify the best locations for complementary tourism services based on the Customer Approach Index (IAC) and their attractiveness. In the latter, expert methods, Delphi method, survey and non-probabilistic sampling. At the same time, there are classic methods that solve these location problems such as: center of gravity, weighted factors, Gibson and Brown method, linear programming methods (Diéguez Matellán et al., 2017). solution forms. This fundamentally depends on the data available and the researcher's expertise. Therefore, in this article the objective is to identify the location of a possible location for the installation of a processing plant for coconut derivatives in the context of the coconut agri-food chain in the province of Manabí, through the methods of weighted factors and the center of gravity, together with the systematization of an existing mathematical model.

This was developed within the framework of the project as part of the Circular value networks project as sustainability alternatives in Latin America and the Caribbean (Ecuador, Mexico and Cuba). The investigation of (Romero Delgado, Rosado Zambrano, Sablón Cossío, & Burbano Mera, 2020) was carried out aimed at the diagnosis of the coconut agri-food chain in the province of Manabí. In relation to the baseline raised in the aforementioned research, the study was carried out by (Cedeño-Aguirre & Flecha-López, 2021), the basis of this research.

1.1 Context of the coconut sector in Ecuador
According to the Ministry of Agriculture and Livestock of Ecuador, the production of coconut palm or coconut palm, concentrates its exploitation in four provinces of Ecuador: Esmeraldas, Manabi, Guayas and Loja. According to statistical data, the volume of production is established in the following range: 77.26% in the province of Esmeraldas, 18.72% in the province of Manabí and the provinces of Guayas and Loja with 4.02%. In turn, it is indicated that, through statistical data, the province of Esmeraldas is the one with the highest concentration in crop production. Until the end of 2017, "the cultivated area amounted to 4011 hectares throughout the province", where annual sales are also established (MAGAP, 2019).

Regarding the adequate conditions for the exploitation of coconut fruit, the ideal region is the coast, where according to the statistical average (INEC, 2018), around 3,508 tons of coconuts are produced annually. The percentage of coconut production in Manabí is 15% of the production in the coastal area of Ecuador (Ocampo Harb, 2019).

2. Methodologies and method

This research is field and quantitative (Hernández Sampieri, Fernández Callado, & Baptista Lucio, 2015). A procedure for the location of a coconut derivatives processing industry was developed using a mathematical model.

Stage 1: Characterization of the variables of the value chain, helps to determine the most feasible location of a coconut plant in the province of Manabí. The methodology of (Cañadas Salazar & Sablón Cossio, 2019) is followed, where the actors and links of the chain are identified. Along with the description of these. These were recorded in the research by Romero and Rosado (Romero Delgado et al., 2020).

Stage 2: Selection of the location method, each location method is analyzed with its risks and potentialities for the decision making of the location of the coconut derivatives processing plant in the province of Manabí. The methods selected for the location of the plant are applied and the one with the highest performance is chosen. The weighted method (Y. Li & Saracoglu, 2021) and center of gravity (Xiang et al., 2017) were selected.

Stage 3: Determination of the model that best fits the one carried out, with the objective function of optimization of the model based on the selected variables, and the information that is counted. Along with the identification of restrictions of the variables of the value chain. The model that best fits is the p-median (Taha, 2012).

Stage 4: Identify the optimal location of the plant within the agri-food chain.

3. Results

It began with the mapping of the coconut sector in Manabí (Romero Delgado et al., 2020). Different actors were identified in the value chain, which is classified as: producers, merchants, sellers and manufacturers; made up of 156 actors distributed as follows: 77 sellers, 36 producers, 35 merchants and 8 manufacturers. In relation to the forecast of the demand for coconut and its derivatives in the value chain of the study, the total consumption of the fruit was identified with a value of 4,231,870. This product has several destinations: Manabí, Guayaquil, Machala, Quevedo, Ambato, Cuenca, Quito and Esmeralda.

Two methods are estimated: weighted factors and center of gravity. At the same time, the connectivity of highways that lead to different large cities, both within the province and those in nearby provinces, was taken into account. This in relation to consumers of coconut and its by-products.

3.1 The weighted method

The comparison was made with the different cantons of Manabí. This to a different extent, many of these cantons have a participation in the coconut value chain, so the following factors were chosen as determinants to be able to implement a coconut processing factory. It is determined:

• Communication and Transportation (A): Good Road communication and ease of transportation are needed for any type of business, so a weight of 0.25 was given to this factor.

• Public services (B): The processing plant needs to take advantage of the high volumes of production in nearby areas, so it is essential to have good public services such as electricity and water. This factor was given a weight of 0.20.

• Climatological characteristics (C): The climate can have a positive or negative influence on the work, whether it is cold or heat or very humid or dry environments, for which a weight of 0.1 was given to this factor.

• Raw material and other supplies (D): The different machinery that a plant requires, require spare parts in case of failure and to avoid long production stops, it is necessary to be able to find the required parts in nearby places, this factor has a weight of 0 .05.

• Variety of suppliers (E): The location of the processing plant needs to be able to take advantage of the greatest possible number of producers to handle large volumes of processed material, which is why it requires having the greatest number of suppliers in nearby areas, for so this factor has a weight of 0.3.

• Availability of labor (G): It is required that the staff can quickly and easily reach the facilities, being these people who live in nearby areas or take small trips to get to work, so this factor has a weight of 0.1.

It is obtained as a result, Table 1.

Table 1: Weighted Factors Method.

N°	Possible location	A	B	C	D	E	G	TOTAL
		0,25	**0,2**	**0,1**	**0,05**	**0,3**	**0,1**	**1**
1	TOSAGUA	7	6	8	6	8	7	
		1,75	1,2	0,8	0,3	2,4	0,7	**7,15**
2	CHONE	7	7	8	6	6	7	
		1,75	1,4	0,8	0,3	1,8	0,7	**6,75**
3	PEDERNALES	8	6	8	7	10	8	
		2	1,2	0,8	0,35	3	0,8	**8,15**
4	PUERTO LÓPEZ	5	5	8	5	6	5	
		1,25	1	0,8	0,25	1,8	0,5	**5,6**
5	PAJÁN	6	5	8	6	6	6	
		1,5	1	0,8	0,3	1,8	0,6	**6**
6	JIPIJAPA	6	7	7	7	5	8	
		1,5	1,4	0,7	0,35	1,5	0,8	**6,25**
7	OLMEDO	6	7	7	6	4	7	
		1,5	1,4	0,7	0,3	1,2	0,7	**5,8**
8	SANTA ANA	7	7	8	7	5	8	
		1,75	1,4	0,8	0,35	1,5	0,8	**6,6**
9	24 DE MAYO	6	5	8	5	5	6	
		1,5	1	0,8	0,25	1,5	0,6	**5,65**
10	BOLÍVAR	6	6	7	5	4	6	
		1,5	1,2	0,7	0,25	1,2	0,6	**5,45**
11	JUNÍN	6	6	8	6	7	7	
		1,5	1,2	0,8	0,3	2,1	0,7	**6,6**
12	EL CARMEN	8	6	7	7	5	7	
		2	1,2	0,7	0,35	1,5	0,7	**6,45**
13	FLAVIO ALFARO	5	6	7	5	5	5	
		1,25	1,2	0,7	0,25	1,5	0,5	**5,4**
14	PICHINCHA	6	5	7	6	3	6	
		1,5	1	0,7	0,3	0,9	0,6	**5**
15	SUCRE	6	6	7	6	8	6	
		1,5	1,2	0,7	0,3	2,4	0,6	**6,7**
16	JAMA	6	5	8	4	8	5	
		1,5	1	0,8	0,2	2,4	0,5	**6,4**
17	SAN VICENTE	7	6	8	5	7	6	
		1,75	1,2	0,8	0,25	2,1	0,6	**6,7**
18	MANTA	10	6	6	8	5	8	
		2,5	1,2	0,6	0,4	1,5	0,8	**7**
19	MONTECRISTI	8	6	8	7	5	8	
		2	1,2	0,8	0,35	1,5	0,8	**6,65**
20	JARAMIJÓ	8	6	7	8	5	8	
		2	1,2	0,7	0,4	1,5	0,8	**6,6**
21	ROCAFUERTE	8	7	9	7	10	8	
		2	1,4	0,9	0,35	3	0,8	**8,45**
22	PORTOVIEJO	9	7	8	8	9	8	
		2,25	1,4	0,8	0,4	2,7	0,8	**8,35**

The Pedernales canton uses part of its production to supply the demand for coconut from nearby towns belonging to the province of Esmeraldas, but its contribution to the coconut sector in Manabí is not as great compared to the cantons of Rocafuerte and Portoviejo, for which the location more convenient to establish a coconut processing factory, it must be close to Portoviejo and Rocafuerte.

Places are chosen that can be used by large producers and coconut trade between cantons, such as:

• The Sosote area, which is located between the cantons of Portoviejo and Rocafuerte, does not require traveling long distances to collect raw material, nor is it a very distant place for merchants who need processed products; on the other

hand, it is It is located near a main highway, which connects with exits to the city of Manta and also has a fast connection to send orders to the cities of Guayaquil in the south and Santo Domingo and Quito in the north.

• In the Pedernales canton, in the Cojimíes sector, there is an area of high coconut production, which supplies coconuts to the main traders and manufacturers in nearby areas. The coconuts are also taken to larger and closer cities such as Santo Domingo and Quito, in the same way its large volume of production allows shipments to more distant cities such as Guayaquil, although due to its location, it is separated from the large coconut trade that is carried out in the central zone of the province, in addition to being a distant point for the transport of its processed matter

• The area located between the canton of Rocafuerte and Tosagua, which can collect the production of raw material that is produced in the surroundings of Tosagua, especially in the La Sabana sector. It is close to the merchants, so it does not require long transportation to reach the marketing points. It is far from the coconut productions of the north of Manabí, but close to small productions of other nearby cantons, and has roads connected to cities such as Portoviejo, Manta, Guayaquil, Santo Domingo and Quito.

3.2 Center of gravity method

The center of gravity method is applied, where the ideal location for the installation of a coconut derivatives processing plant in the province of Manabí is determined. Table 2 shows the results of the producers, these same calculations were made for the rest of the links and actors of the chain under study.

Table 2: Coordinates of each actor with their respective distances and time depending on the possible places of location

UBICACION	COORDENADAS		UBICACIÓN #1 SECTOR SOSOTE		UBICACIÓN #2 SECTOR LA RECTA		UBICACIÓN #3 CANTON PEDERNALES	
	X	Y	DISTANCIA (km)	TIEMPO (min)	DISTANCIA (km)	TIEMPO (min)	DISTANCIA (km)	TIEMPO (min)
TOSAGUA	-0,730183	-80,20227	41	38	29,8	28	155	2 h 6
	-0,783244	-80,233656	37,8	37	26,5	26	160	2 h 13
	-0,764538	-80,211855	40,3	37	29,1	27	156	2 h 8
CHONE	-0,69651	-80,122722	56,5	52	58,7	1 h 7	152	2 h 8
	-0,707949	-80,171986	55,6	51	44,4	41	145	1 h 58
	-0,704595	-80,113131	60,8	1h	49,6	49	156	2h17
	-0,695169	-80,120988	56,5	52	58,7	1 h 7	152	2 h 8
PEDERNALES	0,266749	-80,030882	195	2 h 49	191	2 h 45	27,1	29
	0,219143	-80,026281	190	2 h 45	131	1 h 53	21,9	25
JIPIJAPA	-1,343344	-80,733263	89,2	1 h 24	100	1 h 35	251	3 h 58
SANTA ANA	-1,207395	-80,365082	35	50	45,8	1h1	206	3h25

24 DE MAYO	-1,365997	-80,390283	59,1	1 h 16	69,9	1 h 26	230	3 h 53
JAMA	-0,197819	-80,266711	137	2 h 6	132	2 h	53,4	47
	0,338924	-79,973622	231	3 h 20	227	3 h 17	61,3	59
ROCAFUERTE	-0,953726	-80,470579	1,2	2	10,9	15	172	2 h 33
	-0,946222	-80,460302	2,1	3	9,2	11	173	2 h 33
	-0,967379	-80,429353	14,1	17	14,2	18	179	2 h 40
	-0,962662	-80,450193	5,1	11	10,8	18	175	2 h 45
	-0,979418	-80,441492	9,8	13	12,4	18	177	2 h 44
	-0,907073	-80,478346	5,8	11	10,1	14	170	2 h 36
	-0,905614	-80,473453	8,2	13	8,7	10	166	2 h 30
	-0,884672	-80,460582	12,6	17	8,7	8	176	2 h 36
	-0,955602	-80,466706	2,3	4	13,2	14	174	2h31
	-0,957806	-80,464756	2,3	5	13,2	15	174	2h31
	-0,957652	-80,464756	2,3	6	13,2	16	174	2h31
	-0,957806	-80,464713	2,3	7	13,2	17	174	2h31
	-0,921987	-80,444733	5,8	8	5,6	7	170	2h34
	-0,923777	-80,450922	5,8	8	5,6	7	170	2h34
	-0,923507	-80,450798	5,8	8	5,6	7	170	2h34
PORTOVIEJO	-1,00798	-80,173969	37,4	1 h 7	40,6	1 h 11	205	3 h 38
	-1,030178	-80,241907	37,4	1 h 7	40,6	1 h 11	205	3 h 38
	-1,039226	-80,294357	30,5	42	33,7	45	198	3 h 14
	-1,039226	-80,294357	30,5	42	33,7	45	198	3 h 14
	-1,016147	-80,387626	17	20	20,2	25	185	2 h 51
	-1,012577	-80,373074	19,7	27	38,1	47	190	2 h 53
	-0,981502	-80,444357	9,3	11	12,9	20	181	2 h 38

The center of gravity method was applied, where the coordinates (-0.88785626, -80.4245467) were obtained, which indicate that the optimal place for the implantation of a coconut processing plant would be near the La Recta sector. Which is a parish of the Rocafuerte canton. This result is due to the fact that a large number of coconut producers and traders gather in this area, who also sell to distant cantons and even other provinces.

The information obtained from the result of the center of gravity method partially coincides with the results of the weighted method, in which it could already be observed that the most favored locations are those around the Rocafuerte canton. Implementing a coconut processing plant would allow us to have raw material from large productions in sectors such as: Rio Chico, Tosagua, Portoviejo, relatively nearby cantons, which would allow savings in fuel and coconut transportation, since most of the areas production companies are minutes from the La Recta sector. Due to its proximity to merchants and sellers of coconut by-products, deliveries could be made quickly, and its location on a main highway would allow shipments to distant cities such as Santo Domingo, Quito or Guayaquil.

The possible places within the method of weighted factors are obtained taking into account the characteristics of communication and transportation, public services, climatological characteristics, raw material - other supplies, variety of suppliers and availability of labor, to optimize time and minimize transportation costs. While the possible

location of a coconut derivatives processing plant using the center of gravity method takes into account its coordinates and volumes of coconut, to define a strategic location within the value chain.

The different cantons and parishes produce a quantity of coconut according to the existing demand within them, but in some cases, their production is large enough to supply the demand of more distant towns or cantons, as is the case of Rocafuerte, Portoviejo. and Pedernales, according to the results of the weighted factors method, these cantons usually take the raw material to their vendors and merchants who are distributed in other cantons.

Although the 3 sites chosen for the possible location of a plant have a large coconut trade, having large producers in surrounding areas, 2 of the 3 places have a greater influence within the value network of Manabí, due to that are close to large, medium and small merchants, at the same time, their location in the center of the province, allows them to take advantage of the coconut production of smaller cantons.

The most suitable location according to the center of gravity method is a sector with coordinates (-0.88785626, -80.4245467), near La Recta de Rocafuerte, where it is possible to take advantage of the fact that most of the actors are located in this locality and due to its proximity to the most productive rural sectors of coconut in the central area of Manabí.

The results of the method of weighted factors indicate the importance of the variety of producers when making the location decision, which is why the cantons with high production such as Pedernales, Rocafuerte and Portoviejo are the ones with the highest score, however, when executing the center of gravity method, it was noted that there are notable differences in influence within the coconut value chain in Manabí.

3.3 Model definition

To identify a more exact and reliable location to establish a coconut derivatives processing industry, a p-median mathematical model is proposed (Silva & Santos, 2020). Where the actors of production, marketing, manufacturing and sale of the province of Manabí are taken into account.

Sets:

I={1,2,3} set of plants
J={1…n} customer set
Parameters
c_ij= transport costs of customer j
p is the number of plants to open (p=1) 1-median
Decision variables
y_i= 1 if the plant is opened at site i, 0 if not
x_ij= 1 is transported from plant i to customer j; 0 yes no

Model

$$\text{Min} \sum_{i \in I} \sum_{j \in J} c_{ij} x_{ij}$$

Subject to:

$$\sum_{i \in I} y_i = p$$

$$x_{ij} \leq y_i \qquad \forall i \in I, j \in J$$

$$\sum_{i \in I} x_{ij} = 1 \qquad \forall j \in J$$

$$y_i, x_{ij} \in \{0,1\} \qquad \forall i \in I, j \in J$$

With the definition of the mathematical model, obtaining a location, in which the transportation cost is optimized to implement a coconut processing plant in the province of Manabí, where: Yi= 1;0;0; total cost 62446.512, p-value is 1 and open 1.

The optimal location obtained by the mathematical method of p - median is the Sosote sector of the Portoviejo canton of the province of Manabí, where it is possible to install a coconut derivatives processing plant within the value chain. This for being one of the places with the greatest fluidity of coconut in the links of: production, manufacture, marketing and sale. Due to its location on the Manabí Road network, it facilitates commercialization with urban centers in the province, such as Portoviejo, Manta, Rocafuerte, Sucre, among others, which have high levels of consumption of coconut and its different by-products.

4. Conclusions

The research took as reference plant design information, bibliographic sources that are analyzed for a better understanding of the location term. This in order to implement a coconut processing plant within the value chain in the Ecuadorian context. It was determined that the methods to find the location within a productive sector require a detailed study of the characteristics of said value network. Which must include from actors, costs, locations and all the possible factors that intervene in the production and commercialization process, since many methodologies are restricted to various variables so that their results are accurate and the most functional for a possible company. From the analysis of the data collected in an investigative way, different sectors were found suitable for the implementation of a processing plant for coconut derivatives, which exploits local resources and surrounding areas. With the elaboration of a mathematical model, the identification of a possible location of the coconut processing plant was achieved, which resulted in the Portoviejo canton, Sosote sector. From this study, the project continues with the study of the production processes of the plant. This together with a market and feasibility study to choose the products to be produced and marketed by the agri-food chain.

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