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Study for the Optimal Location of Bitcoin Automatic Teller Machines (BTM) through Operations Research

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Abstract

The main objective of this research was to find optimal locations for the installation of Bitcoin ATMs (BTM) through operations research tools, to help increase the economic income of the company La Bitcoinera. First, the population sample of possible locations was defined as 23 shopping centers in the central district in Honduras, Central America, specifically 12 in Tegucigalpa and 11 in Comayagüela, which were identified by convenience sampling due to the difficulty in obtaining the required information.

Next, the variables to be used in the formula of the center of gravity method were selected with the help of data collection from similar studies and a survey, deciding to use the variables of rental cost, influx of people and the geographical coordinates of each possible location.

Then, applying the center of gravity method, optimal locations were found in Tegucigalpa and Comayagüela for the installation of two BTM's. After several iterations of calculations, it resulted that the closest shopping centers to the optimal locations are Paseo Juan Pablo located in Tegucigalpa and the Metromall shopping center located in Comayagüela.

Subsequently, the proposed locations mentioned above were validated by comparing the current and projected incomes, resulting in the suggested locations considered being feasible for La Bitcoinera because they would generate more income.

Keywords—Operations Research, Feasibility, Center of Gravity Method, Influx of People, Optimal Location.

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I. INTRODUCTION

In an increasingly competitive economy, analyzing the optimal location can be one of the key factors that determines the survival of a company. To identify this factor, various research tools are usually used to identify and analyze different variables.

In relation to the above, in 2014, in Guatemala, a study was carried out to choose the optimal location of a certain business in development, it is mentioned that different methods can be used, including the center of gravity method, although for the author it is not the optimal option but a starting point. It mentions that this method, combined with the load-distance method, could guarantee that the proposed location also has the minimum transport cost [1].

On the other hand, and regarding the nature of cryptocurrencies, their operation and their adoption as a transaction unit, this type of exchange unit is increasingly a recurring theme, and has been accepted and implemented in different economies.

Particularly in Honduras as of August 2021 La Bitcoinera is the first and only company that made available to the public the service of buying and selling cryptocurrencies such as Bitcoin through its Bitcoin ATMs or BTM, starting with a BTM at its headquarters located in the Torre Morazán business center, in Tegucigalpa and then expanding the same year with two more BTMs in Tegucigalpa, one in San Pedro Sula and one in La Ceiba; In the very particular case of this company the decisive factor in the choice of these locations was the availability of space rather than an investigation [2]. And since the company wants to continue growing with more BTMs, it needs a proper study to find suitable locations.

The present research used a quantitative approach and a case study scope because in Honduras, La Bitcoinera is the only company dedicated to the purchase and sale of Bitcoins in ATMs. Regarding the sample, it was defined through a non-probability sampling by convenience and then the Center of Gravity Method was applied as an Operations Research tool to find the optimal locations in Tegucigalpa and Comayagüela for the company according to the defined characteristics.

The following chapters of this article will address the methodology of the research, the results together with their analysis and conclusions; developing with the content the process to achieve the general objective of the research, which consisted of proposing optimal locations for the installation of Bitcoin ATMs (BTM) of the company in question, that help increase income and economic growth through the use of Operations Research tools.

II. METHODOLOGY

A. Research Type

1) Approach: The research was based on the quantitative approach as it focuses on numerical measurements and uses the observation of the process for data collection and then analyzes them through statistics, in order to answer the research questions [3].

2) Scope: It was decided to use case study type research since it is a problem with a unique particularity and complexity, from which you will learn and have an important interest in solving it [4]. This is the case with this research since La Bitcoinera is the only company in Honduras with BTM service, making it a special case, although it has some similarities with ATM banking services.

B. Research Variables

1) Possible Locations: It refers to those locations that apparently meet the characteristics requested by La Bitcoinera and that were analyzed in the investigation to determine if they can become optimal locations or not.

2) Optimal Locations: They are those locations found through the tools used, which have the necessary characteristics for the proper functioning of the BTMs established by La Bitcoinera, while minimizing operating costs.

3) Operational Costs: The cost that must be covered obligatorily for BTMs to function properly in a safe place; including the rental of the space where it is installed, basic services such as electricity and internet, transportation cost and labour for its installation on site.

4) Influx of Potential Clients: Number of people circulating or passing through the location where the BTM would be installed.

5) Completed Transactions: Number of transactions made at BTMs, including the buying and selling of cryptocurrencies.

6) Current Income: Amount of income that La Bitcoinera receives for the transactions made in the BTMs that it currently owns.

7) Projected Income: Amount of income that La Bitcoinera can receive by installing BTMs in the locations found with this research.

C. Population and Sample

1) Population: 23 shopping centers, 12 located in the city of Tegucigalpa and 11 in the city of Comayagüela, which provide the service of renting physical spaces of at least one square meter (1.00 m2) with access to an electrical connection for the installation of a BTM.

2) Sampling: Non-probability sampling by convenience was used, since access to the required information from shopping centers was limited, and there was no access to public lists or databases nor could it be confirmed if these databases had exact records on the number of shopping centers in Tegucigalpa and Comayagüela. Therefore, the registration and

documentation were carried out directly by contact with the identified shopping centers. However, it was decided that the total identified universe accessed (population) would be defined as the analysis sample.

3) Sample: 23 shopping centers, 12 located in the city of Tegucigalpa and 11 in the city of Comayagüela, which provide the service of renting physical spaces of at least one square meter (1.00 m2) with access to an electrical connection for the installation of a BTM.

D. Applied Tools

1) Collection of Published Scientific Studies: In order to achieve the first specific objective, that consisted of carrying out the documentary analysis, various scientific databases were used to find studies in which variables and similar tools were analyzed, and then those studies were used as a reference to define the characteristics of the possible locations.

2) Survey Application: Additionally, a survey was applied to the general public and established customers of La Bitcoinera as a complement to the previous tool to identify other possible characteristics or confirm those that were previously found.

3) Center of Gravity Method: In order to find optimal locations for the BTMs, it was decided that the center of gravity method would be used, which is a technique used for the location of facilities, either production plants or warehouses for subsequent distribution, whose purpose is to reduce transport costs depending on the volume of production, the transport fare and the distance to be travelled; In addition to adjusting to the objectives of the project [5], so it was adaptable for the purpose of this research and find the required locations.

4) Validation: To validate that the locations found with the center of gravity method are feasible for the company, a comparison was made between the current income of the company and the projected income of the new locations found with this research.

III. Results and Analysis

A. Identification of the Variables to Take into Account

1) Collection of Similar Published Scientific Studies: For the identification of the variables to find the locations of the BTMs, information was collected from similar studies in which the center of gravity method or related methods were used, whose objectives were to find one or more locations for production plants, distribution centers, service centers or branches of companies; even if it was not in the same area of the company in this investigation.

The studies found helped to choose the variables to use because they served as a reference after looking at the variables that were used in them, it can be mentioned that in the textbook Business Logistics: Supply Chain Management, the center of gravity method uses a mathematical formula whose variables taken into account are the volume at a point, the transportation fee to send to the point and the distance to the point and all those are equal to the total cost of transportation [6].

Similarly, in an investigation for the location of a distribution center, they take into account the same variables of the center of gravity method mentioned before, but adapted to the case being investigated and is complemented with the Analytic Hierarchy Process. The variables taken into account were, the volume of sales in the company's branches, transport rate to and from each branch, and the distance between each branch, and also taken into account the proximity to national ports and the proximity to national suppliers. [7].

On the other hand, a study that uses the center of gravity method and the Analytic Hierarchy Process (AHP) technique, seeks general and parish collection centers in case of natural disasters, within what is known as Humanitarian Logistics. In this study, the variables are road access, available space, infrastructure resources and travel time [8]. These are some of the keys given by the studies that were found and analyzed to help in the selection of variables, in addition to this, a complementary survey was carried out to find other possible characteristics to take into account.

2) Complementary Survey: A survey was applied to the customers of La Bitcoinera and the general public in order to consult what were for them some characteristics that should be taken into account when choosing the possible locations for BTM ATMs and thus have feedback from users and also as a way to provide a better service from the company. This part of the research focused on the results to two of the questions shown below:

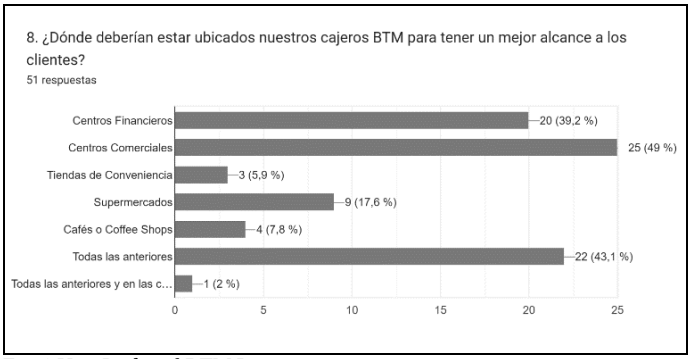

Fig. 1 User Preferred BTM Locations

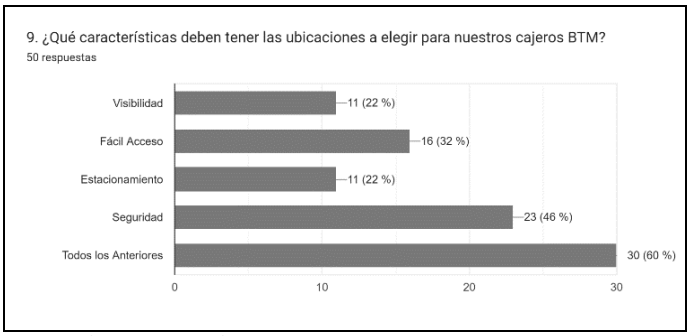

Fig. 2 Preferred Features for BTM Locations

As seen in figures 1 and 2, the majority of respondents chose shopping centers and prioritized location safety over other features, confirming that the choice of population and sample of this research was accurate in using shopping centers as possible locations.

3) Selected Variables: This compilation of studies show that the variables can be adapted to the needs of the research, and from the survey analysis we obtain the following equations of the center of gravity method, that are equivalent to the coordinates (X, Y) of the center of gravity, and the selected values:

$$\bar{X} = \frac{\sum_i V_i R_i X_i}{\sum_i V_i R_i} \quad (1)$$

$$\bar{Y} = \frac{\sum_i V_i R_i Y_i}{\sum_i V_i R_i} \quad (2)$$

Where:

- V_i = Influx of people at the location i.
- R_i = Cost of renting space for the BTM at location i.
- X_i = X-coordinate of location i.
- Y_i = Y-coordinate of location i.

B. Optimal Locations for BTMs through the Center of Gravity Method

1) Identification of Values for the Chosen Variables*:* The values for the variables V_i and R_i were determined through direct consultation with the authorized contacts in the shopping centers part of the population sample; additionally, to find the value of the variables X_i and Y_i, the Google Maps tool was used to find the geographical coordinates of each shopping center in the sample by means of markers on a map of the cities of Tegucigalpa and Comayagüela, as a result the following tables and illustrative maps were obtained:

TABLE I. VARIABLE VALUES CHOSEN FOR TEGUCIGALPA

Tegucigalpa				
	Shopping Center	Monthly Rental Cost in $ (Ri)	Monthly Influx of Customers (Vi)	Latitude and Longitude Coordinates (Google Maps)
0	Torre Morazán (La Bitcoinera)			14.100722, -87.182225
1	Cascadas Mall	1800	630000	14.076507, -87.200733
2	Plaza Santa Mónica Miraflores	900	78000	14.071244, -87.185225
3	Centro Comercial Midence Soto	786	1500000	14.105287, -87.204669
4	Plaza Miraflores	380	600000	14.076740, -87.185916
5	Mall El Dorado	625	240000	14.100108, -87.181967
6	Novacentro	523	180000	14.101552, -87.186594
7	Centro Comercial Centro América	115	33000	14.082934, -87.184956
8	Centro Comercial La Alhambra	500	15000	14.069116, -87.184706
9	Paseo Juan Pablo	403	21000	14.087429, -87.190260
10	Centro Comercial Los Arcos	633	45000	14.100760, -87.177269
11	Plaza Criolla	795.3	72000	14.100464, -87.193158
12	Paseo del Valle	170	6000	14.106255, -87.203032

TABLE II. VARIABLE VALUES CHOSEN FOR COMAYAGÜELA

Comayagüela				
	Shopping Center	Monthly Rental Cost in $ (Ri)	Monthly Influx of Customers (Vi)	Latitude and Longitude Coordinates (Google Maps)
0	City Mall			14.063012, -87.220442
1	Metro Mall	1500	570000	14.074277, -87.212832
2	Plaza Las Hadas	1150	105000	14.041479, -87.232589
3	Plaza Loarque	644	54000	14.045300, -87.211162
4	Ventu Life Center	575	120000	14.059662, -87.227117
5	Plaza La Granja	510	18000	14.083526, -87.208724
6	Plaza Las Torres	1050	6000	14.063573, -87.222634
7	Ameriplaza	180	4500	14.053442, -87.224035
8	Mall Premier	750	1200000	14.104459, -87.234394
9	Plaza La Norteña	490	12000	14.099225, -87.209073
10	Plaza Millenium	150	6000	14.077702, -87.215953
11	Centro Comercial Perisur	350	7500	14.068806, -87.216011

Fig. 3 Map of Possible and Current Locations

On the map, the yellow markers represent the shopping centers located in Tegucigalpa and the purple markers represent those located in Comayagüela, in addition, in Tables I and II, the current location of a functional BTM was included in the first row, so the R_i and V_i values for that location are not shown, but their coordinates obtained from Google Maps are included.

The locations of both cities were taken as independent of each other, in order to perform a calculation of the center of gravity in each city to find two optimal locations for BTMs, that is why the data is kept separated by city. It is important to mention that for each city and its locations the origin of the XY plane was taken as the current location of the BTM in each one, which means that the coordinates (0,0) for Tegucigalpa are located in Torre Morazán and for Comayagüela in City Mall, and for the rest of locations a conversion of the latitude and longitude coordinates into representative values of X_i and Y_i was made through a simple subtraction of the origin coordinate and multiplied by 100 to get values closer to whole numbers. The results obtained are shown in the tables below:

TABLE III. Xi and Yi Coordinates in Tegucigalpa

Tegucigalpa					
	Shopping Center	Latitude (Y)	Longitude (X)	Xi Coordinates	Yi Coordinates
0	Torre Morazán (La Bitcoinera)	14.100722	87.182225	0	0
1	Cascadas Mall	14.076507	87.200733	-1.8508	-2.4215
2	Plaza Santa Mónica Miraflores	14.071244	87.185225	-0.3	-2.9478
3	Centro Comercial Midence Soto	14.105287	87.204669	-2.2444	0.4565
4	Plaza Miraflores	14.076740	87.185916	-0.3691	-2.3982
5	Mall El Dorado	14.100108	87.181967	0.0258	-0.0614
6	Novacentro	14.101552	87.186594	-0.4369	0.083
7	Centro Comercial Centro América	14.082934	87.184956	-0.2731	-1.7788
8	Centro Comercial La Alhambra	14.069116	87.184706	-0.2481	-3.1606
9	Paseo Juan Pablo	14.087429	87.190260	-0.8035	-1.3293
10	Centro Comercial Los Arcos	14.100760	87.177269	0.4956	0.0038
11	Plaza Criolla	14.100464	87.193158	-1.0933	-0.0258
12	Paseo del Valle	14.106255	87.203032	-2.0807	0.5533

TABLE IV. Xi and Yi Coordinates in Comayagüela

Comayagüela					
	Shopping Centers	Latitude (Y)	Longitude (X)	Xi Coordinates	Yi Coordinates
0	City Mall	14.063012	87.220442	0	0
1	Metro Mall	14.074277	87.212832	0.761	1.1265
2	Plaza Las Hadas	14.041479	87.232589	-1.2147	-2.1533
3	Plaza Loarque	14.0453	87.211162	0.928	-1.7712
4	Ventu Life Center	14.059662	87.227117	-0.6675	-0.335
5	Plaza La Granja	14.083526	87.208724	1.1718	2.0514
6	Plaza Las Torres	14.063573	87.222634	-0.2192	0.0561
7	Ameriplaza	14.053442	87.224035	-0.3593	-0.957
8	Mall Premier	14.104459	87.234394	-1.3952	4.1447
9	Plaza La Norteña	14.099225	87.209073	1.1369	3.6213
10	Plaza Millenium	14.077702	87.215953	0.4489	1.469
11	Centro Comercial Perisur	14.068806	87.216011	0.4431	0.5794

2) Center of Gravity Method: Before starting with the calculations to determine the center of gravity, the X_i and Y_i coordinates were graphed in an XY plane to compare with Fig. 3 in order to verify that they have the same behaviour or distribution in terms of the graphed points and the real locations, resulting in the graphs shown below:

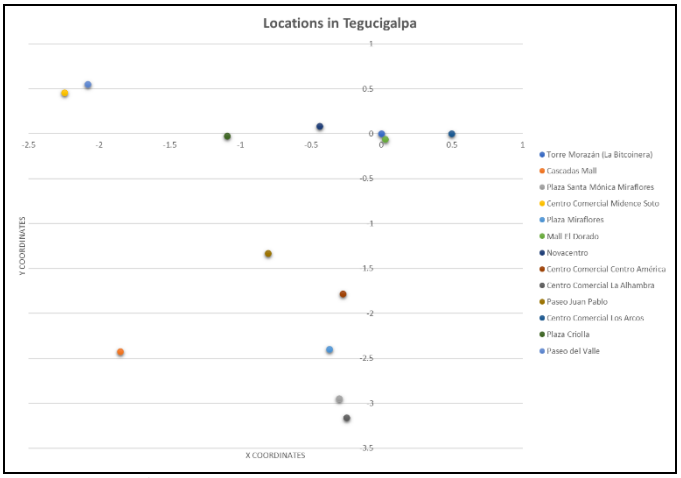

Fig. 4 Graphic of Locations in Tegucigalpa

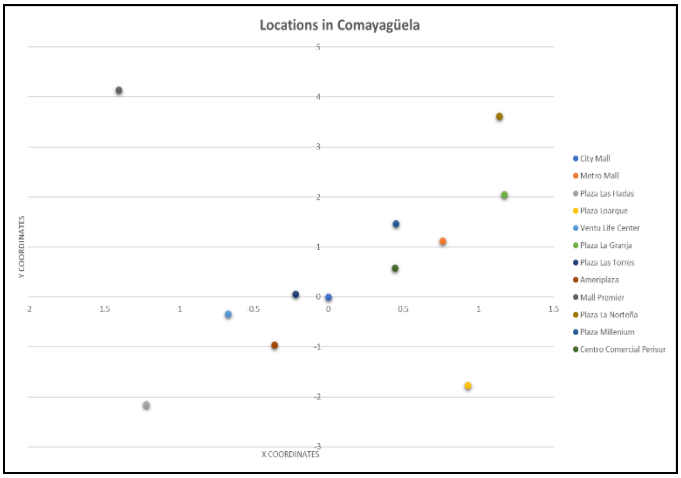

Fig. 5 Graphic of Locations in Comayagüela

Comparing Fig. 3 with Fig. 4 and Fig. 5 it was possible to verify that the X_i and Y_i coordinates used have the same behavior and spatial distribution as the markers placed on the geographical map of both cities and therefore are usable for the calculation of the center of gravity and the result would be reliable to be able to transfer it to a real map and determine the location.

Using equations (1) and (2) the necessary calculations were made with the help of MS Excel to find the $\bar{X}$ and $\bar{Y}$ coordinates, that represent the coordinates of the center of gravity, in addition a table was created with the values of the variables for a better visualization and facilitate the calculation process, the table with the calculations made and the results is shown below:

TABLE V. Center of Gravity Calculations for Tegucigalpa

Calculation Table for Tegucigalpa			
	XiViRi	YiViRi	ViRi
0			
1	-2098807200	-2745981000	1134000000
2	-21060000	-206935560	70200000
3	-2646147600	538213500	1179000000
4	-84154800	-546789600	228000000
5	3870000	-9210000	150000000
6	-41129766	7813620	94140000
7	-1036414.5	-6750546	3795000
8	-1860750	-23704500	7500000
9	-6800020.5	-11249865.9	8463000
10	14117166	108243	28485000
11	-62604107.28	-1477349.28	57261600
12	-2122314	564366	1020000
Sum=	-4947735806	-3005398692	2961864600
	Center of Gravity	X bar=	-1.670480077
		Y bar=	-1.014698205
		Latitude=	14.09057502
		Longitude=	87.1989298
		Latitude and Longitude (Google Maps)	14.090575,-87.198930

TABLE VI. Center of Gravity Calculations for Comayagüela

Calculation Table for Comayagüela			
	XiViRi	YiViRi	ViRi
0			
1	650655000	963157500	855000000
2	-146675025	-260010975	120750000
3	32272128	-61595251.2	34776000
4	-46057500	-23115000	69000000
5	10757124	18831852	9180000
6	-1380960	353430	6300000
7	-291033	-775170	810000
8	-1255680000	3730230000	900000000
9	6684972	21293244	5880000
10	404010	1322100	900000
11	1163137.5	1520925	2625000
Sum=	-748148146.5	4391212655	2005221000
	Center of Gravity	X bar=	-0.373100095
		Y bar=	2.189889621
		Latitude=	14.0849109
		Longitude=	87.224173
		Latitude and Longitude (Google Maps)	14.084911,-87.224173

After performing the calculations for both cities, the $\bar{X}$ and $\bar{Y}$ coordinates were found and in each one, (-1.670480, -1.014698) for Tegucigalpa and (-0.373100, 2.189890) for Comayagüela, then these values were converted to latitude and longitude coordinates to be able to use them in Google Maps and thus visualize it in a clearer way in a geographical map, but first, the position found in the XY plane was graphed to confirm that it was close to the possible locations and then compare it with the location on the geographical map. The graphs for both cities and the reference map are shown below:

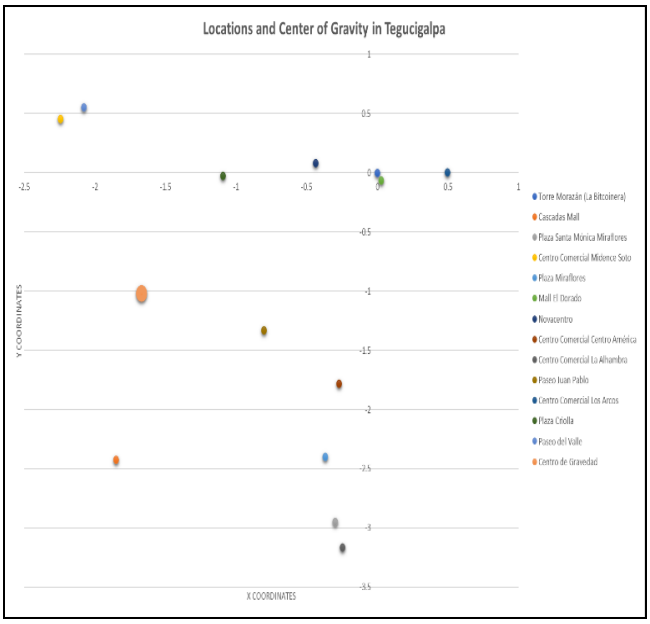

Fig. 6 Locations and Center of Gravity Graph for Tegucigalpa

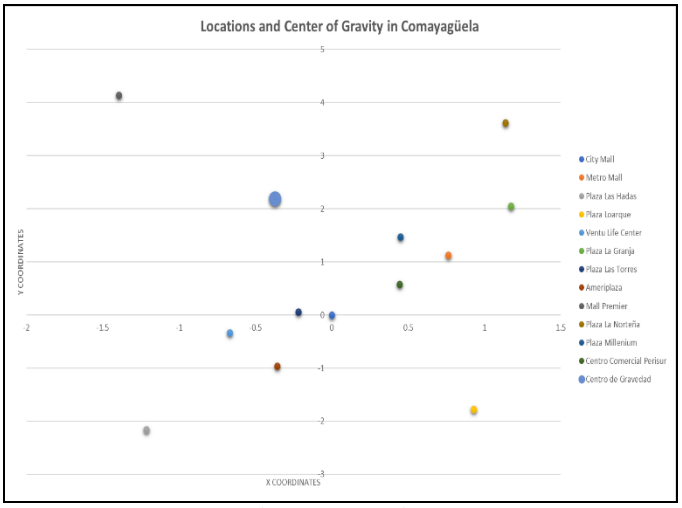

Fig. 7 Locations and Center of Gravity Graph for Comayagüela

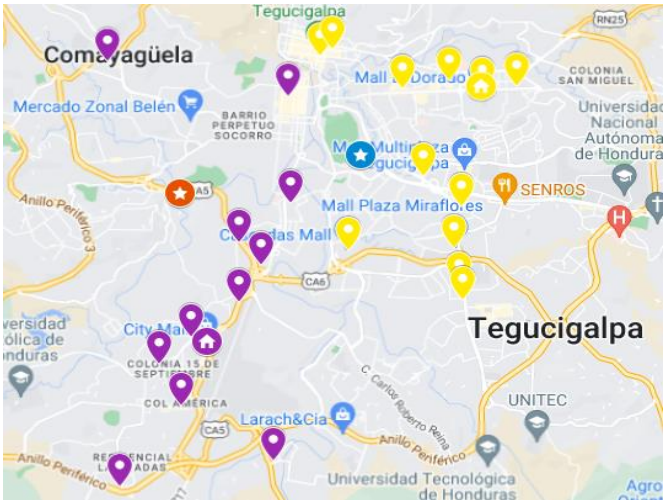

Fig. 8 Map of Locations and Centers of Gravity

The centers of gravity in both cities were represented by a larger point in the graphs of the XY planes and by a marker with a star on the geographical map, with this the first step of the process of the center of gravity method is fulfilled, sometimes the location found is good enough to be considered as optimal, but to ensure that this is the case, the next step of the method, which consists of using an equation to find the distance from the locations to the center of gravity was applied, this equation is shown below:

$$d_i = \sqrt{(X_i - \bar{X})^2 + (Y_i - \bar{Y})^2} \qquad (3)$$

Equation (3) was used for the second step of the center of gravity method, which consists of calculating the distances d_i from the locations to the center of gravity found and then adding those distances in (1) and (2) to form new equations that allow to verify if the location is optimal or should be

adjusted. If the $\bar{X}$ and $\bar{Y}$ coordinates vary after being calculated with the new equations, this process must be repeated for an indeterminate number of successive iterations until they do not change or the change is so small that continuing with the calculations is not productive [5]. As a result, the following equations are obtained:

$$\bar{X} = \frac{\sum_i V_i R_i X_i / d_i}{\sum_i V_i R_i / d_i} \quad (4)$$

$$\bar{Y} = \frac{\sum_i V_i R_i Y_i / d_i}{\sum_i V_i R_i / d_i} \quad (5)$$

The distances were calculated with (3) and then used in (4) and (5) to verify if the location of the center of gravity changed and this was the case, so the process was repeated for both cities and in the case of Tegucigalpa it was determined after 33 successive iterations that the $\bar{X}$ and $\bar{Y}$ coordinates had a change low enough to stop the calculations since the change occurred only in the fourth significant figure after the decimal point, resulting in the center of gravity with coordinates (-1.7196, -1.2198); while for the city of Comayagüela the calculations were stopped until after 70 iterations with a result of the center of gravity with coordinates (0.7102, 1.1712).

As a reference, some of the revised coordinates and the last coordinates of the center of gravity mentioned in the previous paragraph were graphed along with the locations that had previously been shown, in order to visualize the movement of the center of gravity through the successive iterations made, obtaining as a result the following graphs:

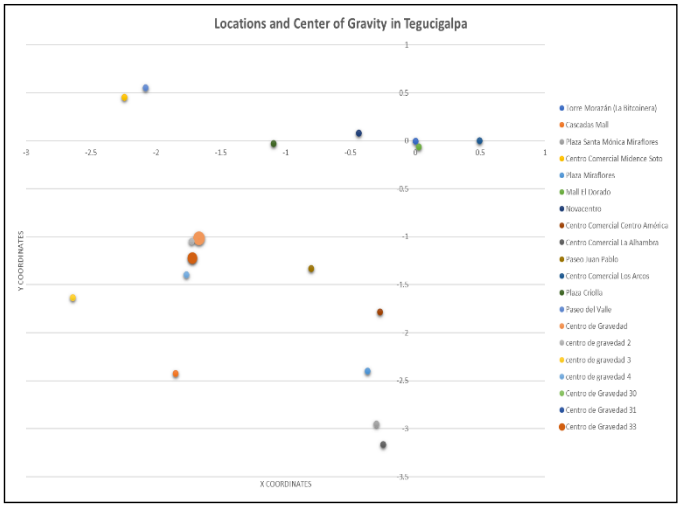

Fig. 9 Revised Center of Gravity Graph for Tegucigalpa

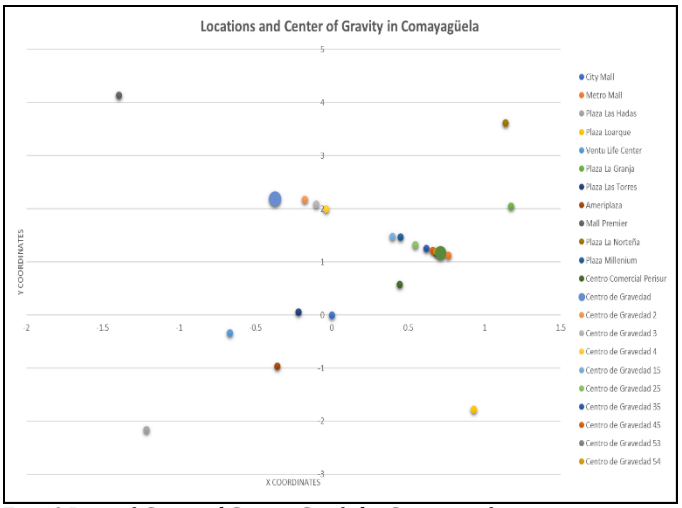

Fig. 10 Revised Center of Gravity Graph for Comayagüela

In addition to the previous graphs, a new map was made where the location of the last center of gravity calculated for each city was marked with a check symbol and also included the markers for the possible locations and that of the first calculated center of gravity marked by a star to have a reference of the initial and final position and its vicinity with the possible locations. The map is shown below:

Fig. 11 Revised Center of Gravity Map

The graphs and geographical map coincide in the behaviour of the revised center of gravity and by having no further changes in the iterations it was determined that the new center of gravity is the optimal location for BTMs in Tegucigalpa and Comayagüela, with latitude and longitude coordinates in Google Maps of (14.088524, -87.199422) and (14.074724, -87.213339) for Tegucigalpa and Comayagüela respectively, it was observed that there are no shopping centers where to install the BTMs exactly in those coordinates and therefore it was decided to choose the shopping center that was closest in distance to the revised center of gravity.

The location closest to the revised center of gravity can be easily found visually in the XY plane graphs shown above, but is even simpler with the use of distances d_i that were already calculated during the iterations for the calculation of the new center of gravity and at the same time you can use the measurement tool available in Google My Maps to verify that the distances to scale correspond to the calculated, the distances calculated for both cities are shown in the following tables:

TABLE VII. Distances Toward the Center of Gravity in Tegucigalpa

Tegucigalpa				
	Shopping Center	**Xi Coordinates**	**Yi Coordinates**	**di**
0	Torre Morazán (La Bitcoinera)	0	0	
1	Cascadas Mall	-1.8508	-2.4215	1.208331459
2	Plaza Santa Mónica Miraflores	-0.3	-2.9478	2.23595912
3	Centro Comercial Midence Soto	-2.2444	0.4565	1.75701432
4	Plaza Miraflores	-0.3691	-2.3982	1.792010676
5	Mall El Dorado	0.0258	-0.0614	2.095121806
6	Novacentro	-0.4369	0.083	1.828651996
7	Centro Comercial Centro América	-0.2731	-1.7788	1.550581887
8	Centro Comercial La Alhambra	-0.2481	-3.1606	2.435172577
9	Paseo Juan Pablo	-0.8035	-1.3293	0.922571508
10	Centro Comercial Los Arcos	0.4956	0.0038	2.530930423
11	Plaza Criolla	-1.0933	-0.0258	1.348748604
12	Paseo del Valle	-2.0807	0.5533	1.809995039

TABLE VIII. Distances Toward the Center of Gravity in Comayagüela

Comayagüela				
	Shopping Center	**Xi Coordinates**	**Yi Coordinates**	**di**
0	City Mall	0	0	
1	Metro Mall	0.761	1.1265	0.069370049
2	Plaza Las Hadas	-1.2147	-2.1533	3.841954624
3	Plaza Loarque	0.928	-1.7712	2.951714583
4	Ventu Life Center	-0.6675	-0.335	2.041284552
5	Plaza La Granja	1.1718	2.0514	0.993427173
6	Plaza Las Torres	-0.2192	0.0561	1.45174564
7	Ameriplaza	-0.3593	-0.957	2.38231751
8	Mall Premier	-1.3952	4.1447	3.641733219
9	Plaza La Norteña	1.1369	3.6213	2.486031677
10	Plaza Millenium	0.4489	1.469	0.39448669
11	Centro Comercial Perisur	0.4431	0.5794	0.649850688

Comparing the distances calculated in Tables VII and VIII, and the distances measured with the Google My Maps tool, it was determined that they coincide in that the nearest shopping centers that were part of the research sample are Paseo Juan Pablo, whose value for d_i=0.922572 and distance measured on a map of approximately 997m, for Tegucigalpa, and Metromall with d_i=0.069370 and a distance measured on a map of approximately 74m, for Comayagüela; obtaining as a result of proposed locations to install the BTM, Paseo Juan Pablo and Metromall shopping centers.

C. Validation of Proposed BTM Locations

1) Current Data Collection: The validation method chosen was the comparison between the company's current income and the projected income for the new locations proposed with this research. For this, as a first step, data from transactions carried out in the current locations of the BTMs was collected. This data was obtained with the help of the company's manager by accessing the history of transactions made in the different BTMs including those that are currently in operation and those that had to be withdrawn or relocated.

The data of lempiras entering the ATM was taken as a reference to the income in local currency, by using the BTMs that had to be withdrawn, Marcala and Casa Quincho, and those that are currently functioning, a monthly average of income in lempiras was calculated and then a comparison with the projected income of the new locations found with the center of gravity method was made. Of the total transactions made at each BTM mentioned before, an average of monthly transactions and income was calculated, and then subtracted the monthly rental cost to calculate the monthly income generated by each BTM. And with that data, a comparison was able to be made with the projected income of the two new proposed locations, the summary data is shown in the following table:

TABLE IX. Average Monthly Income

Past and Current Locations	**Average Monthly Transactions**	**Average Monthly Income (L)**	**Monthly Rental Cost ($)**	**Income (L)**
Casa Quincho	6	3650.33	162	-330.98
Marcala, La Paz	3	2066.00	65	468.56
City Mall	24	11030.17	300	3657.37
Torre Morazán	13	6820.17	500	-5467.83

It is important to mention that the averages of the BTM ATMs in Casa Quinchon and Marcala City were calculated based on the last three months of operation in 2022 since they were withdrawn, while those of City Mall and Torre Morazán were calculated based on 6 months, from September 2022 to February 2023. It is shown that although the BTM of Marcala was generating a small income, the low level of transactions was what caused the decision to withdraw it from the place, while the BTM of Torre Morazán is not generating income, but the volume of transactions is greater, and also the space rented in that location works as the headquarters of the company.

Continuing with the validation, a calculation of the projected income that could be generated in the locations proposed using the center of gravity method was made, through the use of volume of people visiting those locations, a proportion of income according to current locations and the cost of rent in the new locations. Below is a table with the summary of the mentioned data:

TABLE X. Projected Income for Proposed Locations

Proposed Locations	**Monthly Influx of Customers**	**Average Monthly Transactions**	**Average Monthly Income (L)**	**Monthly Rental Cost ($)**	**Income (L)**
Paseo Juan Pablo	21000	1175.328	58766.40	403	48862.27
Metro Mall	570000	31901.76	1595088.00	1500	1558224.00

It is clearly observed that the projected revenues are much higher than the current ones, it is certainly important to mention that these are long-term projections taking into account that the clientele is better established, which as

observed in the field research through the applied survey has a good indication of growth and this was the base for the calculation of income, by assuming that customers will follow the behaviour suggested by the questions asked in the survey, the graphs of which are shown below:

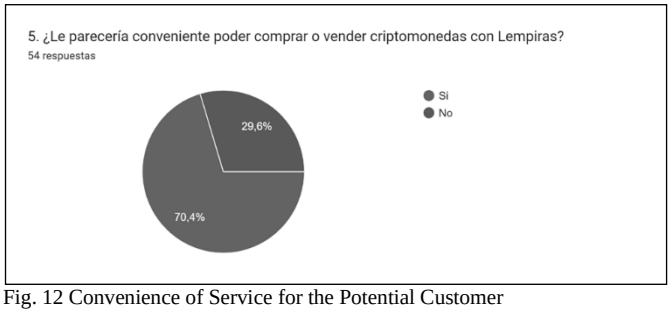

Fig. 12 Convenience of Service for the Potential Customer

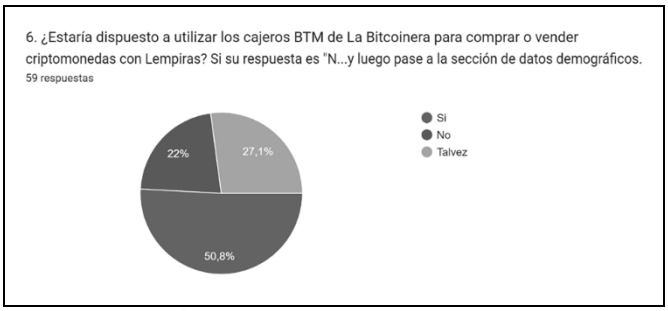

Fig. 13 Percentage of Customers Willing to Make Transactions

Based on these responses, the average number of monthly transactions shown in Table X was calculated; to obtain the average monthly transactions, the amount of monthly customer influx was multiplied by 31.8% to represent the majority of people who answered the survey, between 35 and 45 years of age, as a basis and then the result was multiplied by 70.8% to represent the clientele that according to the results of the survey shown in Fig. 12 and 13 is willing to use the services; and that result was subsequently divided by four to match the four-month average taken into account for BTMs that were withdrawn.

The result obtained is taken as the average of monthly transactions and this is multiplied by 50, since the minimum amount to make a transaction is L. 50.00, to obtain the average monthly income. And the last step to complete Table X was to subtract the rental value of the location, using the day's exchange rate of the dollar (L. 24,576), and thus obtain the projected income in each proposed location. Through this process it is considered that the proposed locations are optimal and valid for the company La Bitcoinera to use them.

2) Research Results Presentation to the Interested Parties: The results were presented and explained to the interested parties, in this case the La Bitcoinera CEO, as another way of validation for this research. After viewing the results as the proposed locations and the projected incomes determined by this research the CEO agreed on the feasibility of this research and the use of the proposed locations for the BTMs.

IV. Conclusions

The compilation of scientific publications allowed to use this information from studies previously carried out as a guide at the time of carrying out this research's work, it also allowed a comparison of the problems that are tried to be solved in the different studies to know what is the best way to face the problem of the research itself, and also allowed to realize that the research that was carried out should be done in a different way than the previous studies were; with this combination of events, the choice of variables to be used to find the optimal locations for BTMs was given a scientific basis and also made simpler.

The center of gravity method is a very simple method to apply once you have the values for the variables required in your equations, and allows you to find optimal locations for different scenarios or problems faced by the researcher. But depending on the case, many iterations of calculations must be performed until the resulting coordinates stop changing with this method as it gets closer and closer to the optimal location. In this case, the optimal locations were found for Tegucigalpa after 33 iterations and for Comayagüela after 70 iterations, but in some cases, it may happen that they extend to larger quantities of iterations making the method impractical to use.

Through the comparison of actual and projected income, it was possible to validate that the proposed locations are viable for La Bitcoinera, by using them in the long term and that the clientele is well established, an income close to one million lempiras could be generated, always taking into account that the rental cost can be variable over time.

V. Recommendations

Research Recommendations

If statistical data from the country is needed, make sure that the institutions responsible for collecting such data have them, that they are not very specific data and that they are easily accessible to the general public, since the few data publicly accessible in local institutions are very widespread and restricted in terms of the type of information and because of this it is difficult to obtain the data that is needed according to the type of research conducted.

Depending on the time and resources available for the investigation, it could be good practice to complement the center of gravity method with other techniques such as those mentioned in the background of the problem in this document, for example, the coordinate recalculation method that helps to recalculate the center of gravity in the event that the coordinates found are located in a place that is not feasible because it is occupied or because it has restrictions of use.

Recommendations for the Company

The company must continue with field research and the application of tools such as surveys to determine the behaviour of its clientele and thus be able to better approximate the type of growth that La Bitcoinera can expect for future decisions to expand or install more BTMs when necessary and not have an excess or lack of these.

VI. Applicability

Regarding the applicability of the present investigation, it can be said that the company involved is of a very specific category, so much so that it is the only one in Honduras with this type of service, but it is similar to the services of ATMs or window type service points provided by banks. That is why this type of research could be applied by banking companies or savings cooperatives for example, but also the methodology can be used by a large number of companies since the original function of it is to find locations for distribution or storage centers that help reduce transportation costs for their products. Therefore, it has a very large and varied applicability.

Regarding the implementation of this research, it is worth mentioning that it was presented to the company since it plans to expand by locating two ATMs in the near future. Due to this need, the result of the research is presented, which consists of the choice of two locations, one in Tegucigalpa and another in Comayagüela. The company receives the research and decides to analyze it to make the final decision to implement it or not, that is why for the moment this research is at the proposal level, but with a high interest shown by the company for its possible implementation.

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