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Application Of The Transportation Method Using The Clarke & Wright Savings Algorithm In A Route Assignment Problem (VRP) Of A Sme In The South Of The State Of Guanajuato

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***Abstract*— The present investigation was carried out in an SME belonging to the restaurant sector located in the south of the state of Guanajuato, where a route assignment problem (VRP) was solved using the transport method through the savings algorithm Clarke & Wright, with the aim of finding the route combinations that generate saving, using the following methodology: A) Identify the geographical coordinates of the 30 clients in Google Maps and their demand B) Develop the tool using the savings algorithm C) identify the optimal route combinations and represent the results in a graph in Excel and Google Maps. As a final result, 7 optimal routes were obtained that allow the SME to generate savings in terms of distances traveled, time and high fuel costs.**

Keywords*— *SMEs, Transport Method, VRP (Vehicle Routing Problem), Clarke & Wright Algorithm, Euclidean Distance.

I. INTRODUCTION

The contribution of Small and Medium Enterprises (SMEs) in the generation of jobs, income obtaining and their role as generators of wealth is recognized throughout the world [1]. They have considerable economic relevance for countries. They contribute in Mexico with a significant percentage of GDP (37.5%) and with a high index of jobs (6 out of 10) [2]. Small and medium-sized enterprises (SMEs) generally serve specific and focused needs of society and industry, so their distribution systems are adjusted to small quantities, particular frequencies to supply their customers and special transport conditions [3]. The VRP (Vehicle Routing Problem) is a combinatorial optimization problem and integer programming, in which each client, including the depot, has an associated demand and each vehicle has a load capacity limit, the formulation of the problem is done by one of the most widespread algorithms for the VRP, is the Savings Algorithm of Clarke and Wright (1964) [4]. This algorithm starts from an initial solution and perform the unions that give greater savings are made. When two routes (0,...,i,0) and (0,j,...,0) can be merged into a single route (0,...,i, j,...,0), a saving distance is generated (0,...,i, j,...,0). The objective of the VRP is to minimize the cost of the routes, which start and end in a depot, for a set of clients with known demands [5]. Among small and medium-sized enterprises (SMEs) are those of the restaurant sector, they offer their clients food services from its establishment or through home deliveries of products to each of its customers. The distribution of products to the clients home in many cases involves long distances in making deliveries and long times and even high distribution costs. Based on the above, this research is focused on the application of the transport method using the Clarke & Wright savings algorithm in an SME belonging to the restaurant sector located in the south of the state of Gto., with the aim of finding the most optimal routes, which guarantee the SME an effective distribution of orders to the home of its clients, thus generating savings in terms of distances, time and considerable savings in fuel costs. The present investigation is developed in five sections, in section II. Review of the literature of real applications of the VRP in different areas and applications of the Clarke & wright saving algorithm, in section III. The methodology, in section IV. The development of the tool, in section V. The results and in section VI. The final conclusions.

II. LITERARUTE REVIEW

This section presents the results of an exhaustive investigation of works related to the implementation and development of VRP (Vehicle Routing Problem) in different cases and work areas.

[6] Developed an investigation to optimize the distribution routes for a branch of the Czech Mail, the distribution routes perform circular routes of vehicles, to optimize the distribution routes they used the Clarke- Wright method. [7] Developed a modeling of a messaging service, called bank swap transport, such as a vehicle routing problem (VRP), developing a hybrid algorithm between the ant colony optimization and the scanning algorithm. [8] Applied the vehicle routing model combined with optimization algorithms for decision making in the distribution of supplies related to the care service to hospitalized patients and suspected of COVID-19 in Camagüey, Cuba. [9]

Developed an investigation to improve the vehicle routing management of a parcel company in Medellín-Colombia, for which an optimization method based on the vehicle routing problem with a heterogeneous capacity fleet was used. [10] Solved the issue of damming deliveries identified in 2018 in a company

dedicated to the parcel and merchandise delivery service, located in Valle del Cauca, Colombia. Quality tools such as Pareto analysis, the Clarke-Wright method and the use of time windows were combined through the VRP solver 3.0 program. [11] Designed a set of routes to minimize the sum of costs using a heterogeneous fleet vehicle routing problem (HFVRP) for a good urban distribution, developing a tabu search algorithm. [12] Proposed a novel mathematical model for the Electric Vehicle Routing Problem with backhauls and optimal operation of the Distribution Network (EVRPB-DN) for minimize the costs associated with the operation of the transport networks (adopting the VRPB approach) and distribution. [13] Developed a solution model for a CVRP-HF vehicle routing problem, making use of software tools, mathematical programming principles and heuristic processes, presented at the Nueva Granada Military University due to mobility conditions towards the Nueva Campus headquarters. [14] Developed an optimization model based on the application of two heuristics for a real situation of routing a fleet of vehicles of a Health Service Provider Institution (IPS) to transport its patients. Using the COVRP routing type. [15] They propose a model and two heuristic algorithms to assign clients to trucks and visiting days as a first phase in the solution of a routing problem, which is closely related to the PVRP (Periodic Vehicle Routing Problem). [16] Developed a method for the solution the motorcycle messenger routing problem with time windows. Two phases are identified in this: in the first, groups of clients are formed, each group is assigned to a route and each route is served by a vehicle; in the second, by means of a mixed integer linear programming model, a routing is done for each of the groupings respecting the strict time windows of some clients. [17] Addressed a vehicle routing problem in mountain cities to determine the most optimal one. A multi-objective mathematical model is proposed, which determines a route that achieves an adequate balance between the cost of transportation and the environmental impact. The model was applied in a retail distribution channel in an Andean city in Colombia. [18] Developed a mathematical model for the analysis of collection routes in circulation at Anji Company milk producer based on the improved C-W algorithm. [19] Created a reverse logistics network associated with the collection of used vehicle oil (AU) in the city of Pereira. The situation was modeled as a capacity-restriction vehicle routing problem CVRP (Capacited Vehicle Routing Problem) which was solved by implementing a two-phase heuristic consisting of

Route first and Group later. [20] In the companies of the comprehensive pest control services sector (CP). It proposes a mixed integer linear programming model that considers the minimization of costs associated with the distance traveled and the idle time of the operators who perform the tasks.

III. Methodology

The methodology used for the development of this research is divided into four stages, in the first stage, the conceptual framework and the review of the literature are presented, In the second stage, the development of the applied tool is presented, which is the transport method, in the third stage the results are presented and finally in the fourth stage the corresponding conclusions are presented. See fig. 1.

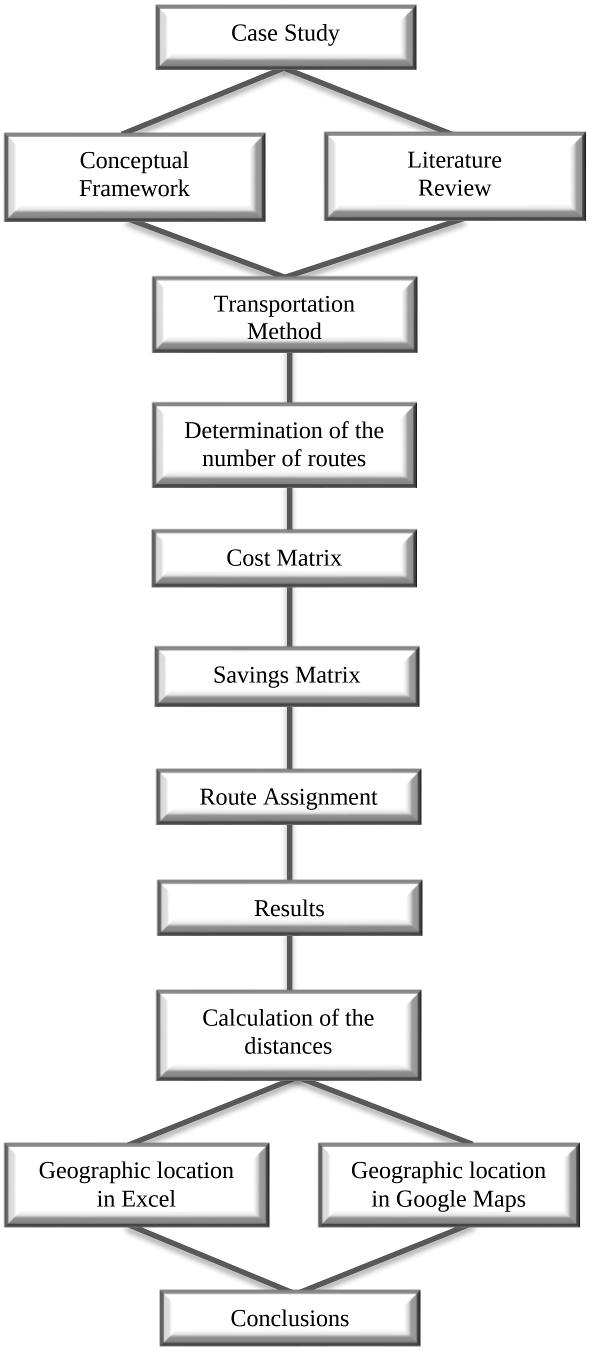

Figure 1. *Methodology*

IV. TRANSPORTATION METHOD

For the development of the transport method were analyzed to 30 of the main clients of the study SME located in the municipality of Yuriria Gto., which make orders at home and the demand of each of them.

To perform distribute the products to the customer's home, the SME has a motorcycle to make deliveries, the motorcycle has a container in the back where it deposits the products; The container that the motorcycle brings has a maximum load capacity of 10 products.

Determination of the number of routes

To calculate the number of routes that the company must have to carry out an effective distribution of the products, the demand of the 30 main clients and the maximum load capacity of the container of the motorcycle with which the company makes deliveries to the are needed address of each client.

Table (1) shows the geographical coordinates of the SME and the 30 clients, it can be observed again in table 1 the calculation of the optimal routes, to obtain this result, the total of the sum of the daily demand of the 30 clients was divided, giving a total in the sum of the demand of 67 products between the maximum load capacity of the container that the motorcycle has, in where, its maximum loading capacity is a total of 10 products, resulting in the number of routes for the company to carry out an effective distribution of its products to the clients address is a total of 7 routes.

The routes obtained at the time of performing the corresponding calculation, in addition to providing the company with an effective distribution of its products to the address of the respective client they generate savings in terms of distances traveled, savings in delivery time and savings in fuel costs.

TABLE I. CALCULATION OF THE NUMBER OF ROUTES

GEOGRAPHICAL COORDINATES				**X**			**Y**
SME				-101.13044			20.21333
CLIENTS	**COORDINATES**		**DEMAND**	**CLIENTS**	**COORDINATES**		**DEMAND**
	X	**Y**			**X**	**Y**	
Client 1	-101.13016	20.21229	2	Client 16	-101.12796	20.21385	7
Client 2	-101.13016	20.21229	2	Client 17	-101.12686	20.21421	6
Client 3	-101.12519	20.20723	2	Client 18	-101.13024	20.21302	6
Client 4	-101.12635	20.2145	1	Client 19	-101.12897	20.21272	2
Client 5	-101.13495	20.21151	2	Client 20	-101.13086	20.21212	1
Client 6	-101.13348	20.21428	1	Client 21	-101.1293	20.21455	1
Client 7	-101.13384	20.2124	2	Client 22	-101.13379	20.21459	2
Client 8	-101.11097	20.21531	1	Client 23	-101.12926	20.21361	1
Client 9	-101.13421	20.21472	2	Client 24	-101.1403	20.21509	1
Client 10	-101.13342	20.20777	2	Client 25	-101.13834	20.21219	6
Client 11	-101.1364	20.2077	1	Client 26	-101.13296	20.21374	2
Client 12	-101.13588	20.21279	2	Client 27	-101.13276	20.21346	4
Client 13	-101.12449	20.2135	1	Client 28	-101.13479	20.21347	1
Client 14	-101.13074	20.21147	2	Client 29	-101.12516	20.21404	2
Client 15	-101.13314	20.21018	1	Client 30	-101.13187	20.20888	1
TOTAL DEMAND							67
MOTORCYCLE CAPACITY							10
NUMBER OF ROUTES							7

Cost matrix

Based on the result obtained from the amount of routes, the calculation of the distances to go from the company to each of the 30 clients and to go from one client to another was carried out, making use of the coordinates of each one and using the equation of the Euclidean distance. See equation 1.

$$Euclidean\ Distance\ \sqrt{(X2-X1)^2+(Y2-Y1)^2} \qquad (1)$$

Where:

X2: Coordinate of point 2
X1: Coordinate of point 1
Y2: Coordinate of point 2
Y1: Coordinate of point 1

For the correct elaboration of the cost matrix found in table 5, first, the corresponding calculations were made horizontally for each line, from the 0 that represents the company to 30 that are the total of the main clients, it can be seen that in the first column of the matrix there is a value of 0 that means that there are no distances or displacements, subsequently, for the value of (SME 0 – Client 1), which is the distance to go from the SME to client 1, by using the Euclidean distance formula, the distance of X1 was calculated, which is the geographical coordinate of client 1 (-101.13016) X2 is subtracted, which is the geographical coordinate of the SME (-101.13044), the result obtained was squared, then to that result the distance of Y1 was added, which is the geographical coordinate of client 1 (20.21229), Y2 was subtracted, which is the coordinate geographic of the SME (20.21333), the result obtained is raised to the square and to the sum of these two results, the square root was taken, yielding the first result of 0.001077, which represents the distance from the SME to client 1. Better represented in another way: See equation 2.

$$Euclidean\ Distance\ \sqrt{\left((-101.13016)\text{–}(-101.13044)^2\right)+\left((20.21229)-(20.21333)^2\right)}=\ 0.001077 \qquad (2)$$

Subsequently, the coordinates of the SME are fixed and in the same way the calculation of the entire row is made horizontally of the remaining clients using the Euclidean distance formula to calculate the distance from the SME to the remaining 29 clients, then in the second line the same procedure is repeated, but now the distance from client 1 to client 30 is calculated, by fix the coordinates corresponding to client 1, performing the corresponding calculations and complete the line, later, in the third line, the distances from client 2 to client 30 are now calculated, fixing again the coordinates corresponding to client 2, and so on, it is done in the remaining lines, always fixing the coordinates of the next client to calculate the distance with the remaining clients to complete and obtain the distances of the calculations between the coordinates of one client to another.

The results obtained by making the calculations horizontally were also reflected vertically in each of the corresponding columns to complete the matrix. In the table (2) shows the complete calculation of the cost matrix.

TABLE II. COST MATRIX

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	0	0.00107703	0.00107703	0.00804814	0.00425406	0.004863384	0.00318498	0.0035249	0.01957042	0.00401808	0.00630825
1	0.00107703	0	0	0.00709257	0.00440457	0.004853092	0.00387072	0.00368164	0.01942618	0.00472307	0.00557297
2	0.00107703	0	0	0.00709257	0.00440457	0.004853092	0.00387072	0.00368164	0.01942618	0.00472307	0.00557297
3	0.00804814	0.00709257	0.00709257	0	0.00736196	0.010657204	0.0108824	0.01007727	0.01635527	0.01172435	0.0082477
4	0.00425406	0.00440457	0.00440457	0.00736196	0	0.009104949	0.00713339	0.00777882	0.01540131	0.00786308	0.00976103
5	0.00486338	0.00485309	0.00485309	0.0106572	0.00910495	0	0.00313589	0.00142274	0.02427922	0.00329419	0.00404085
6	0.00318498	0.00387072	0.00387072	0.0108824	0.00713339	0.003135889	0	0.00191416	0.02253355	0.00085235	0.00651028
7	0.0035249	0.00368164	0.00368164	0.01007727	0.00777882	0.001422744	0.00191416	0	0.02305439	0.00234932	0.00464901
8	0.01957042	0.01942618	0.01942618	0.01635527	0.01540131	0.024279217	0.02253355	0.02305439	0	0.02324749	0.02368236

	0	1	2	3	4	5	6	7	8	9	10
9	0.00401808	0.00472307	0.00472307	0.01172435	0.00786308	0.003294192	0.00085235	0.00234932	0.02324749	0	0.00699476
10	0.00630825	0.00557297	0.00557297	0.0082477	0.00976103	0.004040854	0.00651028	0.00464901	0.02368236	0.00699476	0
11	0.00819869	0.00774633	0.00774633	0.01121985	0.01213435	0.004076592	0.00719881	0.00535197	0.02654425	0.00735367	0.00298082
12	0.00546674	0.00574181	0.00574181	0.01204947	0.0096822	0.001582182	0.00282491	0.00207694	0.02503714	0.00255221	0.00559035
13	0.00595243	0.00579767	0.00579767	0.00630895	0.00211178	0.010647615	0.00902377	0.00941448	0.01364062	0.00979626	0.01061027
14	0.00188404	0.00100439	0.00100439	0.00698428	0.00533414	0.00421019	0.00392475	0.0032365	0.02013948	0.0047543	0.00456863
15	0.0041488	0.00365137	0.00365137	0.00847968	0.00804776	0.002246108	0.00411407	0.00232775	0.02275579	0.00466439	0.00242621
16	0.00253393	0.00269696	0.00269696	0.00717616	0.00173626	0.007371275	0.00553672	0.00605615	0.01705262	0.00631026	0.00817178
17	0.00368657	0.00381791	0.00381791	0.007177	0.00058669	0.008528663	0.00662037	0.00721086	0.01592803	0.00736767	0.00919278
18	0.00036892	0.00073437	0.00073437	0.00768288	0.00416203	0.00494613	0.00347638	0.003653	0.01940559	0.00431867	0.00613799
19	0.00159154	0.00126531	0.00126531	0.00666547	0.00316746	0.006101188	0.00477218	0.0048805	0.01818538	0.00560871	0.0066562
20	0.00128082	0.00072035	0.00072035	0.00748739	0.00509946	0.004135239	0.00339559	0.00299313	0.02014419	0.00424058	0.00504739
21	0.00166973	0.0024181	0.0024181	0.00839491	0.00295042	0.006415925	0.00418871	0.00502336	0.01834575	0.00491294	0.00793365
22	0.00357912	0.00429731	0.00429731	0.01131943	0.00744054	0.0032912	0.00043841	0.00219057	0.02283136	0.00043966	0.00683003
23	0.00121277	0.00159762	0.00159762	0.00756765	0.00304306	0.006065155	0.00427286	0.00473714	0.01836884	0.00507293	0.00717016
24	0.01001585	0.01051949	0.01051949	0.01703208	0.01396247	0.006437305	0.00686793	0.00699769	0.02933083	0.00610123	0.01004574
25	0.00798183	0.00818061	0.00818061	0.01405433	0.0122105	0.003457528	0.00529034	0.0045049	0.02754726	0.00484333	0.00661383
26	0.00255314	0.00315317	0.00315317	0.01013672	0.00665355	0.002988812	0.00074967	0.00160312	0.02204597	0.00158836	0.0059877
27	0.00232364	0.00285112	0.00285112	0.00980397	0.00649382	0.002932337	0.00109124	0.00151327	0.02186839	0.00192096	0.00572815
28	0.00435225	0.004778	0.004778	0.01144979	0.00850262	0.00196652	0.00154019	0.00143087	0.02389096	0.00137801	0.00586233
29	0.00532752	0.00529741	0.00529741	0.00681007	0.00127581	0.010111627	0.00832346	0.00883357	0.01424672	0.00907551	0.01037017
30	0.00467412	0.00381473	0.00381473	0.00688076	0.00787749	0.004050099	0.0056349	0.00403377	0.02186675	0.00629136	0.00190646

TABLE II. CONTINUATION

	11	12	13	14	15	16	17	18	19	20
0	0.00819869	0.005466736	0.005952428	0.001884038	0.0041488	0.00253393	0.00368657	0.00036892	0.00159154	0.00128082
1	0.00774633	0.005741812	0.005797672	0.00100439	0.00365137	0.00269696	0.00381791	0.00073437	0.00126531	0.00072035
2	0.00774633	0.005741812	0.005797672	0.00100439	0.00365137	0.00269696	0.00381791	0.00073437	0.00126531	0.00072035
3	0.01121985	0.012049469	0.006308954	0.006984275	0.00847968	0.00717616	0.007177	0.00768288	0.00666547	0.00748739
4	0.01213435	0.0096822	0.002111777	0.005334135	0.00804776	0.00173626	0.00058669	0.00416203	0.00316746	0.00509946
5	0.00407659	0.001582182	0.010647615	0.00421019	0.00224611	0.00737128	0.00852866	0.00494613	0.00610119	0.00413524
6	0.00719881	0.002824907	0.009023774	0.003924755	0.00411407	0.00553672	0.00662037	0.00347638	0.00477218	0.00339559
7	0.00535197	0.002076945	0.009414484	0.003236495	0.00232775	0.00605615	0.00721086	0.003653	0.0048805	0.00299313
8	0.02654425	0.025037142	0.013640619	0.020139476	0.02275579	0.01705262	0.01592803	0.01940559	0.01818538	0.02014419
9	0.00735367	0.002552215	0.009796265	0.004754303	0.00466439	0.00631026	0.00736767	0.00431867	0.00560871	0.00424058
10	0.00298082	0.005590349	0.010610269	0.004568632	0.00242621	0.00817178	0.00919278	0.00613799	0.0066562	0.00504739
11	0	0.005116493	0.013247192	0.006800625	0.0040961	0.01044299	0.01154953	0.00813929	0.0089669	0.00708717
12	0.00511649	0	0.011412108	0.005306788	0.00378414	0.00799062	0.00913109	0.00564469	0.00691035	0.00506451
13	0.01324719	0.011412108	0	0.006571408	0.00926525	0.00348761	0.00247407	0.00577	0.00454739	0.00651777
14	0.00680062	0.005306788	0.006571408	0	0.00272472	0.00365962	0.00474995	0.00162865	0.00216689	0.00066098
15	0.0040961	0.003784138	0.009265252	0.00272472	0	0.00634833	0.00746186	0.00405901	0.00488267	0.00299366
16	0.01044299	0.00799062	0.003487607	0.003659617	0.00634833	0	0.00115741	0.00242638	0.00151559	0.00337682
17	0.01154953	0.00913109	0.002474065	0.004749947	0.00746186	0.00115741	0	0.00358336	0.00258306	0.0045131
18	0.00813929	0.005644688	0.00577	0.00162865	0.00405901	0.00242638	0.00358336	0	0.00130495	0.00109289

	11	12	13	14	15	16	17	18	19	20
21	0.00986572	0.006811314	0.004923271	0.0034	0.00581743	0.00151182	0.00246357	0.00179569	0.00185952	0.00288765
22	0.00736778	0.002758278	0.009363658	0.00436313	0.00445765	0.00587678	0.00694041	0.00388167	0.00517004	0.00383221
23	0.00926864	0.006670592	0.004771268	0.002601922	0.00517874	0.00132197	0.00247386	0.0011439	0.00093606	0.00218634
24	0.00835596	0.00498261	0.015889751	0.010222426	0.0086818	0.01240214	0.01346878	0.01027076	0.01157522	0.00989619
25	0.00489119	0.002532114	0.013911815	0.007634029	0.00557495	0.0105119	0.01165636	0.00814241	0.00938498	0.00748033
26	0.00695091	0.003070651	0.0084734	0.003175106	0.00356455	0.00500121	0.00611808	0.00281368	0.00411831	0.00265224
27	0.00681375	0.003191128	0.008270097	0.002835578	0.00330194	0.00481582	0.00594748	0.00255812	0.00386157	0.00232499
28	0.00599041	0.001284718	0.010300044	0.004516913	0.00368057	0.00684056	0.00796445	0.0045722	0.00586813	0.00415541
29	0.01290477	0.010792632	0.000860523	0.006143395	0.00886454	0.00280644	0.00170848	0.00518139	0.00403218	0.00601468
30	0.00468116	0.005600732	0.008706825	0.002825774	0.00181739	0.00632369	0.00731498	0.00444933	0.00481203	0.00339377

TABLE II. CONTINUATION

	21	22	23	24	25	26	27	28	29	30
0	0.001669731	0.00357912	0.00121277	0.010015847	0.00798183	0.00255314	0.00232364	0.00435225	0.005327523	0.00467412
1	0.002418098	0.00429731	0.00159762	0.010519487	0.00818061	0.00315317	0.00285112	0.004778	0.005297405	0.00381473
2	0.002418098	0.00429731	0.00159762	0.010519487	0.00818061	0.00315317	0.00285112	0.004778	0.005297405	0.00381473
3	0.008394909	0.01131943	0.00756765	0.017032079	0.01405433	0.01013672	0.00980397	0.01144979	0.006810066	0.00688076
4	0.002950424	0.00744054	0.00304306	0.013962471	0.0122105	0.00665355	0.00649382	0.00850262	0.001275813	0.00787749
5	0.006415925	0.0032912	0.00606515	0.006437305	0.00345753	0.00298881	0.00293234	0.00196652	0.010111627	0.0040501
6	0.004188711	0.00043841	0.00427286	0.006867933	0.00529034	0.00074967	0.00109124	0.00154019	0.008323461	0.0056349
7	0.005023355	0.00219057	0.00473714	0.006997692	0.0045049	0.00160312	0.00151327	0.00143087	0.008833572	0.00403377
8	0.018345749	0.02283136	0.01836884	0.029330825	0.02754726	0.02204597	0.02186839	0.02389096	0.014246719	0.02186675
9	0.004912942	0.00043966	0.00507293	0.006101229	0.00484333	0.00158836	0.00192096	0.00137801	0.009075511	0.00629136
10	0.00793365	0.00683003	0.00717016	0.010045735	0.00661383	0.0059877	0.00572815	0.00586233	0.010370174	0.00190646
11	0.009865723	0.00736778	0.00926864	0.008355962	0.00489119	0.00695091	0.00681375	0.00599041	0.012904774	0.00468116
12	0.006811314	0.00275828	0.00667059	0.00498261	0.00253211	0.00307065	0.00319113	0.00128472	0.010792632	0.00560073
13	0.004923271	0.00936366	0.00477127	0.015889751	0.01391182	0.0084734	0.0082701	0.01030004	0.000860523	0.00870682
14	0.0034	0.00436313	0.00260192	0.010222426	0.00763403	0.00317511	0.00283558	0.00451691	0.006143395	0.00282577
15	0.005817431	0.00445765	0.00517874	0.008681803	0.00557495	0.00356455	0.00330194	0.00368057	0.008864536	0.00181739
16	0.00151182	0.00587678	0.00132197	0.012402145	0.0105119	0.00500121	0.00481582	0.00684056	0.002806439	0.00632369
17	0.002463575	0.00694041	0.00247386	0.013468779	0.01165636	0.00611808	0.00594748	0.00796445	0.001708479	0.00731498
18	0.001795689	0.00388167	0.0011439	0.010270759	0.00814241	0.00281368	0.00255812	0.0045722	0.00518139	0.00444933
19	0.001859516	0.00517004	0.00093606	0.011575224	0.00938498	0.00411831	0.00386157	0.00586813	0.004032183	0.00481203
20	0.002887646	0.00383221	0.00218634	0.009896186	0.00748033	0.00265224	0.00232499	0.00415541	0.006014682	0.00339377
21	0	0.00449018	0.00094085	0.011013247	0.00934298	0.00374856	0.00362763	0.00559522	0.004171295	0.00622526
22	0.004490178	0	0.00463479	0.006529173	0.00514417	0.00118802	0.00152899	0.00150147	0.008647508	0.00602416
23	0.000940851	0.00463479	0	0.011138761	0.00919036	0.00370228	0.00350321	0.00553177	0.004122487	0.00540231
24	0.011013247	0.00652917	0.01113876	0	0.00350023	0.00746312	0.00771418	0.00574321	0.015176366	0.01047039
25	0.009342976	0.00514417	0.00919036	0.003500229	0	0.00559883	0.0057227	0.00377371	0.013309204	0.00726753
26	0.00374856	0.00118802	0.00370228	0.007463116	0.00559883	0	0.00034409	0.00184981	0.007805767	0.00498073
27	0.00362763	0.00152899	0.00350321	0.007714175	0.0057227	0.00034409	0	0.00203002	0.007622099	0.00466567
28	0.005595221	0.00150147	0.00553177	0.005743213	0.00377371	0.00184981	0.00203002	0	0.009646854	0.00544008
29	0.004171295	0.00864751	0.00412249	0.015176366	0.0133092	0.00780577	0.0076221	0.00964685	0	0.00846461
30	0.006225255	0.00602416	0.00540231	0.010470387	0.00726753	0.00498073	0.00466567	0.00544008	0.008464615	0

Savings Matrix

In this third stage of the transport method, the savings matrix was developed, to complete the savings matrix, the results obtained in Table (2) were used, which is the cost matrix, using the following equation to calculate the respective savings between two points. See equation 3.

$$Sij = Coi + Coj - Cij \quad (3)$$

Where:

Coi: distance of point 1
Coj: distance of point 2
Cij: distance between point 1 to point 2.

By means of this equation, the savings of the different combinations of sending them from one client to another are calculated; in the table (6) shows the calculations obtained from the savings matrix, it can be seen that the first combination is from client 1 with client 2, to calculate the respective savings of this combination, the results obtained in the cost matrix found in Table (2) are taken, where the value of the distance from client 1 is added to the distance from client 2 and the distance of sending it from client 2 to client 1 is subtracted, resulting in a saving of 0.0021541, better represented in another way: See equation 4.

Savings= Distance Client 1 + Distance Client 2 – Distance Client 2 and 1

$$Sij = 0.001077 + 0.001077 - 0 = 0.0021541 \quad (4)$$

Subsequently, the combinations of the distances of client 1 with the distances of the remaining clients were made, completing the line and to obtain the respective savings, then the combinations of the distances of client 2 with the distances of the remaining clients were made until the line was completed to obtain the respective savings of those combinations and so on, it was carried out with the following clients until the respective lines were completed, calculating the different combinations through the distances obtained in the cost matrix, thus obtaining the respective savings. In the table (3) shows the complete calculation of the savings matrix.

TABLE III. SAVINGS MATRIX

	0	1	2	3	4	5	6	7	8	9	10
1			0.00215407	0.0020326	0.00092652	0.001087325	0.00039129	0.00092029	0.00122127	0.00037205	0.00181231
2				0.0020326	0.00092652	0.001087325	0.00039129	0.00092029	0.00122127	0.00037205	0.00181231
3					0.00494023	0.002254316	0.00035072	0.00149576	0.01126329	0.00034187	0.00610869
4						1.24913E-05	0.00030564	1.3023E-07	0.00842316	0.00040906	0.00080127
5							0.00491247	0.00696554	0.00015459	0.00558728	0.00713078
6								0.00479572	0.00022185	0.00635071	0.00298295
7									4.0924E-05	0.00519366	0.00518414
8										0.00034102	0.00219631
9											0.00333158

TABLE III. CONTINUATION

	11	12	13	14	15	16	17	18	19	20
1	0.00152939	0.000801957	0.001231789	0.001956681	0.00157446	0.000914	0.0009457	0.00071158	0.00140327	0.00163751
2	0.00152939	0.000801957	0.001231789	0.001956681	0.00157446	0.000914	0.0009457	0.00071158	0.00140327	0.00163751
3	0.00502698	0.001465403	0.007691611	0.002947899	0.00371725	0.0034059	0.00455771	0.00073418	0.00297421	0.00184157
4	0.00031839	3.85925E-05	0.008094708	0.00080396	0.00035509	0.00505173	0.00735394	0.00046094	0.00267814	0.00043542
5	0.00898548	0.008747937	0.000168197	0.002537232	0.00676607	2.6038E-05	2.129E-05	0.00028617	0.00035374	0.00200896
6	0.00418486	0.005826809	0.000113634	0.001144264	0.0032197	0.00018219	0.00025118	7.752E-05	4.3407E-06	0.00107022

	11	12	13	14	15	16	17	18	19	20
7	0.00637161	0.006914688	6.28417E-05	0.00217244	0.00534595	2.6813E-06	6.0752E-07	0.00024082	0.00023594	0.00181259
8	0.00122486	1.23673E-08	0.011882228	0.001314981	0.00096343	0.00505173	0.00732896	0.00053374	0.00297658	0.00070705
9	0.0048631	0.006932605	0.000174248	0.001147819	0.00350249	0.00024175	0.00033698	6.8333E-05	9.1674E-07	0.00105833
10	0.01152612	0.006184636	0.001650408	0.003623655	0.00803083	0.0006704	0.00080204	0.00053918	0.00124359	0.00254168
11		0.008548932	0.000903925	0.003282102	0.00825139	0.00028963	0.00033573	0.00042832	0.00082333	0.00239234
12			7.05624E-06	0.002043986	0.00583139	1.0046E-05	2.2216E-05	0.00019097	0.00014792	0.00168304
13				0.001265059	0.00083597	0.00499875	0.00716493	0.00055135	0.00299657	0.00071548
14					0.00330811	0.00075835	0.00082066	0.00062431	0.00130869	0.00250387
15						0.00033439	0.00037351	0.0004587	0.00085766	0.00243596
16							0.00506309	0.00047647	0.00260988	0.00043793
17								0.00047212	0.00269505	0.00045429
18									0.00065551	0.00055685
19										0.00088941

TABLE III. CONTINUATION

	21	22	23	24	25	26	27	28	29	30
1	0.000328665	0.00035884	0.00069218	0.000573394	0.00087825	0.000477	0.00054955	0.00065128	0.001107151	0.00193642
2	0.000328665	0.00035884	0.00069218	0.000573394	0.00087825	0.000477	0.00054955	0.00065128	0.001107151	0.00193642
3	0.001322958	0.00030782	0.00169325	0.001031905	0.00197564	0.00046456	0.00056781	0.0009506	0.006565593	0.00584149
4	0.002973364	0.00039263	0.00242376	0.000307433	2.5391E-05	0.00015364	8.3876E-05	0.00010369	0.008305766	0.00105069
5	0.000117189	0.0051513	1.0994E-05	0.008441926	0.00938768	0.00442771	0.00425469	0.00724912	7.92795E-05	0.00548741
6	0.000666	0.00632569	0.00012489	0.006332895	0.00587647	0.00498845	0.00441738	0.00599704	0.000189042	0.0022242
7	0.000171272	0.00491345	5.2211E-07	0.006543052	0.00700183	0.00447491	0.00433526	0.00644628	1.88477E-05	0.00416525
8	0.002894401	0.00031818	0.00241435	0.000255441	4.9926E-06	7.758E-05	2.5666E-05	3.1711E-05	0.010651223	0.00237779
9	0.000774873	0.00715755	0.00015792	0.007932702	0.00715659	0.00498286	0.00442076	0.00699233	0.000270096	0.00240085
10	4.43292E-05	0.00305734	0.00035085	0.006278361	0.00767624	0.00287369	0.00290374	0.00479817	0.001265598	0.00907591
11	2.69595E-06	0.00441003	0.00014281	0.009858574	0.01128933	0.00380091	0.00370858	0.00656053	0.000621437	0.00819164
12	0.000325152	0.00628758	8.909E-06	0.010499973	0.01091645	0.00494922	0.00459925	0.00853427	1.6269E-06	0.00454012
13	0.002698887	0.00016789	0.00239393	7.85241E-05	2.2442E-05	3.2164E-05	5.9707E-06	4.6367E-06	0.010419428	0.00191972
14	0.000153769	0.00110003	0.00049488	0.001677459	0.00223184	0.00126207	0.0013721	0.00171938	0.001068166	0.00373238
15	1.09482E-06	0.00327027	0.00018283	0.00548284	0.00655567	0.00313738	0.0031705	0.00482048	0.000611782	0.00700553
16	0.00269184	0.00023627	0.00242473	0.000147632	3.8611E-06	8.5855E-05	4.1751E-05	4.5619E-05	0.005055014	0.00088436
17	0.002892726	0.00032528	0.00242547	0.000233639	1.2037E-05	0.00012163	6.2731E-05	7.437E-05	0.007305614	0.00104571
18	0.000242959	6.6362E-05	0.00043779	0.000114005	0.00020833	0.00010837	0.00013443	0.00014897	0.00051505	0.00059371
19	0.001401755	6.2145E-07	0.00186825	3.2164E-05	0.00018839	2.6363E-05	5.3612E-05	7.5667E-05	0.00288688	0.00145363
20	6.29045E-05	0.00102773	0.00030724	0.001400481	0.00178232	0.00118171	0.00127946	0.00147767	0.000593661	0.00256117
21		0.00075867	0.00194165	0.000672331	0.00030858	0.00047431	0.00036574	0.00042676	0.002825959	0.0001186
22			0.00015709	0.007065794	0.00641678	0.00494423	0.00437377	0.00642991	0.000259135	0.00222908
23				8.98517E-05	4.2303E-06	6.3618E-05	3.3192E-05	3.3246E-05	0.002417801	0.00048457
24					0.01449745	0.00510587	0.00462531	0.00862489	0.000167004	0.00421958
25						0.00493613	0.00458277	0.00856037	1.48658E-07	0.00538842
26							0.00453268	0.00505558	7.48911E-05	0.00224652
27								0.00464587	2.90628E-05	0.00233209
28									3.29208E-05	0.00358629

	21	22	23	24	25	26	27	28	29	30
29										0.00153703
30										

Routes assignment

In this fourth stage of the transport method, the assignment of routes was developed, for the development of this allocation, the data obtained in the savings matrix table (3) were used, first, it is ordered from the highest to the lowest savings, then the corresponding combinations of the routes were made, resulting in a total of 435 possible combinations, if these combinations had any connection with another route, it was added, later, the demand for route 1 and route 2 is reflected, if in this case these routes has some connection route, the demand for that route is added, then the sum of the demand for routes 1 and 2 is made and the demand for the connection route is added to that result, as the case may be; if the sum of the demand is less than 10, which is the maximum cargo capacity of the motorcycle container, that route would be open for new connections, otherwise, if the sum of the demand is greater than the cargo capacity of the container, the route cannot be completed, therefore it is not a feasible route. It should be noted that if there is a combination of two clients that are located on different routes, that combination cannot be carried out, because the two have already been assigned and belong to two different routes, therefore the legend "two different routes" is assigned.

The amount of routes obtained by dividing the total clients demand, which is a total of 67, by the cargo capacity of the container, which is 10, resulted in 7 optimal routes. In the table (4), the route assignment is shown.

	SAVINGS	POSSIBLE ROUTE	ROUTE 1	ROUTE 2	CONNECTION	DEM 1	DEM 2	DEM C	DEM 1+2	DEM 1+2+C	CAP	POSSIBLE NETWORK RESTRICTION	
1	0.01449745	24-25	24	25		1	6		7	7	10	0-24-25	
2	0.01188223	8-13	8	13		1	1		2	2	10	0-8-13	
3	0.01152612	10-11	10	11		2	1		3	3	10	0-10-11	
4	0.01128933	11-25	11	25	Two different routes						10		
5	0.01126329	3-8	3	8	13	2	1	1	3	4	10	0-3-8-13	
6	0.01091645	12-25	12	25	24	2	6	1	8	9	10	0-12-25-24	
7	0.01065122	8-29	8	29	3,13	1	2	3	3	6	10	0-8-29-3-13	
8	0.01049997	12-24	12	24	25	2	1	6	3	9	10	0-12-24-25	
9	0.01041943	13-29	13	29	8,3	1	2	3	3	6	10	0-13-29-8-3	
10	0.00985857	11-24	11	24	Two different routes						10		
11	0.00938768	5-25	5	25	12,24	2	6	3	8	11	10	0-5-25-12-24	*NO*
12	0.00907591	10-30	10	30	11	2	1	1	3	4	10	0-10-30-11	
13	0.00898548	5-11	5	11	10,30	2	1	3	3	6	10	0-5-11-10-30	
14	0.00874794	5-12	5	12	Two different routes						10		
15	0.00862489	24-28	24	28	12,25	1	1	8	2	10	10	0-24-28-12-25	*Complete*

Route Assignment

*   *

*   *

425	2.6959E-06	11-21	11	21	Two different routes						10	*Complete*	
426	2.6813E-06	7-16	7	16	Two different routes						10	*Complete*	
427	1.6269E-06	12-29	12	29	Two different routes						10	*Complete*	
428	1.0948E-06	15-21	15	21	Two different routes						10	*Complete*	
429	9.1674E-07	9-19	9	19	Two different routes						10	*Complete*	
430	6.2145E-07	19-22	19	22	Two different routes						10	*Complete*	
431	6.0752E-07	7-17	7	17	Two different routes						10	*Complete*	
432	5.2211E-07	7-23	7	23	Two different routes						10	*Complete*	
433	1.4866E-07	25-29	25	29	Two different routes						10	*Complete*	

At the end of the routes assignment, it can be seen in Table (3) that in the last combinations each of the clients is already assigned to a route that is already complete, therefore, these new route combinations cannot be possible, because they are already complete.

V. RESULTS

Through the development of the assignment of routes, it gave us as a result the 7 optimal route combinations that allow the SME to generate savings in terms of distances, time and fuel costs.

Route 1: 0-12-28-25-24
Route 2: 0-3-21-19-4-13-29-8
Route 3: 0-7-20-5-30-11-15-10
Route 4: 0-18-22-9
Route 5: 0-16-26-6
Route 6: 0-17-23
Route 7: 0-2-27-1-14

Making use of the saving equation (2) and taking the results obtained at the time of calculating the distances to go from the SME to the 30 clients and to go from one client to another found in table (1), the saving of the distances of the 7 assigned routes of sending them from one client to another is calculated.

In table (5), the results obtained from the combinations of the 7 routes are shown, likewise, the results obtained by calculating the saving of the distances of the 7 routes are shown. When performing the corresponding calculations, gives us as a result a total in the sum of the calculation of the saving of the distances of the 7 routes with the different combinations of 0.117722589. See table 5.

TABLE IV. CALCULATION OF DISTANCES

OPTIMAL ROUTES		
Routes		***Distance***
1	0-12-28-25-24	0.031592088
2	0-3-21-19-4-13-29-8	0.034568209
3	0-7-20-5-30-11-15-10	0.033782827
4	0-18-22-9	0.007223908
5	0-16-26-6	0.005074304
6	0-17-23	0.002425472
7	0-2-27-1-14	0.00305578
TOTAL		0.117722589

Geographic location in Excel and Google Maps

The results of the combinations of the 7 routes obtained, the distribution of each one of them was captured in a graph in Excel and in the same way they were captured in Google Maps where it focuses more on reality.

At the time of capturing the location of the 7 routes, it can be seen that when making the comparison between the graph in Excel and Google Maps, it is possible to have a congruence in terms of the distribution of the routes.

In the Figure 2 shows the distribution of the routes in a graph in Excel and in the figure 3 shows the distribution in Google Maps.

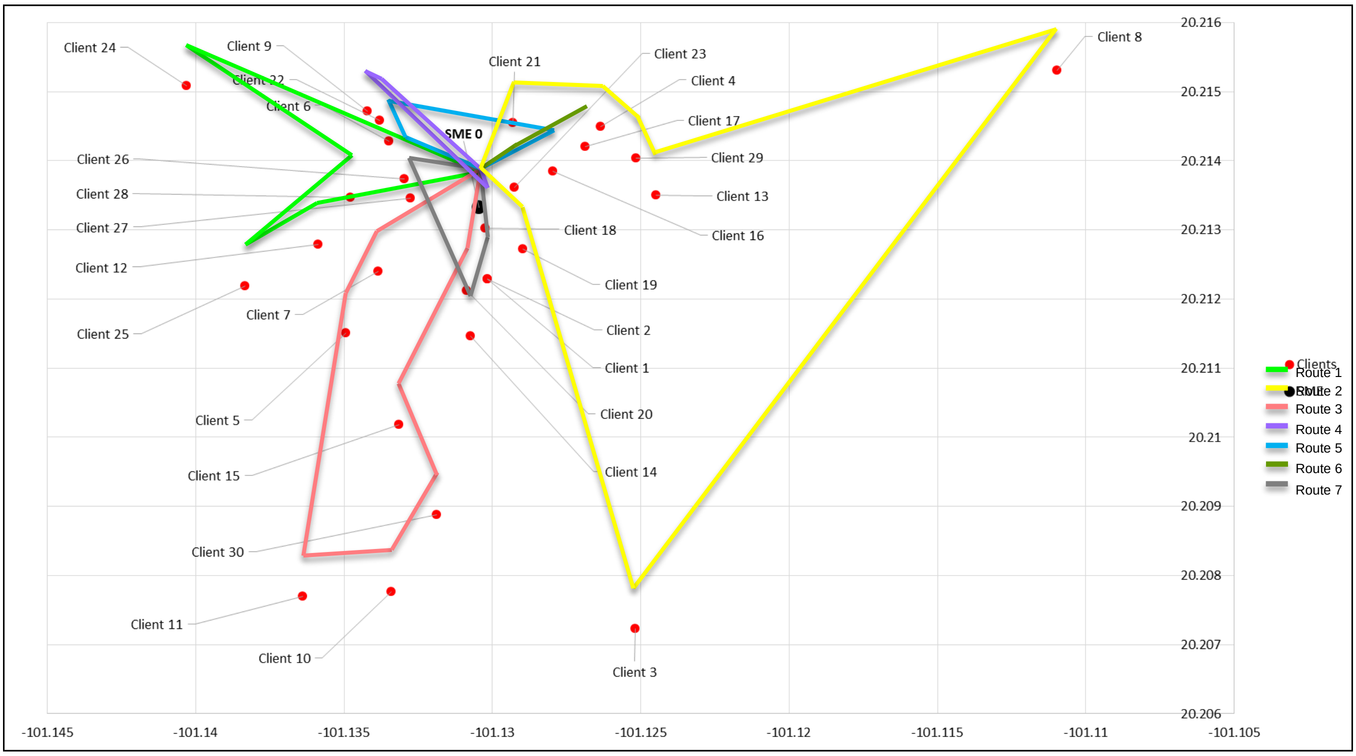

Figure 2. *Geographic location in Excel.*

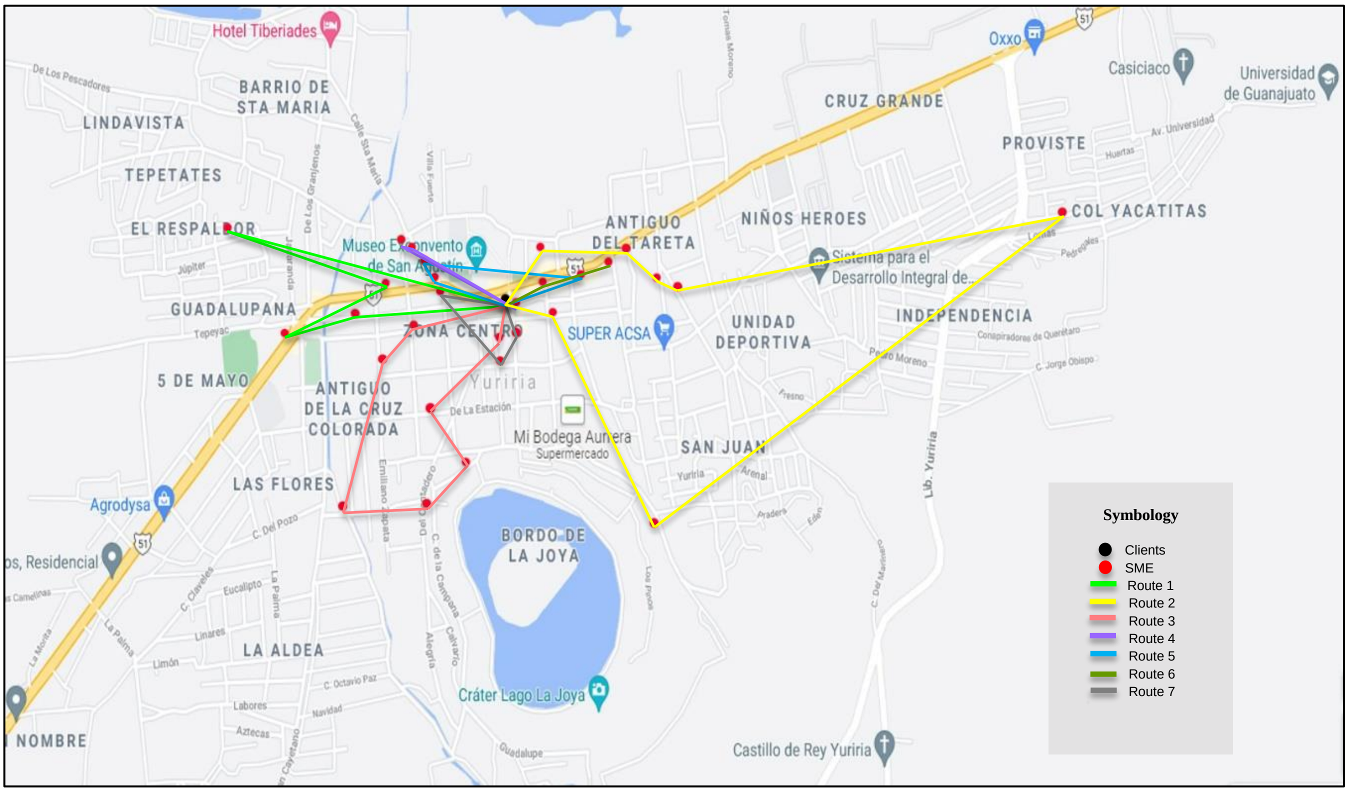

Figure 3. *Geographic location in Google Maps.*

VI. Conclusions

The study SME belonging to the restaurant sector does not have a tool that optimizes the distance traveled when distributing orders, therefore, an important area of opportunity has been found to be able to develop and implement the transportation tool using the Clarke & Wright Savings algorithm to solve your transportation problems, which, when implemented, gave us as a result 7 combinations of routes which guarantee the SME under study an effective distribution of its products to the home of each of its clients, these routes obtained guarantee savings in terms of distances traveled, savings in delivery time when carrying orders and significant savings in the cost and expense of fuel for the motorcycle where deliveries are made. It is important to highlight the importance of this tool using the Clarke & Wright Savings algorithm for any company regardless of its sector, because it is a very effective and important solution for the VRP and through its application significant savings can be obtained in terms of distribution, time and money.

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