Structuring Reverse Logistics for Waste Cooking Oil with Geographic Information Systems

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Abstract

The objective of this paper is to utilize Geographic Information Systems (GIS) as a routing tool for a Reverse Logistics application involving waste cooking oil. The study object is a company which carries out oil collection in the city of Itajubá, Minas Gerais (MG), Brazil. The research method is modeling and simulation. After collecting the necessary data, routing scenarios were generated and analyzed using GIS, with parameters varying for the number of vehicles utilized in collection, capacity and scheduling restrictions imposed by the supplying establishments. Based on the results of the simulation, it was seen that there was a great impact caused by the sequencing of the collection points over the total distance covered. It was possible to re-route the sequence using a Milk Run approach, thus rationalizing the routes, the quantity of oil collected and the vehicle capacity.

1. Introduction

On an ever-increasing scale, both enterprises and society as a whole are expected to seek out sustainable development solutions which aim to produce without harming the environment or compromising the ability of future generations to meet their needs. One of the main reasons for this preoccupation is the rate at which products are discarded, seeing that most of these products are not ecologically disposed of and cause both societal and environmental damage. With the goal of minimizing these impacts, products which have already been utilized can be sent to recycling and reuse processes, where they are treated in order to be reintroduced on the market.

If society benefits on one hand from compliance with environmental legislation and the diminishing of harmful impacts on the environment, enterprises and organizations might also benefit through the leveraging of economic opportunities (Leite, 2003). One conditional factor needed in order for these recycling and reuse processes to occur is the collection of residual material and its delivery to processing units, where a transformation process turns them into new products. The process of returning a used product to the business cycle is known as Reverse Logistics (RL), and aims to manage the flow of products from their consumption point to their origin, reuse or final discarding.

In search of new sources of alternative energy and freeing itself from dependence on petroleum and its derivatives, biodiesel has shown itself to be a viable option for the Brazilian market. Biodiesel is obtained from soybeans, peanuts, sunflower seeds, palm oil seeds and other oil seeds which are easily found throughout the country. Oil used for frying food is also an option (Biodieselbr 2011). In the case of the latter example, the cost of raw material drops to practically the transportation costs related to the reverse logistics of this material, seeing that the product is generally discarded by society after use.

Within this context, the objective of this investigation is to use GIS as a routing tool to determine collection routines in the reverse logistics of frying oil destined for bio-diesel production. This paper is structured as follows: After this introduction, in section 2 the theoretical review will touch on RL, frying oil, vehicle routing and GIS. In sections 3 and 4, the research method and simulation development are addressed. Section 5 discusses the study's findings and conclusions, which is followed by bibliographic references.

2. Theoretical review

New environmental protection laws seek to make enterprises more responsible for discarding the materials which they produce, thus making them seek a more efficient collection system for their residue or by-products. Within this context, the concept of RL stands out as an attractive approach to dealing with these new legal stipulations. Leite (2003) states that RL is an area of logistics which is responsible for managing the return of goods, post-sale and post-consumption, to the productive or business cycle, thus aggregating economic, ecological, and logistical value. Seeing as RL uses many of the elements of Direct Logistics, such as material flow, transports, stock, and information systems, efficient planning and sound structuring are necessary to diminish undesired costs are not added to the supply chain (Campos, 2006). According to Oliveira and Lima (2010), RL has become extremely important in the management of urban solid waste; obviously, joining RL with recycling enables environmental, economic and societal gains.

Specifically in the case of waste cooking oil, the RL chain is made up of both large generators (bars, restaurants, hotels and diners), and small generators (residences). According to Guabiroba and Dagosto (2011), large waste cooking oil generators sell their residuals to pre-established clients, who process this oil and transform it into other products. Even so, in many cases, part of this oil is discarded inadequately. In a large number of residences, waste cooking oil goes down the drain and into domestic sewer and water treatment systems. Furthermore, a liter of oil is capable of contaminating a thousand liters of water, enough water for a person to survive for 40 years. The presence of oil in rivers creates a non-breathable layer which keeps light and oxygen from entering, thus compromising the aquatic food chain (Biodieselbr, 2011).

When collected and sent to retreatment units, the oil can be reutilized as a raw material for many products, such as soap, biodiesel, paint, varnishes and even pet and livestock food. The focus of this study is on biodiesel production, a biofuel derived from renewable biomass to be used in internal combustion motors or, according to regulations, to generate other types of energy, which can partially or totally substitute fossil fuels. As previously stated, in the search for new energy alternatives which minimize petroleum dependence, biodiesel has shown itself as a great option, given the potential that Brazil presents in producing biofuels. In 2010, Brazil was the world's second most prolific producer of biodiesel, coming after only Germany (Biodieselbr 2011).

Biodiesel is obtained from soybeans, palm oil, peanuts and sunflowers seeds, among other oilseeds easily found in Brazil, aside from waste cooking oil g and animal fat. Common alcohol (ethanol) is added to the oil, and this mixture goes through a transesterification process with the main goal of separating glycerin from vegetable oil, thus making it less dense and more viscous. The glycerin obtained can be utilized for soap production. Seeing the importance of the potential for biodiesel in Brazil, the government created the National Program of Biodiesel Production and Use (PNPB – Programa Nacional de Produção e Uso do Biodiesel) and in January of 2004, Brazilian Federal Law 11.097 was created, which officially introduced biodiesel into the energy matrix and established a 5% minimum to be added to diesel sold to final consumers. The law reinforces the importance of developing new technology to optimize biodiesel production (Biodieselbr, 2011).

According to Guabiroba and Dagosto (2011), using waste cooking oil as raw material for biodiesel production can considerably reduce production costs, seeing that around 68% of total costs come from acquisition of the raw material (unused oil). Costs can drop by as much as 24% when waste cooking oil is used, thus making biodiesel more competitive on the market. Due to the geographically dispersion of generating sources, collecting waste cooking oil in urban areas can be a complex and expensive activity. When logistics are not well-structured, any additional transport, fuel or handling costs will be added to the final cost of the fuel. Considering all of this together, the use of computational simulation to optimize the collection waste cooking oil is an attractive option to resolve collection problems.

Guabiroba and Dagosto (2011) assert that most of the time, it is the supplier who acts in the collection process, calling the company when the recipients are full. This style of collection is known as a Milk Run, where raw material collection is carried out at scheduled times, normally using a single vehicle. Traditionally used by the automotive industry, the main objective for this supply system is to reduce collection costs through economy of scale and route rationalization, thus helping maintain low raw material acquisition costs and in turn helping reduce the cost of the final product (Röhm *et al*. 2010).

Special attention must be paid to the routing for waste cooking oil due to the fact that transport makes up a large portion of the recycling costs. An efficient collection system will make the recycling or reuse process viable and profitable; while an inefficient collection system can make a process infeasible, thus heightening the chances of the oil being discarded in ways which are harmful to the environment.

Routing is utilized to determine the series of routes and sequencing of stops for geographically dispersed points in places where demand exists and was previously determined. Aside from this, routes should be defined in order to minimize total service costs, thus assuring that each collection point is visited just once (Cunha, 2000).

Over the past two decades, many software packages have been developed to resolve routing problems. However, this type of software generally does not address the geographic location of the points to be serviced (clients); this, in turn, makes GIS an interesting option (Enomoto and Lima, 2007). According to Church (2002), six inter-related factors stand out as explanations for the use of GIS: (1) a wide range of GIS software available via commercial and academic applications; (2) an increase in computational capacity in storing and retrieving large quantities of data in reasonable time and costs; (3) more sophisticated high-resolution printers; (4) greater availability of geographic data from private companies and governmental agencies at accessible costs; (5) expansion of the use of remote sensors, which requires the use of systems able to deal with large quantities of data; (6) the development of Global Positioning Systems (GPS), which facilitate the collection of spatial data at relatively low costs and with high levels of precision.

Due to the specific requirements for transport and the adoption of information technology in this area, researchers have increased their efforts to improve GIS so that it can be applied to the area of transports and routing. In this paper, TransCAD 5.0, which is a GIS used for transports which utilizes, among other basic GIS functions, specific routines for solving logistical problems. Among these routines, the software also possesses a specific module which resolves different types of vehicle, operational research and transport problems in general. The software's vehicle routing routine deals with data preparation, problem resolution, vehicle scheduling, route elaboration, reports and graphs.

3. Materials and methods

Chwif and Medina (2007) assert that simulation allows for the evaluation and analysis of real systems via the construction of computational models, which enable researchers and professionals to respond to the "What if…" question. This ability makes simulation a powerful decision-making tool. Thus, in accordance with the objective of this research, modeling and simulation were utilized to analyze the transport problem with the goal of finding optimal mathematical solutions for a global goal. One of the advantages of its application is that the generated proposals can helps decision-makers in the moment of their choices, mainly when applied to complex problems.

In order to obtain data, a Garmin, Oregon 300, GPS device was used on the routes to typical collection sites during operating hours. Along the trajectories, the entire route was recorded and information such as collection points, average speed, time stopped per point and total trajectory time were captured. Then, the collected data were converted into a format which is compatible with TransCAD (shp), utilizing the software Trackmaker PRO. After these procedures, it was decided that researchers would group the simulation into two groups, given that not all of the large suppliers were included in the weeks that the data were collected. The first group is made up of those comparisons carried out with the real operation of the company (one scenario) and in the second group are those possible simulated with alterations to key parameters. Such parameters include vehicle capacity, number of routes to visit all points, and scheduling restrictions for suppliers, among others.

The company Minas Bioenergia (www.minasbioenergia.com.br) was created in 2007 and operates in Itajubá, Minas Gerais, where the company collects and processes waste cooking oil to be sold to biodiesel production facilities. The processing center has a capacity of 5,000 liters and is located in the city center. The company has developed a Clean Water Project (Projeto Água Limpa) which stimulates the population to carry their oil to Eco-Points (schools and churches). For each four liters oil collected, donating institutions earn points which can be traded for prizes such as sports equipment, books and computers. Furthermore, the company has set up partnerships with bars, restaurants and health care providers in order to obtain significant volumes of oil. With increasing demand, it is fundamental for Minas Bioenergia to develop efficient logistical operations which are able to serve all collections points at the lowest possible price. The vehicle used for collection is a VW Saveiro, whose capacity is 500 liters of oil, stored in 10, 50-liter containers. These containers are made available by the suppliers; on the day of collection, empty containers are exchanged for filled containers. In schools and churches, the oil is collected in PET bottles, as these recipients are more accessible to the community. In these locations, collections occur less frequently, as the company waits for these grass-roots points to save up a volume worthy of traveling out to the collection point. Suppliers call Minas Bioenergia to advise that the recipient has been filled and can be collected.

Suppliers normally solicit the collection for the same day, which can complicate the scheduling of routes. Furthermore, some suppliers even threaten to throw the oil out if it is not collected on the same day. This creates an increased sense of urgency for some collection points, thus forcing the driver to modify the established routing. A point being visited on one day of the week does not necessarily indicate that it will always be serviced on that day, as the collection frequency is quite different for each one. With no established route, the cost of collecting the oil would become too great for the company to handle, seeing that the vehicle would return to the deposit multiple times without being at full capacity. Thus, the objective of this investigation is to propose routes which can optimize the collection system for Minas Bioenergia in order that the company can have a better visualization and greater control of their processes through the use of GIS and Milk Run strategies.

4. Routing scenarios

As cited in item 4.1, scenarios were generated using GIS for two distinct groups (Current System and with alterations to the parameters), which are detailed below.

4.1. Current system (no scheduling restrictions)

In this first scenario, the objective is to reproduce the company's current collection system, maintaining the same parameters verified in the seven routes obtained using a GPS device: number of collection points, average speed, average time per stop – 15 minutes in commercial establishments (bars, restaurants, butchers and supermarkets), and 60 minutes in industrial centers and ACIMAR (The Association of Recyclable Materials Gatherers of Itajubá). Table 1 shows the results of the routing using GIS and the comparison with the data from the GPS.

Table 1. Scenario 1 – Current System

GPS				GIS		Comparisions	
Rota	Total Time	Distance Covered (km)	Average Speed (km/h)	Total Time	Distance Covered (km)	Reductio Time (%)	Reductio Distance (%)
1	0h 42	11,4	16	0h 22	3,8	47,6	66,7
2	1h 48	19,2	16	0h 54	5,6	50,0	70,3
3	0h 58	15,9	23	0h 38	8,5	34,5	46,5
4	1h 21	9,0	23	1h 08	3,3	16,0	63,3
5	3h 05	14,7	23	2h 56	10,1	5,0	31,3
6	2h 34	20,4	23	2h 08	10,0	17,5	51,0
7	1h 08	8,1	23	1h 05	2,1	4,4	74,1
To-tal	11 h36	98,7	-	9h 11	43,4	20,83	56,0 2

By analyzing the routes individually, it can be seen that the sequence of stops significantly influences the distances and times. Routing the same points in GIS, the stop sequence changed. This happened because the software was programmed to work with minimal distances, which resulted in substantial reductions. For example, in Scenario 1 there was a 66.7% reduction in the total distance covered, which also helped to reduce time consumed on the route by 47.6%. In scenario 6, the sequence of points remained the same, but there was a reduction of 51% in distance and 17.5% in time, simply by choosing an alternative route (Figure 1).

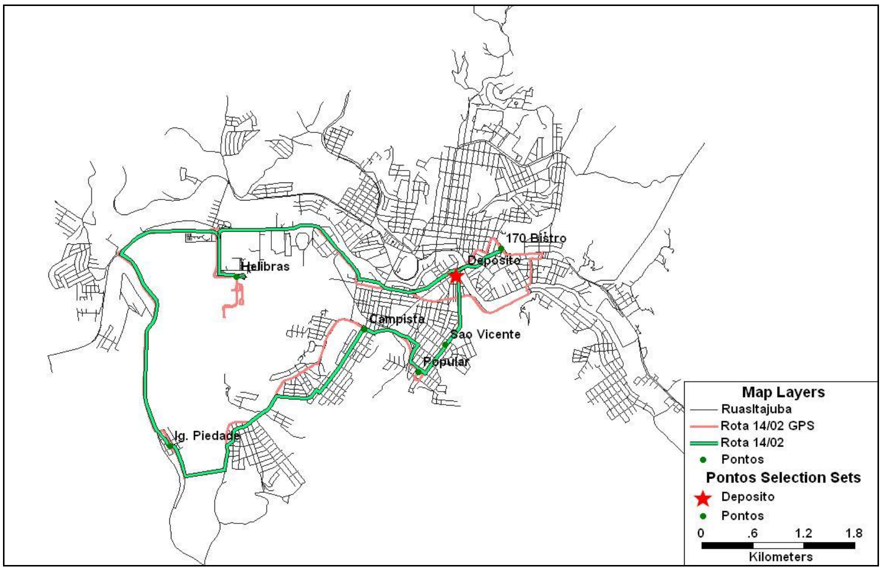

Fig. 1. GPS Route vs. x GIS in Scenario 6

4.2. Routing scenarios using GIS

In the second group of scenarios (Scenarios 2 to 7), the objective was to analyze the results of the alterations in the parameters in the collection system. These scenarios were carried out utilizing the data collected in the GPS as well as utilizing the additional information provided by the company, such as the number of collection points which had not been registered in the collection period using GPS (Table 2). The consolidated results are shown in Table 3. It is important to highlight that, in all of the scenarios, all of the demand was considered in relation to its frequency in order to arrive at the total collected for the month. For the purposes of this simulation, these total values were considered as the basis for daily routing; however, these could be combined throughout the month, as will be discussed the next sub-item.

Table 2. Collection Points for Minas Bioenergia

Classification	Supplier	Volume average/month (liters)	Collection frequency (times/month)	Scheduling restrictions
Butchers	Boa Vista	35	1	8h–17h
	São Judas	137	4	8h–17h
	São Vicente	50	1	8h–17h
	Assados do Sul	150	4	8h–17h
Association	Acimar	1000	2	8h–17h
Industry	Helibrás	48	1	8h–16h
	Imbel	400	4	8h–16h
Bars, restaurants and diners	Bar do Pedro	30	1	8h–17h
	Bar do Rogério	70	2	8h–17h
	Carvão e lenha	50	1	8h–17h
	Dom Cesário	55	2	8h–17h
	Mister Food	30	1	8h–15h
	Mistura Brasileira	49	2	8h–16h
	Pastelaria do Jair	50	1	8h–17h
	Pastelaria do Kawai	58	1	8h–17h
	Pastelaria Real	50	1	8h–17h
	170 Bistrô	60	1	16h– 18h
	Pizza & Cia	67	2	16h–18h
	Pastel de Milho	53	1	15h–17h
	Red Bar & Chopp	144	2	15h–17h
	Restaurant Quente Frio	50	1	8h-7h
	Restaurant Sem Nome	130	2	8h–14h
	Restaurant Shitake	83	2	8h–17h
	Restaurant Telhado	37	1	8h–15h
	Restaurant Tererê	40	1	8h–15h
	Xodó	50	1	8h–15h
Supermarket	PiuSapore	40	1	8h–17h
	Campista	73	1	8h–17h
	Popular	30	1	8h–17h
	Rosa Garcia	59	2	8h–17h

Scenario 2 was generated without scheduling restrictions for collection in any establishments, and without capacity restrictions per vehicle, with the objective of determining the total collection time if the vehicle had to pass through all points in the same day and had the capacity to collect the raw material. The total time for this case was 10h19min, with a total distance of 14.3 km and total volume collected of 3.178 liters. Considering the current capacity of the truck (500 liters), a vehicle with larger capacity would be beneficial. Larger, loading/hauling vehicles such as the Sprinter and Ford F4000 are two examples of viable alternatives which possess capacity for 3,800 and 3,910 liters, respectively.

Scenario 3 did not consider scheduling restrictions at collection points either; however, the vehicle capacity was altered to the current capacity available with the company vehicle. In this case, 7 routes were generated. As the routes do not need to be carried out at the same time, only two vehicles would be sufficient to visit all of the suppliers in one day, while respecting commercial business hours (8 a.m. to 5 p.m.).

Table 3. Results from Scenarios 2 to 7

Scenarios	**Route**	**Number of Points Served**	**Total Route Time**	**Total distance (km)**	**Volume collected Liters**
2	1	30	10h19	14,3	3.178
3	1	9	03h16	7,6	416
	2	2	01h25	4,5	460
	3	1	00h39	4,1	500
	4	1	00h39	4,1	500
	5	6	01h37	3,2	411
	6	5	01h18	1,5	444
	7	7	01h51	2,9	447
	Total	**31**	**10h45**	**27,9**	**3178**
4	1	10	03h34	7,8	483
	2	2	01h26	4,5	460
	3	1	00h40	4,1	500
	4	1	00h40	4,1	500
	5	8	02h11	4,6	491
	6	4	01h05	2,3	407
	7	5	01h18	3,1	337
	Total	**31**	**10h54**	**30,5**	**3178**
5	1	8	03h03	11,9	497
	2	5	02h01	10,4	499
	3	1	01h41	7,2	481
	4	4	01h25	6,7	489
	5	4	01h29	9,5	494
	6	4	01h29	9,6	480
	7	2	00h59	9,6	400

	8	5	01h26	7,2	473
	Total	**32**	**13h33**	**72,1**	**3813**
6	1	6	02h32	11,2	481
	2	3	01h30	10,2	480
	3	1	01h26	7,2	500
	4	1	00h40	6,7	500
	5	1	00h40	6,7	500
	6	1	00h40	6,7	500
	7	1	00h40	6,7	500
	8	4	01h06	4,2	476
	9	5	01h21	3,9	486
	10	2	00h35	3,5	409
	11	3	00h48	2,1	460
	12	2	00h34	2,4	389
	13	1	00h16	1	300
	14	3	00h46	0,4	375
	Total	**34**	**13h34**	**72,9**	**6356**
7	1	20	08h47	21,2	4423
	2	12	03h08	5,3	1522
	3	2	00h32	1,6	411
	Total	**34**	**12h27**	**28,1**	**6356**

For Scenario 4, the capacity was kept the same for the collection vehicle (500 liters), but hourly restrictions were used. Most of the points are visited during commercial business hours (from 8h to 17h); nonetheless, there are some establishments which set up different, shorter time windows, such as the cases of 170 Bistrô and Pizza & Cia (from 16h to 18h). The result obtained was similar to the previous scenarios, shifting only the combination of points served in each of the 7 routes generated. Two vehicles with a capacity of 500 liters would be sufficient to attend all of the points in the same day without scheduling restrictions.

Scenario 5 aimed to simulate what would happen if the collection points gradually increased their supply of oil. In order to do this, a 20% increase in volume to the current level was considered, while leaving vehicle capacity at the current level. The program generated 8 different routes and, as seen in Scenarios 4 and 5, two collection vehicles would be sufficient to meet the needs of all the collection points in a single day, seeing as in route 8, the 4 clients with shorter time windows of availability were grouped together. Scenario 6 aimed to simulate a more substantial increase (100%) in the volume collected by the company. Vehicle capacity was kept the same. In total, 14 routes were generated which could be done in a single day by two vehicles. Scenario 7 observed these same conditions;

however, 5000 liter vehicles were considered, thus reducing the number of routes to 3, needing to be covered by only two vehicles.

Table 4 shows a comparison among scenarios 2 to 7. From Scenario 2 to Scenario 3, for example, where no time restrictions are considered, there would be a substantial increase in distance covered (95%) and a small increase in the amount of time (4%) for the same volume, which was a direct consequence of the utilization of two small vehicles instead of one larger capacity vehicle. Based on these generated scenarios, it can be stated that there is a pattern behavior: the impact of using a greater number of vehicles is always greater in terms of distance than time. Thus, when a company opts to amplify the number of vehicles utilized, it will better meet the needs of its clients in terms of scheduling, but this will also imply a greater collection cost in terms of kilometers covered. It should be noted, however, that in spite of the great potential in using GIS to generate routing scenarios, the quantitative results must be contextualized and, in many cases, interpreted as important indicators that adjustments to certain system parameters could bring benefits to the collection system. For example, in Scenario 3, if the schedule were two hours longer (from 0800h to 1900h), having 11 hours available would be sufficient for just one vehicle to complete all routes. In Scenario 7, if the client 170 Bistrô were to accept a slightly longer scheduled collection time (increasing by just 1 hour), routes 2 and 3 could be put together into just one.

Table 4. Comparison of Results

Scenario	**Stops Visited**	**# of vehicles (Capacity)**	**Total Route Time**	**Total Distance (km)**	**Volume Collected (liters)**
2	31	1 (3.800 liters)	10h19min	14,3	3.178
3	31	2 (500 liters)	10h45min	27,9	3.178
4	31	2 (500 liters)	10h54min	30,5	3.178
5	33	2 (500 liters)	13h33min	72,1	3813
6	34	2 (500 liters)	13h34min	72,9	6356
7	34	2 (5.000 liters)	12h27min	28,1	6356

4.3. Collection scheduling

Although it is relevant to consider daily routing options using GIS, for the goals of this study, it would not be advisable to disregard the monthly collection routine carried out by Minas Bioenergia. Thus, it is important for a weekly collection schedule to be elaborated in order that all collection points can be better served. To do this, a clustering approach was used with GIS, which groups points according to their proximities, respecting system restrictions. In this case, schedules were considered for establishments (Table 2) and vehicle capacity was considered for the company's current truck (500 liters). The model's output presented 6 distinct groups, which can be seen in Figure 2 (4 routes and two points with high individual demand, ACIMAR and IMBEL).

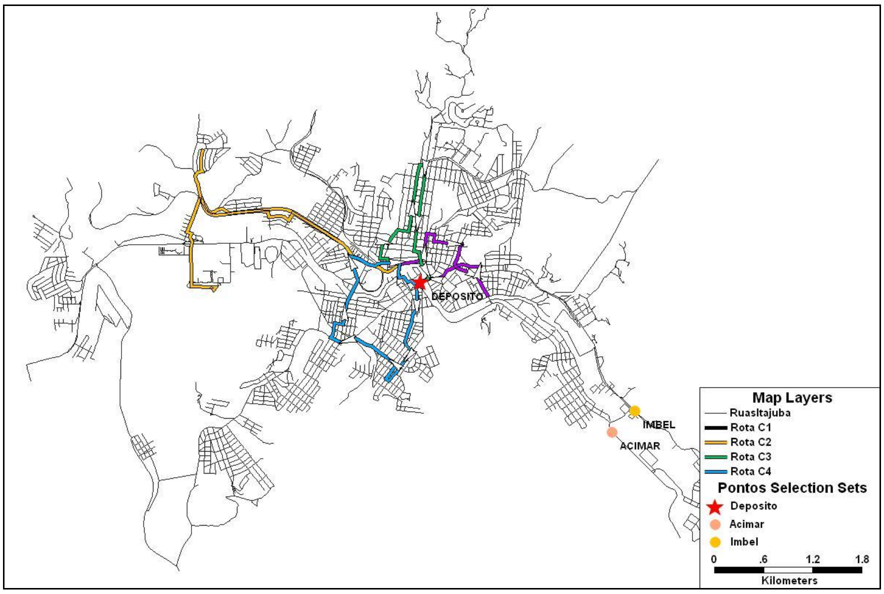

Fig. 2. Clusters

Based on this scenario, scheduling was elaborated for the company, as described in Figure 3. Two days out of the week (Tuesdays and Thursdays) would be dedicated to oil processing, while the other days would be used for collection purposes. The first week demonstrated great collection volumes, concentrating on frequent monthly collection points. The third week saw a greater collection volume than the second and fourth weeks, due to the bi-monthly collection points being included in this week. Just three collection points demanded weekly collection in current operations: Imbel, São Judas Butcher and Assados do Sul Butcher. Another point to be considered are the many time windows available during the morning hours, which is a direct consequence of the number of points which only allow for collection in the afternoon. However, these times can be used by the company to carry out collection at schools and churches throughout the city which were not considered during this study due to their low frequency and demand.

Week 1	Monday	Tuesday	Wednesday	Thursday	Friday
morning	Bar do Rogério São Vicente Pastel do Jair Mister Food Campista Telhado Piu Sapore Quente e Frio Carvão e Lenha Sem Nome	Oil Processing	-	Oil Processing	-
			Lunch		
afternoon	Imbel Ranchinho Helibrás Sup. Popular Aç. Boa Vista		Tererê Pastel do Kawai Pastelaria Real Dom Cesário Xodó Mistura Brasileira Assados do Sul Aç. São Judas Red Bar & Chopp 170 Bistrô Rosa Garcia		Acimar Bar do Pedro Shitake Pizza & Cia

Week 2	Monday	Tuesday	Wednesday	Thursday	Friday
morning	-	Oil Processing	-	Oil Processing	-
			Lunch		
afternoon	Imbel		Assados do Sul Aç. São Judas		-

Week 3	Monday	Tuesday	Wednesday	Thursday	Friday
morning	-	Oil Processing	-	Oil Processing	-
			Lunch		
afternoon	Sem Nome Imbel Bar do Rogério		Mistura Brasileira Dom Cesário Assados do Sul Aç. São Judas Rosa Garcia Red Bar & Chopp		Acimar Shitake Pizza & Cia

Week 4	Monday	Tuesday	Wednesday	Thursday	Friday
morning	-	Oil Processing	-	Oil Processing	-
			Lunch		
afternoon	Imbel		Assados do Sul Aç. São Judas		-

Fig. 3. Collection scheduling

5. Conclusions

GIS proved to be a valuable tool for executing routes and scenarios in general due to its ease in treating data and information as well as including restrictions to the studied process. Furthermore, it enabled researchers to obtain and treat geographic data in GPS interface, bringing an alphanumeric database to the geo-referenced information. The routing routine also allowed for the definition of the ideal capacity of the vehicles in the simulated scenarios, while the clustering tool aided in better division of the current collection service points.

For the specific case of the analyzed company, the ease in using GIS to generate routing scenarios turned out to be very useful in terms of scheduling, mainly when analyzing the potential growth of the oil for collection. Comparing current parameters, collected using a GPS device, along with the routes generated using GIS, it was possible to conclude that the current vehicle (with a capacity of 500 liters) is sufficient to carry out the collection in the main supplier points, since this collection does not need to be carried out during a single day of the month. Considering the relatively small amount collected, times and route distances still do not constitute restrictions to the process. Along these lines, with a routine for cluster formations using GIS, it was possible to define the routes based on the volumes, restrictions and current vehicles, which aided in the elaboration of the collection process schedule per week. This scheduling forecasts weekly time windows, and even with an eventual increase of 100% of the volume collected (simulated in the routing routine), the company would be able to take care of the oil supply without purchasing or upgrading their current vehicle.

Through the utilization of this scheduling, there should be an increase in supplier fidelity and trust, as they will become more accustomed to a set schedule during a pre-determined period of the day. However, in order to put this plan into action, the company must be available to change the way in which it executes its process: instead of suppliers calling and asking for the company to pick up the oil, the company should accept a Milk Run model, in which they visit multiple suppliers and collect the oil containers, even when they are not completely full. Even if there is a loss in volume collected using this system due to half-filled containers, the company will gain in terms of scheduling, as the scheduled collections allow for better planning and overall production efficiency.

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