Reverse Logistics of Recovery and Recycling of Non-Returnable Beverage Containers in the Brewery Industry: A "Profitable Visit" Algorithm

Mario Monsreal[1,2,3]

[1] AutoID LAB, Zaragoza Logistics Center, Zaragoza, Spain.
[2] Center of High Management in Engineering and Technology,
Anáhuac University Mexico, México City, México.
[3] Latin-American Center of Logistics Innovation-México, México City, Mérida, México.

Abstract. Reverse logistics is one of industries´ activities that is still little known and developed. This paper analyses the necessities of collecting non-returnable packaging at the point of sale, as well as their processing and sale to recycling companies, while considering marketing and operational variables for the reverse scheme. The objective is to increase the quality of recycling material by avoiding contamination and therefore, raising the quantity of recycled material used in the production of new packages. The pilot project analyses the operation of a brewery company in a medium-sized city in México. A collection system for non-returnable glass bottles and cans is designed by applying routing algorithms. Specifically a new "profitable algorithm" based on the well-known Nearest Neighbor is proposed and compared in order to achieve higher volume of collected material while lowering the cost of collection.

Keywords: Reverse Logistics, Non-Returnable Packages, Recycling, Routing algorithm

1 Introduction

Recycling of beverage packaging is a common activity in Western Europe, Japan, Canada and the United States. Usually, non-refillable beverage bottles and cans are returnable in order to be recycled. On the other side of the coin, in developing countries, there are still deficiencies in the development of organized packaging recycling systems.

This paper analyses the requirements of a reverse logistics network of non-returnable beverage packaging in Mexico's Brewery Industry and presents the results of the economic analysis in the case of implementing the system in a particular city selected for the pilot study.

The interest of recycling non-returnable packaging is a voluntary company initiative, therefore a deposit system is not considered.

The objective is to increase the quantity of recycled material used in the production of new packaging, while keeping recycling costs at their minimum. It allows resources to be saved and waste to be reduced.

2 Reverse Logistics Network

The concept of reverse logistics has been created to respond to the necessity of businesses to develop and/or restructure their material returns. There are different reasons that have motivated the development of this area such as strict environmental regulations, customer demand or economically driven opportunities to reuse products or recycling materials [1].

There are many definitions of reverse logistics in the literature [2]. However, the most suitable definition might consider the reverse logistics within the frame of the logistics in general. Rubio Lacoba (2003) [3] defines the reverse logistics as "the process of planning, developing, and efficiently controlling the flow of materials, products, and information from the place of origin to the place of consumption in such a way that while satisfying the consumer's needs, the available remaining material is managed to be reintroduced into the supply chain, obtaining an added value and/or if not possible procuring a suitable disposal of this remaining material". The concept of reverse logistics is taken as a reference to analyze the current situation in the management of non-returnable packaging and to propose an improved system.

2.1 Current Situation

Currently non-returnable packages are disposed of by consumers in the unsorted municipal waste. At the dumpsite, they are partially recovered by "waste pickers" and sold to recycling companies. Packaging producers buy recycled materials; however, given their low quality, as they have already been mixed with other substances, only a small proportion, around 20 percent of these materials can be used in the production of new packages [4]. Figure 1 describes the material flow in the current situation.

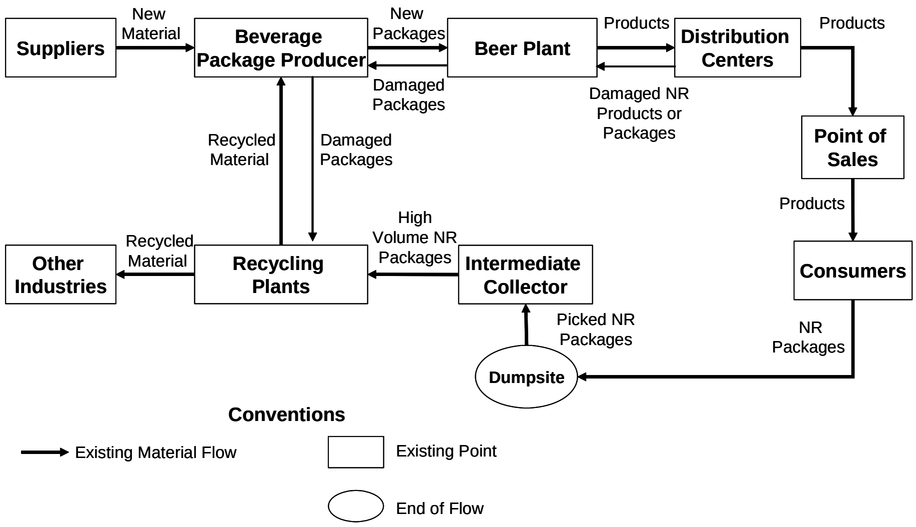

Fig. 1. Current situation.

2.2 Proposed Network

In order to increase the quality of recycling material by avoiding contamination at the dumpsite and therefore, raising the quantity of recycled material used in the production of new packaging; it is necessary to collect the non-returnable packages separate from other waste. The proposed recovery and recycling network [5] (Figure 2) considers collecting the packages at the point of sale and transporting them to a recovery center to be conditioned before sending to recyclers.

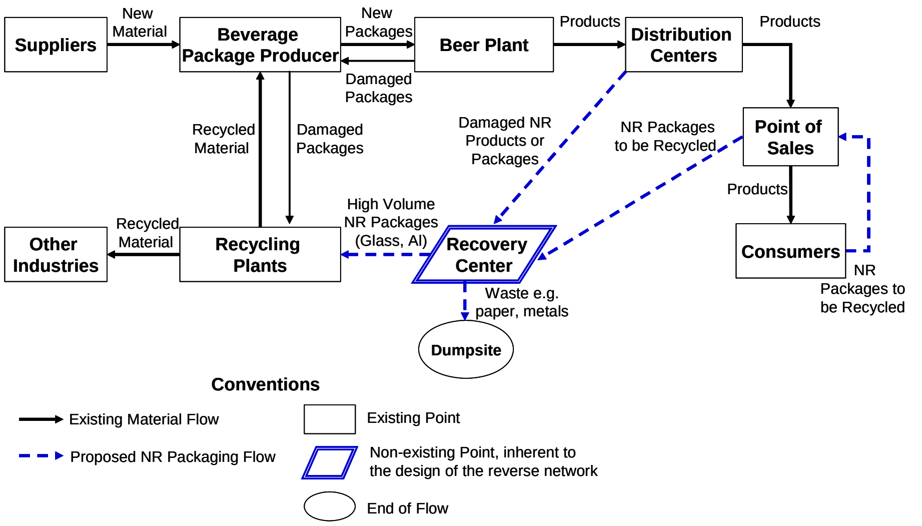

Fig. 2. Proposed recovery and recycling network.

3 Pilot Study

3.1 Delimitation

The pilot project analyses a medium-sized city in México, which was selected as one of the cities in the Mexican Republic with the highest consumption of beverages in returnable containers. This city is placed in the fifth position of consumption by volume and in which the company has the largest market share. [6] The pilot project analyzes the recycling of non-returnable packaging in the brewery industry. In this case, non-returnable glass bottles and aluminum cans (see figure 3).

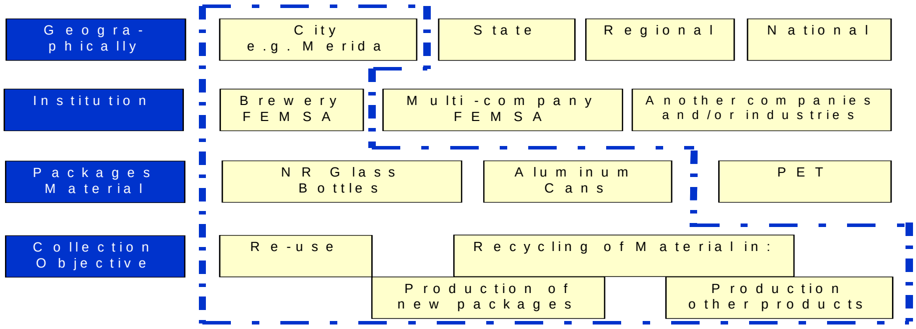

Fig. 3. Delimitation of the Pilot Project.

Figure 4 represents the proportion of non-returnable packaging in the year of the study and figure 5 shows the growth projections until the year 2015.

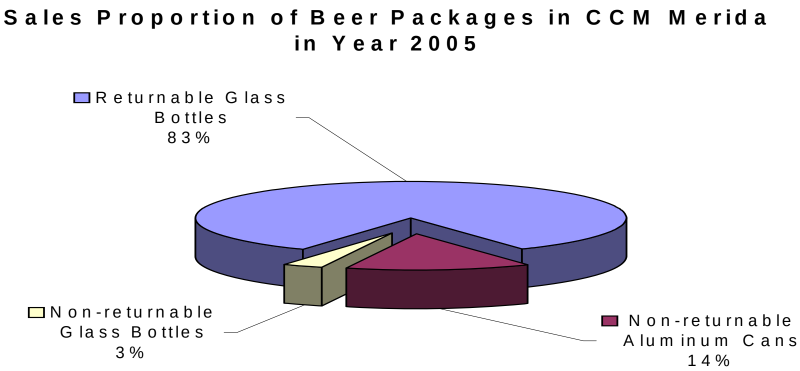

Fig. 4. Proportion of beer packaging in year of the study.

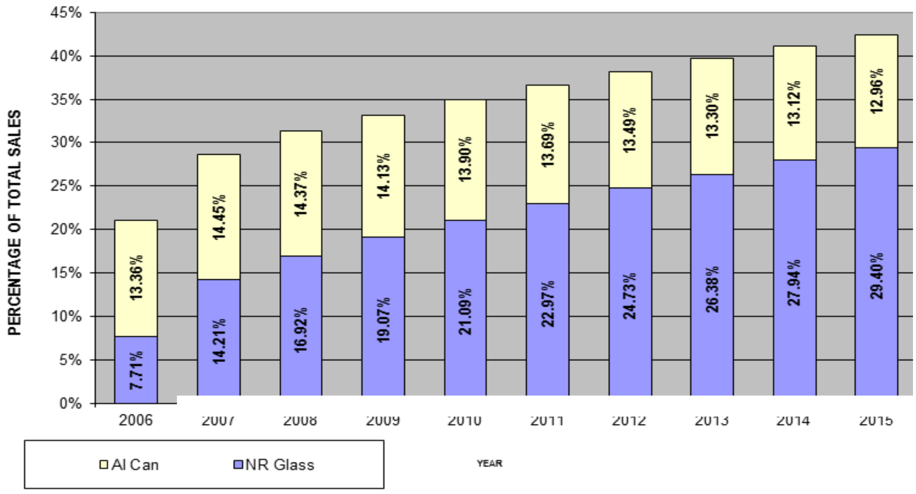

Fig. 5. Growth projections in non-returnable packaging.

3.2 Collection and Routing

One of the determining factors in the reverse logistics network is to ensure a sufficient return volume that will guarantee a continuous flow of materials in the recovery and recycling network. The collection in a reverse logistics system has two basic objectives [1]:

1. The effective acquisition of products or materials from used material generators or clients, involves offering convenient service and consistent timing as well as considering the processes in which the products or materials will be transformed and incorporated to determine how materials should be handled during collection.
2. To operate the collection and transport in an efficient form from the cost perspective. The need for temporary storage of product accumulation after collection, transport volume, separation at the source, and the characteristics of special transport vehicles should be considered in order to facilitate this objective.

Figure 6 represents the principle aspects and some of the possible configurations of collection and transport in reverse logistics systems. The dotted line points out the configuration that was assumed for the first routing algorithm.

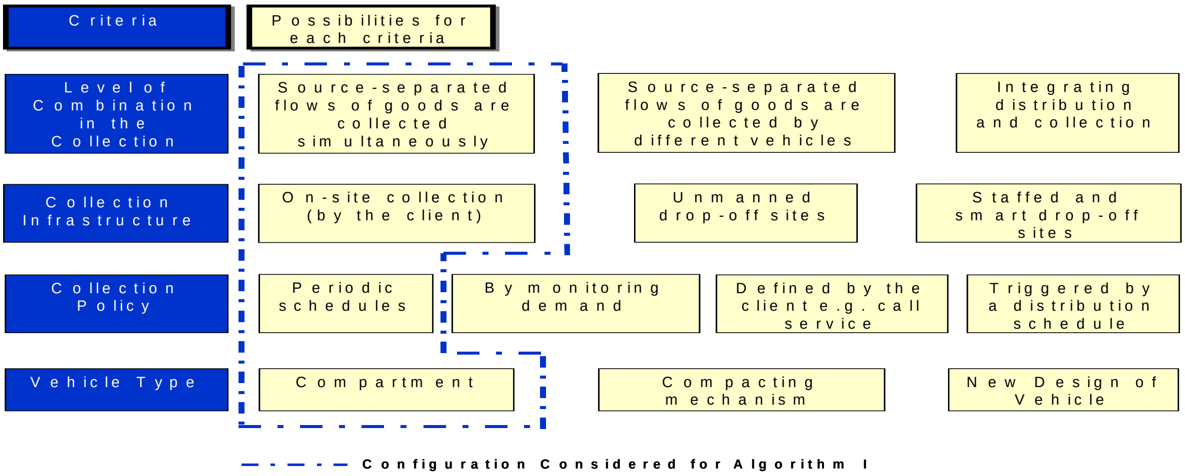

Fig. 6. Configuration considered for the first and second routing algorithm.

3.3 Routing Planning - Algorithm I

The basic approach for route models is known as route problems for vehicle with limited capacity (Capacitated Vehicle Routing Problem – CVRP). This model is known in mathematics as NP-hard or of difficult solution when it increases the number of sites that should be visited. Therefore, only small and medium instances of the problem can be solved optimally. For this reason, one resorts to the use of powerful heuristic algorithms that will find a good solution. Our problem is based on the CVRP but with additional constraints. It requires that each vehicle performs multiple trips while complying with a time window, i.e. a workday period. Therefore, our problem is known as the CVRP with Multiple trips with time Windows or CVRPMTW.

First, one uses the nearest neighbor algorithm to calculate an initial solution. In this first run of the algorithm, the vehicle is taken to the closest client. Consecutively, it goes to the closest neighbor revising each time not to exceed the maximum capacity of the transport vehicle nor the maximum route time including the time to return to the origin. The initial solution is improved by applying the shift and route reduction algorithm presented by Schultze and Fahle [7] known as Vehicle Routing Problem with Time Window Constraints – VRPTW. Figure 7 describes the information flow in the algorithm to attain the collection routes and their cost.

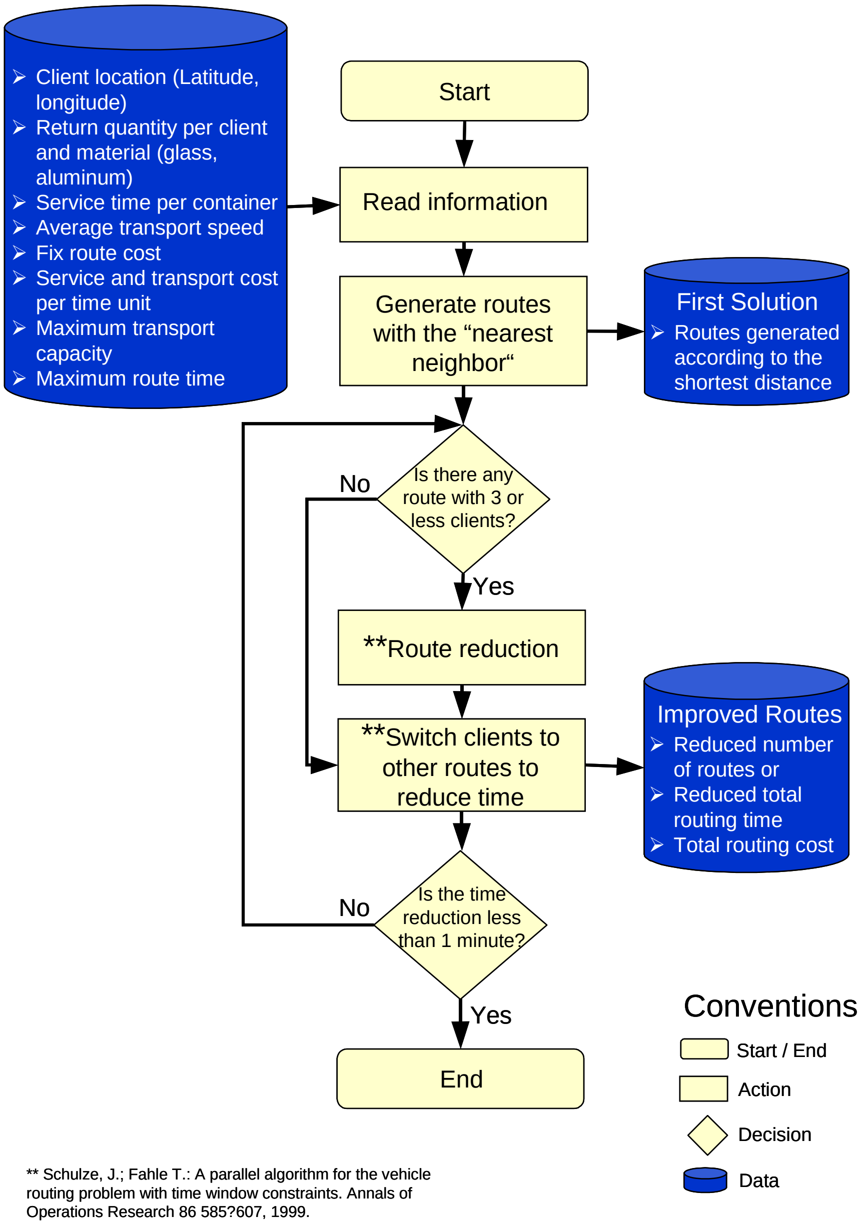

Fig. 7. Algorithm I used to plan the collection routes.

The results define the routes with service time, time of transit, and their respective costs, taking into account the possibility to group routes (i.e. Multiple trips). The maximum operation time for a vehicle was 7 hours a day (420 minutes/day). The algorithm was programmed in Microsoft VisualBasic™ and was executed from Excel™.

3.4 Results - Algorithm I

In total, 1688 clients were analyzed that acquired products in non-returnable packaging in the city of Merida. A 10% rate of package recovery was assumed. Clients were classified into two groups according to their monthly contribution: Clients that contributed a monthly 10% or more of the transporter vehicle capacity, were assigned one visit a week. There were 448 clients in this group. The rest of the clients, 1240, were visited once every two weeks.

Table 1 represents the results of applying the algorithm to the set of all the clients that are visited weekly, as well as sub-groups of these clients classified in four quadrants according to their location.

Table 1. Result of the algorithm for weekly collection.

Weekly Visit (Clients with monthly return >= 10% vehicle capacity)

	Total Clients 448		Quadrant 1 178 Clients		Quadrant 2 24 Clients		Quadrant 3 22 Clients		Quadrant 4 224 Clients	
	No. Routes	*Total Time (min.)*	*No. Routes*	*Total Time (min.)*	*No. Routes*	*Total Time (min.)*	*No. Routes*	*Total Time (min.)*	*No. Routes*	*Total Time (min.)*
Algorithm Solution	33	3.732,56	13	1.344,32	2	387,97	2	398,02	15	1.490,59
Number of grouped routes **(Assuming operation time = 420 min/day)**	10		4		1		1		4	

Result: It is necessary to operate 2 vehicles five days in a week

The total time of the routes for all of the clients (3.732,56 min) is slightly greater than the sum of route time for the four quadrants (3.620,90 min). The number of routes grouped (10) is the same as adding the number of grouping routes of the quadrants. One can conclude that it is necessary to have 2 transporter vehicles operating five days a week to cover all weekly routes of non-returnable packaging. Figure 8 illustrates the routes on the city map.

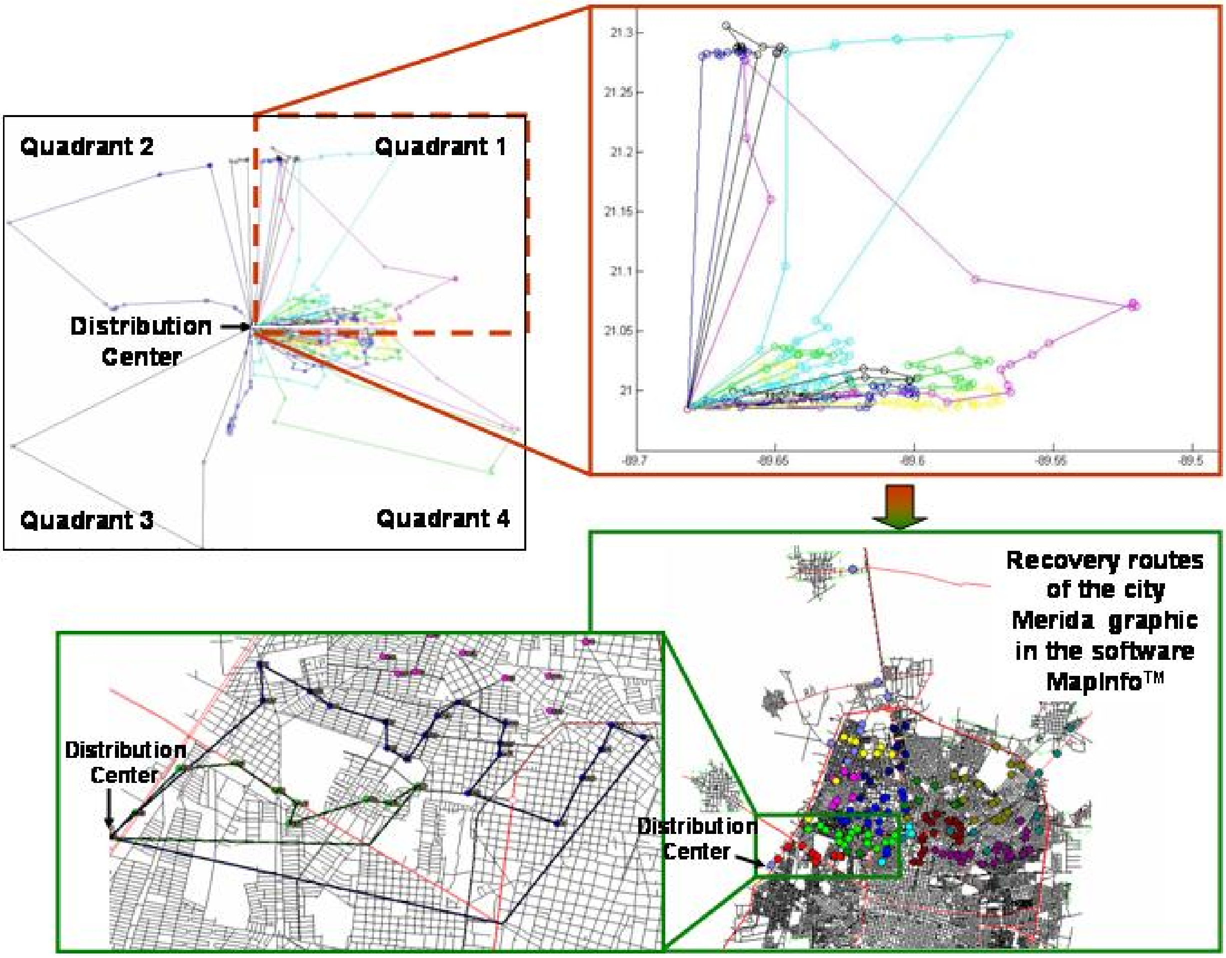

Fig. 8. Graphed routes per sectors on the city map.

Table 2 represents the results for clients who were visited once every two weeks. In this case, the route time for all clients (3.073,70 min) is slightly less than the sum of the route time for the 4 quadrants (3.162,73 min). The number of grouped routes is 8 for all clients and 10 for the sum of each quadrant. The results obtained by applying the algorithm to all clients are slightly better than the results obtained by applying it separately to each quadrant. The number of grouped routes is eight, therefore one vehicle can sufficiently cover in an 8 day period (one day per route) the routes for the collection of non-returnable packaging of clients that are visited every two weeks.

Table 2. Result of the algorithm for bi-weekly collection.

Biweekly Visit (Clients with monthly return < 10% vehicle capacity)

	Total Clients 1240		Quadrant 1 389 Clientes		Quadrant 2 106 Clientes		Quadrant 3 103 Clientes		Quadrant 4 642 Clientes	
	No. Routes	*Total Time (min.)*	*No. Routes*	*Total Time (min.)*	*No. Routes*	*Total Time (min.)*	*No. Routes*	*Total Time (min.)*	*No. Routes*	*Total Time (min.)*
Algorithm Solution	16	3.073,70	5	833,29	1	332,10	2	547,61	9	1.449,73
Number of grouped routes (Assuming operation time = 420 min/day)	8		3		1		2		4	

Result: It is necessary to operate 1 vehicle 8 days within two weeks

3.5 Algorithm II

The second algorithm, although very similar to the first, in the beginning of the flow, has two substantial differences. The first is the profitability variable that, through a logical flow, outputs two possible values, 0 or 1, or “inactive”, “active” respectively. This determines if the visit to the specific client being evaluated is profitable in terms of a specified threshold which can be in terms of cost. If indeed it is, so then a visit to this client is granted by the algorithm; note that costs (and thus profit) incurred (provided) by the visit are related to the material volume and traveling distance to the specific client. Therefore this algorithm assures the efficiency of each visit leveraging distance and volume of material to be picked up. The second difference is the automatic visit frequency allocation of clients based on profitability variable and/or route saturation. This cycle can determine the direction of the visit frequency in which the client should be moved (higher or lower), and of course, whether it should be moved in order to purge and balance the initial solution. Figure 9 shows the main flow of algorithm II and figure 10 represents the flow to decide the profit variable.

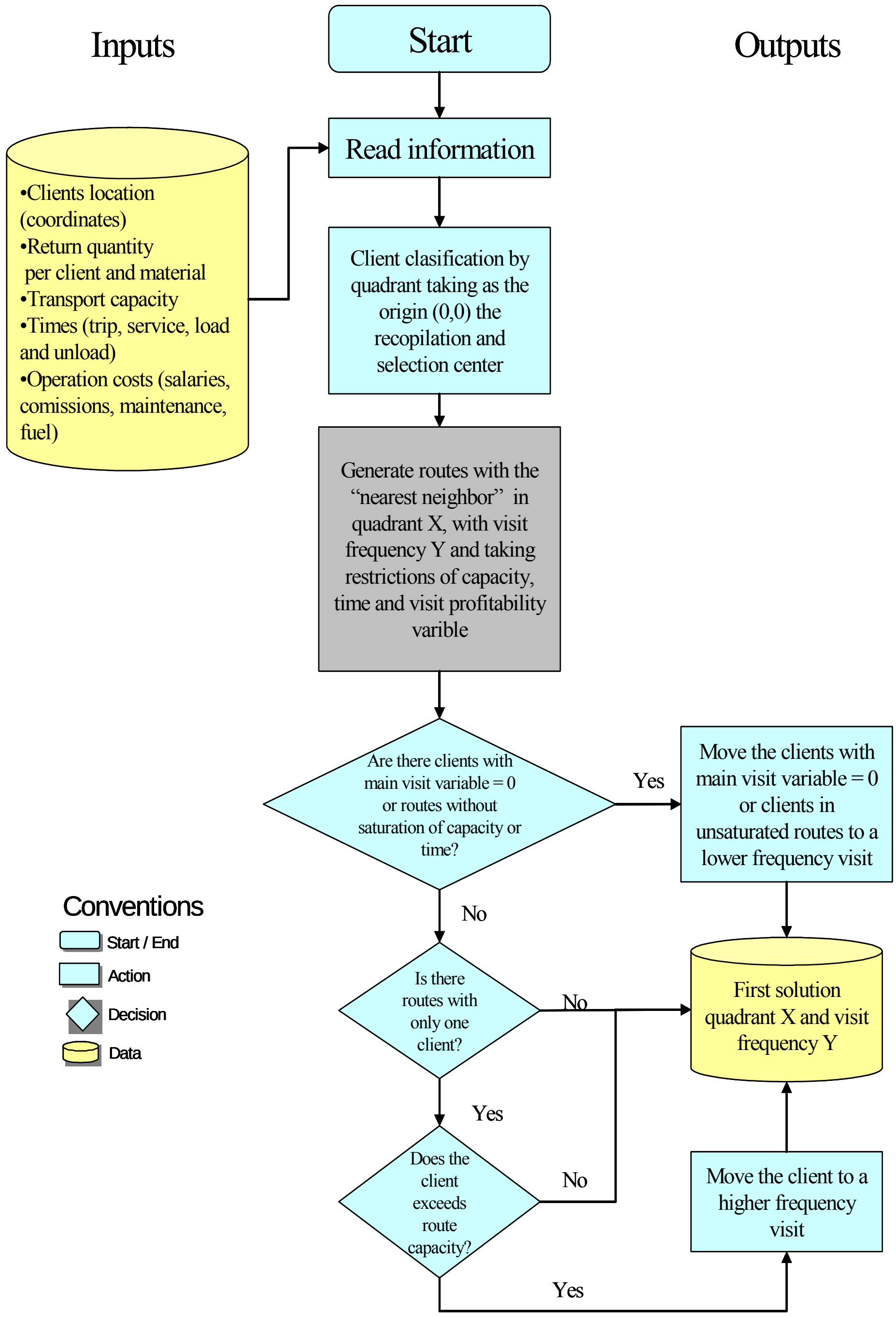

Fig. 9. Algorithm II used to plan the collection routes.

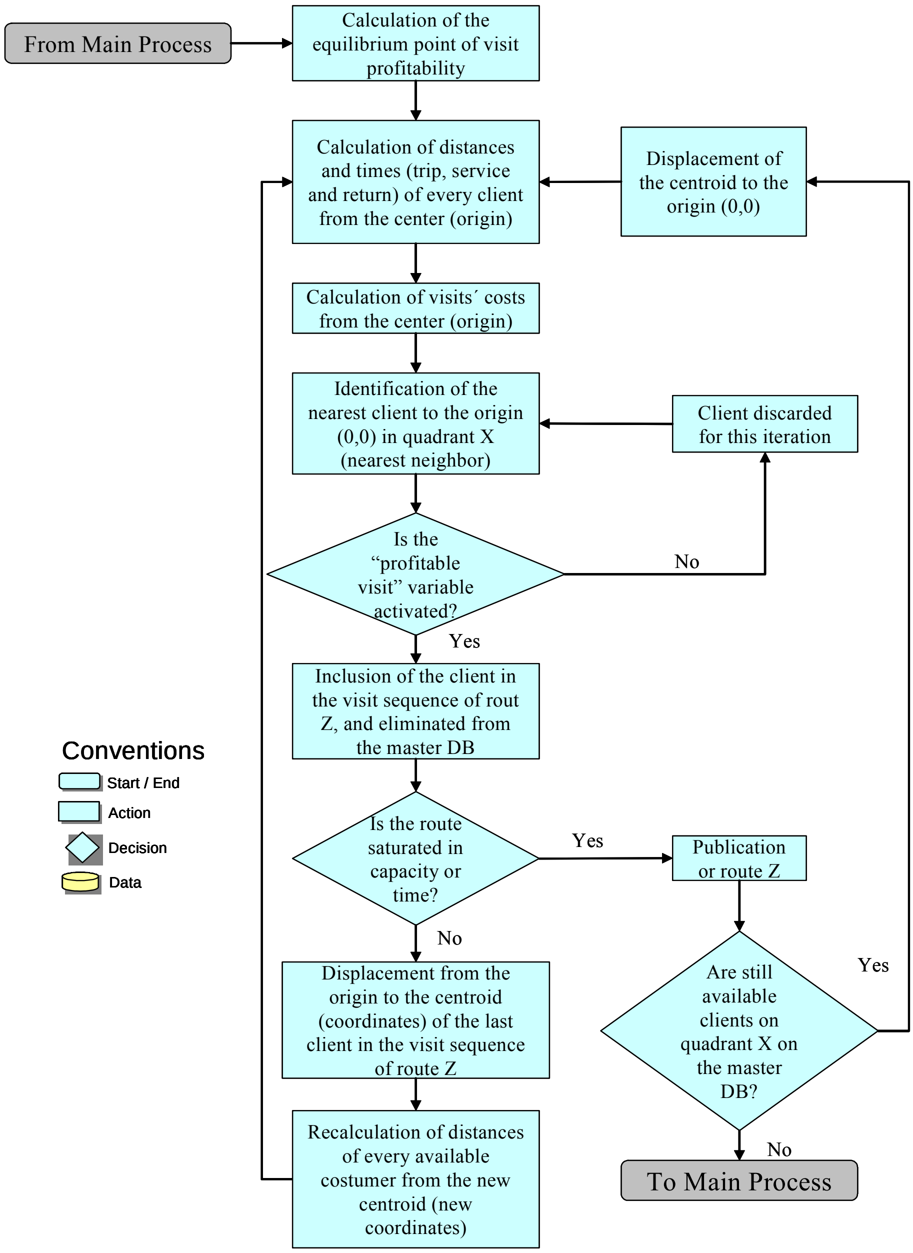

Fig. 10. Flow profitability variable in algorithm II.

3.6 Results - Algorithm II

As in algorithm I, 1688 clients, with non returnable product sales, were evaluated, also considering a 10% sales collection volume. As can be observed in Table 3 only 1225 clients had profitable visit values, and therefore an assigned visit. Nine grouped routes and a total time of 3100.09 min. is much less time than a weekly visit scenario for algorithm I. With the second algorithm there are no higher or lower visit frequencies. In this case, the remaining clients presenting non profitable values are not visited. However, the collection amount was 97.4% of the amount collected by algorithm I.

Table 3. Results algorithm II.

10% Collection Percentage
Weekly Visit

	All Clients 1225		Quadrant 1 429 Clients		Quadrant 2 73 Clients		Quadrant 3 53 Clients		Quadrant 4 670 Clients	
	Routes	Time (min.)	Routes	Time (min.)	Routes	Time (min.)	Routes	Time (min.)	Routes	Time (min.)
First Solution "nearest neighbor"	37	3,100.09	15	1,187.79	2	286.19	2	192.68	18	1,433.43
Grouped routes number (Assumming operation time = 420 min/day)	9		3		1		1		4	

3.7 Reconditioning

Collected non-returnable beverage packaging is transported to a centralized recovery center. At the recovery center, materials are prepared for shipment to a recycler. Glass is sorted according to color; the paper label is removed, and finally, the glass is crushed. Aluminum cans are compacted into bales in order to increase transportation efficiency.

The end material has less contamination and obtains a higher price when sold to recyclers, who take care of the purification process.

Bales of aluminum cans can be sold directly to processing facilities. At the processing facility they are shredded, crushed, discolored, melted down and cast into ingots. The ingots are fed into rolling mills that reduce the thickness of the metal from 20-plus inches to a sheet of about 10/1,000 of an inch thick. This metal is then coiled and shipped to can manufacturers where they are turned into new cans.

Crushed glass is sold to glass recyclers where contaminants are removed; the glass is washed and crushed into small pieces in order to have a clean cullet [8]. This cullet is sold to container manufacturers where it is mixed with virgin material and fed into a furnace. The resulting molten glass is drawn from the furnace and channeled through a feeder into the bottle-making machines.

3.8 Aluminum Can Recycling

Aluminum is a metallic material that can be recycled and re-used as often as necessary without any representative loss in quality. The high value of the metal is maintained and offers a sufficient economic incentive for the metal to actually be collected, treated, melted and used again in a similar or comparable way at the end of the product's service life [9].

The alloy used to produce an aluminum can sheet is a precise mixture which includes primarily manganese and magnesium. The recycling of the material should be done with similar alloyed materials and free of contaminants. Aluminum recyclers have defined quality levels for accepting recycling material [9].

If a can is not recycled, it will take around 500 years to degrade. In the same way, a recycled can may save 95% of the needed energy to produce a new can and will support the conservation of the mineral bauxite. Recycled aluminum is most often used for the production of new beverage containers, components for the automobile and aerospace industries, and building materials such as windows frames and rain gutters [10].

The aluminum can has many advantages as beverage packaging: it requires less energy to cool, there is no danger of crushed packaging, less space is required for empty packaging and an empty can only weighs one twentieth of an empty glass bottle [11].

3.9 Glass Recycling

Glass is manufactured from a mixture of three main ingredients: sand, soda ash, limestone and other additives, which create the color of the glass. In order to make recycled glass competitive with virgin material it is important that the glass scrap feedstock is of high quality in terms of color separation and low contamination. Recycled glass can replace virgin materials by up to 100 percent in the manufacture of new glass bottles and jars, depending on the quality, or can be used for a variety of other purposes such as a blasting abrasive [12], production of fiberglass insulation, decorative glassware, ceramic goods, and a roadbed aggregate [10].

Currently, FEMSA Beverage Packaging is able to re-use only 30 percent on average of recycled glass in the production of new bottles due to the quality of the reclaimed scrap glass, called "cullet".

The substitution of recycled glass instead of virgin materials enables bottle manufacturers to operate at lower furnace temperatures and improve emission characteristics e.g. nine gallons of fuel oil are saved for each ton of glass that is made from recycled cullet instead of virgin materials [10]. Recycling one ton of glass into new bottles and jars saves 315 kg of tons of CO_2 compared to using raw materials taking into account all the raw material extraction, processing, and transport energy used [13].

4 Summary and Outlook

A concept for recovering and recycling non-returnable beverage packaging was developed. First, the reverse logistics network was defined according to the current situation and the proposed packaging reverse flow. Second, the packaging collection was planned using routing algorithms in order to identify how it can be carried out and the involved cost. Subsequently, required processes at the recovery center are analyzed for conditioning the materials before sending to the recycler.

As per the routing algorithms a new profitable routing algorithm based on the nearest neighbor was proposed and tested. This algorithm showed substantial advantages. First it takes into account the cost of arcs and nodes (traveling distances and service times), as well as automatically determines the visit frequency for each client. Also, it evaluates whether a visit should be granted or not based on its "profitability". The latter is a relevant feature for reverse logistic schemes since these types of schemes have a rather high amount of uncertainty. Due to this mentioned uncertainty an algorithm that assures that each visit of the route is profitable (including its return to the depot) ensures that even if the circuit is broken at any moment and the vehicle forced to return to its point of origin (depot), the company will not lose money or even economic profit. This is not the case with some other algorithms based on complete cycle evaluations or without the profitable visit decision.

Further development of the reverse logistics network configuration includes the classification of the point of sales according to the probability that consumers take back non-returnable packages. In this sense, e.g. bars and restaurants where consumers drink the product in-site will have a higher recovery rate than supermarkets.

From a social point of view, currently "waste pickers" make their income by sorting the waste at the dumpsite and selling the material to recycling companies. It is necessary to offer an alternative to relocate these people to other jobs, for example, some of them could work at the recovery center.

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