Applying Reverse Logistics and Cost Reducing in the Solid Residuals Management

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Abstract--**This work is based on reverse logistics processes from an entity whose core business is to collecting and recycling products through the separation of useful materials for reuse, solid waste destruction, processing and selling of organic material useful inputs. So that reverse logistics and the models used to supply are important to the company. In this article the problem of reducing the cost of pickup truck in charge of recycling materials is introduced. This truck has a route that includes collection points, where it meets the bags of material collected in bags distributed to homes in a given district. The truck has space restrictions (volume of cargo), fuel and daily distance traveled. This way, the paper suggests to use a routing model to decrease the distance between the Center and the collection points so that it can establish an optimal route to minimize fuel and tracking on the truck. Aiming eventually reduce transport costs and monitoring inputs. Thus key concepts of reverse logistics models liable to be used for purposes of reverse logistics inventory are reviewed. And the Traveling Salesman Problem as an alternative to optimize the routing of the truck is reviewed.**

I. INTRODUCTION

The disposal of solid waste are long a problem for our society; in the case of Municipal Solid Waste the first link in the chain of the problem starts from the moment the local resident cares only about getting rid of them, without worrying about the fate that awaits it and the consequences that will bring to the environment. The following link is constituted by the government by not having effective programs of Solid Waste Management.

Solid residual include organic, plastic, fiber, synthetic and other materials that are typically contained in waste residuals. In Peru, the politics about treating solid residuals are in an incipient stage. But it is obvious that we have lots of waste and it needs to be treated and we need several politics in order to underpin this problem.

One of the most important environmental problems in our country is related to solid waste, so that, aiming to tackle this problem on July 21, 2000 the country adopted the Law 27314 - General Law of Solid Waste, in which the government and then the Commission National Environment - CONAM (currently MINAM) commit municipalities to develop a Comprehensive Environmental Management Plan Solid Waste (PIGARS). Under this law the different municipalities of the country began the work of management of solid waste. In the case of the provincial municipality of Arequipa in February 2004. The Comprehensive Plan for Solid Waste Management of the Provincial Municipality of Arequipa becoming the first document in the context of the formulation of PIGARS. In such a plan the objectives and plan goals are detailed, sub-programs of education, awareness and participation among the actors which are campaigns in the source segregation, all of that seeking to become a constant and fixed income. In this context, the Provincial Municipality of Arequipa took actions about the closure of informal dumps that exist in the city and by putting attention to the formalization of recyclers. There are also NGOs which have also developed works with recycling associations in various districts. In this area it is that the present investigation seeks to form part of the management process and best collection of solid waste, in the first instance in a specific district and with the passing of time expand it to reach other districts. From the meetings with the NGO in question, three kind of problems were submitted: a) few funds to execute their activities, b) having pour level about technology in use and c) several problems associated with the logistics approach. The two former problems are linked with a politics approach, so that we are not interested in research this way. But, it is interested to research about how to diminish costs related to the transportation of the solid residuals.

This way, we have an interesting social problem, because the social inclusion is a big concern within not developed countries. So that, it is possible to indicate that if the logistics cost are diminished, the budget for labor could be increased. But, despite the logistics problems are many and so complicated, we are focus on the solid waste transportation. However we are concerned about how to reduce the cost of fuel and optimize the distances that are in the route of the collector truck. It seems like a problem for a operational research approach, as possible to perceive around the paper it is a daily problem and we offers simple solutions far from algorithms.

In a former moment we are concerned about produce an algorithm like the Travel Salesman Person (TSP), that it is oriented to optimize diverse routes in order to reflect the most feasible and economic of them. But, when seeing to the problem is not possible to use this kind of algorithms because they have many limitations about distances and constraints that in the "real life" are not reflected. Hence, this paper contains our experience in the form of a case study and how we tried to underpin the route problem.

II. PROBLEM BACKGROUND

The environmental issue is one of the problems that our city faces, thus joining programs that seek the solution or reducing the impacts of this problem is what motivates to perform this research, so that it can be performed a research that optimizes vehicle routes, for recall the reusable household waste. This was the starting point for research, because of that the research background was sought on this subject. In addition, the opportunity to interview an NGO staff which provided us information about recycling activity in the district under study. By analyzing this information it was observed a problem in the process of solid waste collection in the district (and generally in all districts), it arises mainly due to the dynamism and variability in the volume of solid waste collected by associations of recyclers. It means there are areas where recyclers collect solid waste from homes in substantial numbers and sometimes these homes do not provide enough raw material (this is linked with the behavior about household waste and recycling [6]), which is why the amount of solid waste collected by recyclers are carried to temporary collection points which mostly include parks and corners, where everything is piled and is expected the vehicle arrive to these collection points in order to collect solid waste.

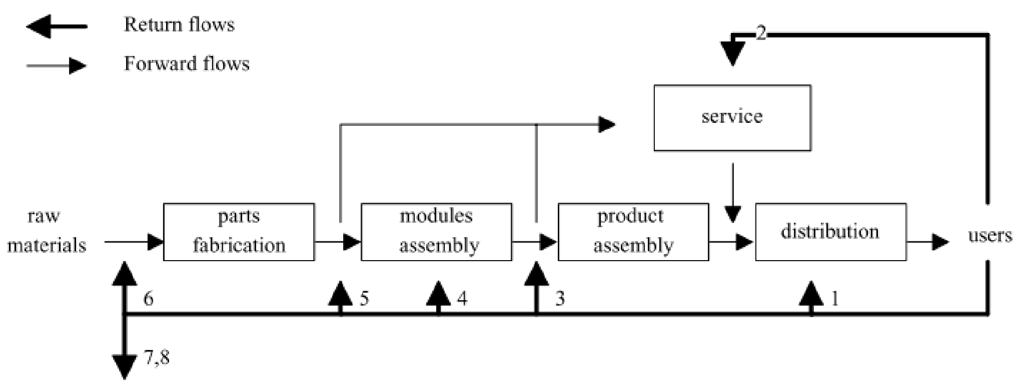
The problem is that the vehicle that collects solid waste and specifically their routes have been set arbitrarily based on the points of temporary gathering, which often hurts recyclers who have to wait for long periods of time to the vehicle and often this makes unnecessary trips since it does not have an optimal route by which to collect solid waste. The purpose of the research is to analyze the collection points so that the established position of these and then optimize the route of the solid waste collection vehicles so as to reduce collection time is taken, distances and costs associated with the vehicle.

So that the NGO conducted a survey of households segregate solid waste in the district in question providing information about 2014 homes to participate in segregation as a source, this study further comprises determining the volumes collected by the recycling association (formed only by women) in the assigned areas. Updating the data on the volumes of solid waste was necessary, this was done by area by collecting information in the field accompanying recyclers in their daily work by the staff of the NGO. Under the basis of the initial information then the NGO wanted to develop a plan to optimize routes of recycling, however, this research does not turn on a positive impact because it was not considered that not always the homes provided solid waste, generating that the beaten track varies by the conditions described above. Thus, instead of performing such optimization it is best to optimize the route of collectors vehicle for which, in the first instance a literature review of the concepts related to the issue of segregation of solid waste including quoted the general waste law is conduct solid and comprehensive plan for solid waste management. The proposition formulated for this investigation indicates that by using a mathematical model of operations research it is possible to optimize the path of the vehicle solid waste collector which will result in improved collection times and vehicle operating costs.

III. THE REVERSE LOGISTICS APPROACH

In the modern enterprise it is common to see the firms getting products or materials from their customers either to recover them value or as aftermarket services.

The difference, from traditional logistics, is that these activities take place in the opposite direction, so reverse logistics can be defined as the process of planning, implementation and control in an efficient manner, the flow of raw materials, materials and work in progress finished, and related information from the point of consumption to the point of origin, in order to recover the value of the materials or ensure their proper disposal products [2]. There are many other references about reverse logistics, but most of them explain the fate of goods when they have not more uses for the consumer.



Waste Management	1. Product Recovery Management		Direct Reuse
7. Incineration 8. Landfilling	5. Cannibalization 6. Recycling	2. Repair 3. Refurbishing 4. Remanufacturing	1. Direct reuse/ resale

Figure 1. Integrated Supply Chain view[1]

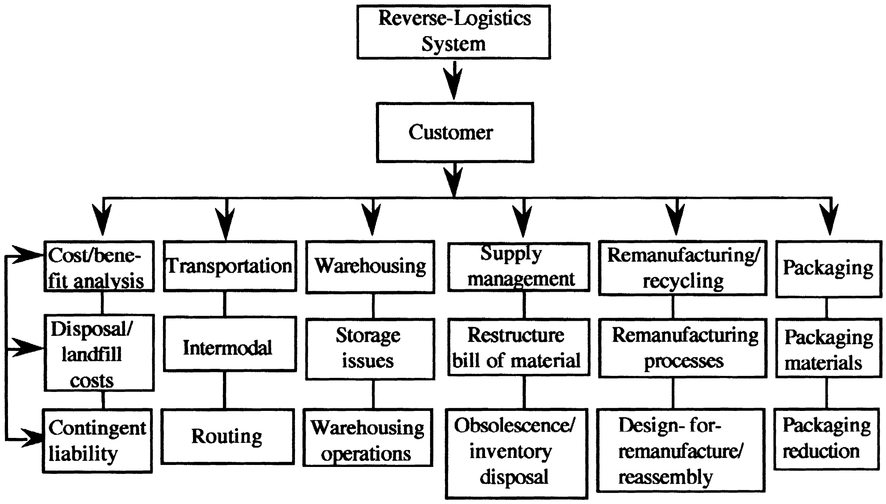


Figure 2. Factors influencing the reverse logistics [4]

Because the reverse logistics is a big umbrella and for the purpose of the research is more feasible to use the term Product Recovery Management[1] whose flow is introduced in the Figure 1. But, elements from the reverse logistic are used below to underpin our main objective. Also, because the term *reverse logistics* is historically not applied to the recall of solid waste[3] or even to the household waste. Hence it is important to choose what kind of literature is expected when treating reverse logistics. In this case is considered better to pursuit the transportation models, traceability or even stochastic models in order to explain the best way to collect household waste. At the former moment it is important to contextualize the household waste that is the object of study for this research.

IV. HOUSEHOLD WASTE RECOVERY AND RECYCLING

"*The household waste also referred to as residential refuse or domestic waste comprises wastes that are the consequence of household activities. These include food preparation, sweeping, cleaning, fuel burning and gardening waste. They also include: old clothing, old furnishings, redundant appliances, packaging and reading matter. In developing countries, this category consists largely of kitchen wastes; whilst in developed countries, there is a large portion of paper and an appreciable quantity of glass, metal and plastics. The garden waste and bulky waste component of residential refuse often cannot be accommodated by the optimal system for regular storage and collection of residual refuse and may require a special system.*" [5]. Part of this waste could be treated in order to be returned to the industry that originated it. In developing countries this function corresponds to the municipalities, but follow problems are associated with this concern: a) Lack of public participation/awareness, b) Lack of funds for acquisition of equipment and recurrent expenditure on household waste services, c) Traditional attitudes towards scavengers, the lack of social acceptance and embarrassment of people who are dealing with waste, d) Lack of enforcement of law and legislation.

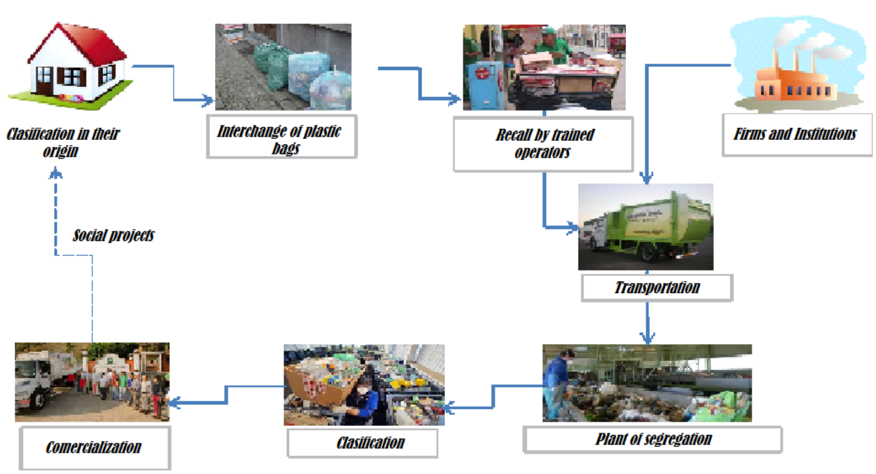


Figure 3. Sequence of management of household waste (actual situation).

Otherwise, household waste management is influenced by the people behavior and the attitude with the environment [6] this way it is important to perform studies about the psychographic variables around the perception of the household wasting problem if aiming to contribute to diminish this problem[7].

Municipalities contribute by creating programs for recovery and recycling household waste. In specific for the purpose of this research the cycle works like in the Figure 3.

V. DIAGNOSIS AND DATA COLLECTING

The routes to be analyzed is located in the district of Arequipa city in Peru, these are divided into four zones each assigned to a collection day of solids from the waste collection vehicle. Analysis methodology comprises in the first instance to identify the points of temporary collection on the map of each work area; then it will proceed to calculate the distance and time between each collection point considering where the collection vehicle begins the tour.

To collect information regarding harvest volumes by the recycling the following information relating to it was provided by the NGO.

TABLE 1: AVERAGE WEIGHT OF SOLID WASTE PER HOUSEHOLD

Day	Effective Household	Non effective household	Total	Expected monthly visits	Effective monthly visits	Total weigth (kg)	Effective weigth (kg)	Average weight per visit (kg/visit)
Monday	229	72	301	1204	916	579.16	544.16	2.38
Wednesday	170	54	224	896	680	392.15	392.15	2.31
Friday	108	44	152	608	216	323.8	323.8	3.00
Saturday	276	86	362	1448	1104	636	636	2.30
Total	783	256	1039	4156	2916	1931.11	1896.11	2.50

Source: Elaborated.

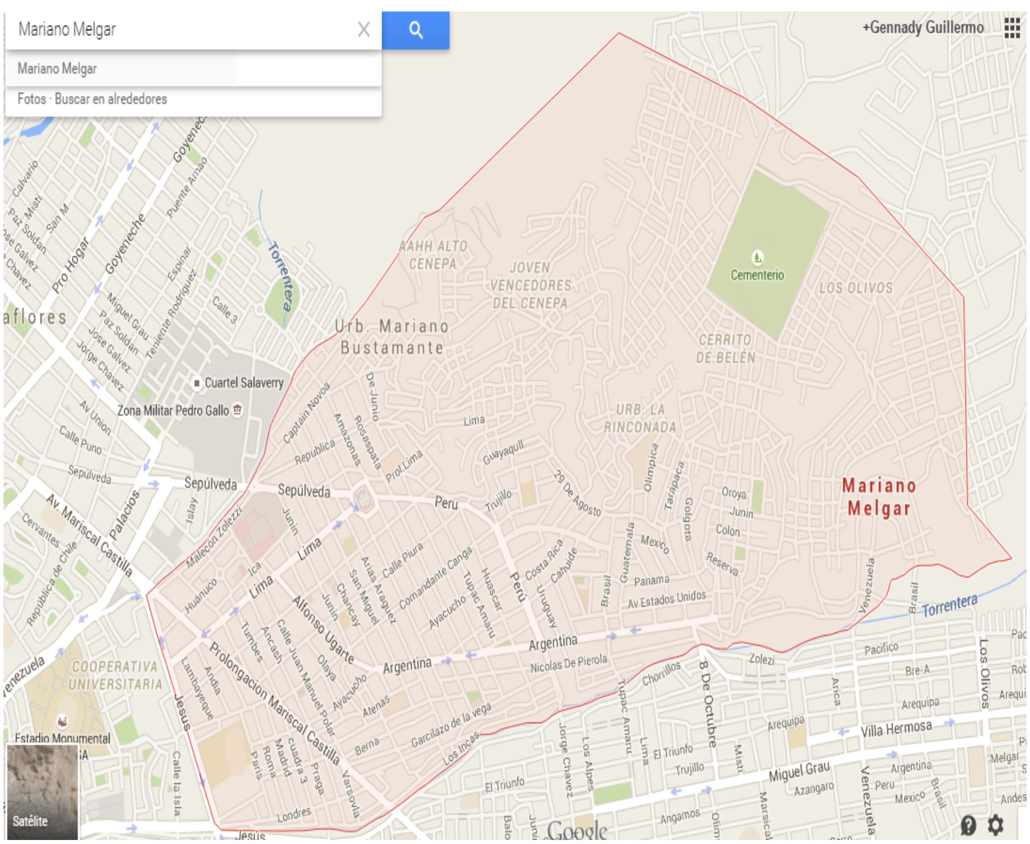


Figure 4: Zone under study. Font: Google Maps.

As can be seen in the Table 1 during the four days when recycling solid waste collected in average gain 2.50 Kg per visit to each home, each working day are embodied in a given area. The purpose of displaying these maps to determine the number of points of temporary stockpiles for which the points of temporary collection which are afterwards represented by triangles in the maps and location will be taken to the Google Maps program since this provides information taking into account the sense of the streets to set the distances between them and the travel time.

VI. DESIGNING A POSSIBLE SOLUTION

In the next paragraphs is presented a briefly review of similar case, intended solutions and other situations that aimed to solve the micro routing problem.

Traditionally there are three important parts of solving the problem: a) macro route distribution, b) balance of the route and c) micro route. The macro route refers to divide the city into zones and subzones broadly to standardize the characteristics of all areas. Distribution refers to divide and balance routes, by determining the working days and dividing by the collection of areas within balanced routes for all crews have equal workload. Finally, the step of Micro route refers to dividing each subfield into sectors, to solve a set of isolated problems. So that, there are three approaches to solving the problem of micro-routes: (1) deterministic (2) deterministic-heuristic and (3) heuristic. In applying the deterministic-heuristic approach tries to solve the problem of micro route using a computer to examine many possible alternatives and select the best alternative based on some heuristic algorithms.

From this basis, it is considered plausible the use of heuristic or meta-heuristic models, because exists software that offers good results if feed adequately. This way the next step was to collect information about what kind of information is required, also what constraints and what variables seen good to be used. For this purpose was used the paper of Racero & Perez[8] that proposed a solution for the topic of solid waste recall in a city of Mexico aware of the different characteristics and by adapting and adjusting a model to the reality Mexico. The purpose was to obtain an optimal design collection, set the number and type of units and ideal for routing schedule, to avoid inconvenience to the population. The term developed in the proposal were the macro-routes, which refers to the division of the city into operational sectors and then determining the number of trucks needed in each and assigning a slice area each collection vehicle. To do this, it is necessary to start with the segmentation, which divides the city into sectors, if it were feasible because of its size and taking into account the geographical characteristics. Afterwards the zoning, which involves divide each sector in areas that will be covered by a collector vehicle during the week.

With respect to the population, the document estimated the life of a project to collect between 5 and 8 years, so estimates must estimate the population for 10 years. Regarding the frequency of collection, the document speaks of a minimum collection of 2 times a week and is due to minimize the costs of this service. It should be noted however, the effect of custom and conformity in the population, which would not allow for this in the Peruvian model.

An important term for differentiation route optimization solid waste is the *productive distance; i.e.* wherein solid wastes are charged. Nonproductive, are called dead distance, the formula of distance covered in the collection, where it denotes this distance is then:

$$km = \frac{P}{d} = \frac{a\ x\ T\ x\ r}{60}$$

P = population of the area to attend a vehicle at every turn.
a = density of population hab / km.
d = proportion of productive distance relative to the total distance.
T = time available for collection in minutes.
r = ground speed of the vehicle during harvesting, in km / hr.

The purpose of this formula is that exist an equality, *i.e.* the kilometers (km) traveled are equal to projected ones. If the projected distance was much greater than the real, it means that the time available would not be enough to do the job. If however, the actual distance carried out much higher than projected, it would be superfluous time and unnecessary expenses. The route design seeks to increase the value, which means that the productive maximum distances are usually lies between 0.9 and 0.6. The number of vehicles required, denoted by, is calculated as follows:

$$N_v = \frac{G\ x\ P\ x\ 7\ x\ Fr\ x\ K}{N\ x\ C\ x\ dh}$$

P = Production of solid waste in kg / person / day
Fr = Factor booking
K = Coverage Factor
N = Number of trips per shift
C = Capacity of the vehicle in kilograms
dh = Business days

The crew size ideal collection, denoted by, is calculated by:

$$Nr = \frac{N\ x\ C}{R\ x\ H}$$

R = Yield in kg/Man/h
H = Length of working time in hours

After making the zoning, routes are designed in detail for what is taken into account the urban layout and topography of the area, width and type of streets, the method of collection, the collection team, population density and solid waste generation. After all the above process, the micro-route is designated. This refers to the specific route to be performed by solid waste collection vehicles daily. The most recommended methods for micro-route are deterministic. Racero and Perez[8] point to two as the most important:

algorithm of Little in order to solve the traveling salesman problem (TSP), focusing on a discrete demand for fixed downtimes or corners; and Chinese Postman algorithm for continuous demand type collection sidewalk, indoor air or the like. The former is aligned with this research.

For more realistic to waste collection case, the algorithm of the Chinese postman is an application of the network solution flow directed arcs. Euler circuit, which refers to any continuous path covering each arc of the network at least once used. If the arches have more than one address, you can use simple rules to see if there is a solution of Euler path, which must be odd. In this problem the intended route is to reduce the distance traveling along the streets (arches) one-way back to his central post office.

In conclusion for this part, the authors state that it is important to know the limitations of the algorithms of the models. Also a route system well designed results in what the collection service and waste transport is efficient, based on reducing operating costs and maintenance, reduced dead distances, capacity utilization of the collection vehicles and more staff collaboration to realize that the new routes allow you to save unproductive labor. It is also important to note that is necessary to discuss the importance of adequately informing the public, by logical foundation for his approval is needed.

VI. RESULTS AND CONCLUSIONS

In the actual situation, the NGO traces the micro-route every day manually. Is expected to generate a model or a procedures for generate daily micro routes, but in the actual stage it was only feasible to determine a micro route for one day and many problems appear from the matter. For example, there are many constraints to be considered, sense of the streets, traffic, distance to the fuel, etc. And limitations of the TSP algorithm was encountered in order to attend our problem, for example, in some cases the collecting truck needs to return to the storage because is full or because is better for it to return and discharge than to continue to a far place. TSP algorithm is only valid in one way and for long distances. This way, results from the field were passed but in rigor the need for new approximations remain more visible after introducing these results.

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APPENDIX A: PRODUCTS TO BE RECOVERED AND RECYCLED

PAPER AND PAPERBOARD

- White Bond first (bond paper, Bristol cardboard, glazed cardboard)
- Bond and printed file (office paper or editorial cuts, leaves laser printing, photocopying, continuous paper printers, books and magazines without color.)
- Kraft (clean cement covers, covers sugar and other foods.)
- Cardboard (first generated by supermarkets, shops, groceries, second all used boxes collected in the street).
- Youngest (boxes of food, juices, biscuits, milk, Tetrapak packaging, pharmaceutical boxes.)
- Newspaper (newspapers, magazines, books, newspaper and phone books.)

PLASTICS

- PET bottles of mineral water, soft drinks.
- HDPE bottles, buckets, tubs, cases serum, food containers, gel, shampoo, detergent.
- PVC, household containers, bottles and food containers, hoses, insulation for electrical cables, vinegar, oil.
- LDPE, Packaging fine sheets, other sheet materials.
- PP bottles, buckets, tubs, large containers, food containers, disposable dishes.
- Spumaflex (PS), clotted, thick or thin white foam; packaging materials used to absorb shocks (packaging appliances).
- HDPE, cases of harder material, sound when printed grocery bags, striped bags, boxes of milk or detergent.
- LDPE, soft case that stretches breaking, and it does not sound when wrinkle, bags used in food markets.
- Sponge mattresses, household sponges, pillows, stuffed animals inside, etc.