The ANOVA Applied in Selective Collection Made by Scavengers for Better Transportation Logistics of Recyclable Materials

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Abstract

The separate collection made by scavengers has been structured each day. Often new methods appear to minimize the effort of collectors, but they still face serious logistical difficulties in transporting recyclable materials especially when they have to travel long distances and higher slopes streets.

The purpose of this paper is to settle mobile warehouses to receive recyclable items, with trucks that receive in bulk all materials collected by the collectors, who will deliver them to someone who will be in the truck for weighing and subsequent payment to the collector. With the help of the Analysis of Variance – ANOVA, studies were made so that this receipt is a quick operation, with the historical record of each sampling in a spreadsheet and value calculations based on this description, thus minimizing errors in weighing in bulk and improving, in every collection, the system reliability.

Keywords: selective collection; scavengers; waste material picks; collector; solid waste; garbage; ANOVA; statistical methods.

1 Introduction

The separate collection made by scavengers has been structured each day. Methods to minimize the effort often arise, but the collectors still face serious logistical difficulties in transporting recyclable materials, especially when they have to travel long distances and higher slopes streets.

Some methods are uneconomical, with costly and inaccessible investments to the collectors reality.

An example is the installation of fixed warehouses, scattered throughout the city, for recyclable materials delivery and commercialization, which, beyond being expensive, would cause discomfort to the surrounding residents for causing outbreaks of dirt and odors, also proliferation of vectors such as rats, cockroaches, flies , etc.. If these fixed warehouses were managed by collectors, the surrounding community, in a way, would reject further the initiative, because, among other problems, many residents, by distrust, do not accept the collectors.

The purpose of this study is to install up mobile warehouses, with trucks that receive, in bulk, all materials collected, rather than fixed receiving warehouses. The scavengers will deliver the materials to someone who will stay in the truck for weighing and subsequent payment to the collector. Using the Analysis of Variance method – ANOVA this receipt should be a quick operation, with the historical record of each sampling in a spreadsheet and value calculations based on this description, minimizing weighing in bulk errors and improving, in every collection, the system reliability.

The aims of this research are: analyze the receipt processes of recyclable materials; relate the weighing of materials collected daily by the pickers with the history of what was collected during a certain period;

show that is possible reduce time in material separation tasks, delivering in homogeneous groups formed trough ANOVA; speeding up the materials weighing; propose one more efficient and faster ways to commercialize recyclable materials.

2 Literature Review

According to Cempre (2007), Brazil produces around 140,000 tons of waste per day. The portion of this waste disposal is around 90% in dumps or landfills, and only 10% is sent to for recycling or composting. A great part of this considered good material is going to waste and a lot of money is being thrown away, mainly due to not reusing the materials, how complements Calderoni (1998).

The waste generation in urban areas depends on some factors that are important, among others, in pertaining problems assessments to solid waste, described by Andrade (1989):

- economic, environmental, sanitary, community, cultural, political, number of local inhabitants and city expansion, usual types of packaging, collections types and collection equipment types, road system and flooring routes types, distance to final destination and appropriate way to final destination, the relative area of production, discipline and control of the producers points, seasonal variations; climatic conditions; habits; educational level; segregation at source; systematization of origin, specific laws and regulations.

The number of scavengers available in Brazil is very controversial. MNCR (2007) mentions that there are between 500 thousand to a one million of scavengers. Due to the country size and diversity, this model suffers variations in each region of the country, where the activity is governed by the market laws, which contributes to the process support itself and create working conditions for those unemployed or those without employment expectation.

The scavengers, also known as collectors, pickers, paper gatherer, rag picker, trash collection, unofficial waste sorters/recyclers, trash scavengers, waste material pick, litter-picker e litter collector and others, according Gutberlet et al. (2009). Maccarini and Hernandez (2007) divide the activity into three basic classifications: the scavenger, who lives in the dumps collecting recyclable materials and then sell them to intermediaries. There are those who collect on the streets with their carts, wagons or other vehicles (Figure 1), which are often called paper gatherer and also negotiate their materials with intermediaries. Finally, those who work in sorting recyclable materials centers are often linked to a cooperative or association.

The separate collection made by the scavengers is, hence, according Movimento Nacional de Catadores de Recicláveis - MNCR (2007), a new model to the select collection perform. Preferably consists of, rather than the municipal agency to collect the material selection, the collectors, duly registered and organized, are who do.

According Eigenheer (1989), usually scavengers live in suburbs or slums and collect materials at random in the streets of the block and commercial centers of towns. Most of them are semi-literate and are not organized in associations, as stated by Cempre/Eurostat (2006). Due to lifestyle, for realize activity does not perform professionally recognized, many are marginalized and discriminated by society. Some often get involved in police incidents, due to alcohol ingestion and similar, like Folha de São Paulo (2006) reports.

Figure 1 - Scavenger with his trolley, collecting on the streets

The following is a brief description of recyclable characterization and statistical analysis. Costa Neto (1989) says that when the product is formed by solid material, if the homogenization is not feasible, such as recyclable materials in this study, it is possible to employ the quartering, as called by Tchobanoglous (1993). This method recommended the division in four parts of the material to be characterized, sorting one or more parts to constitute a sample thereon or removing the sample.

Toledo & Ovalle (1988) recommend, after obtaining these data for the characterization, the use of simple arithmetic average of relative quantity ($\bar{q}_{0,t}$) defined by:

$$\bar{q}_{0,t} = \frac{\sum_{i=1}^{n} q_{0,t}^{i}}{n}$$

Where:

$q^{i}{}_{0,t}$ = simple arithmetic average of relative quantity;

$\bar{q}_{0,t}$ = amount of these materials at the present time and basic zero;

n = number of samples.

For the selective collection there are various possibilities for statistical calculations, such as proposed by Hines (2006). Therefore, to increase the reliability of data collected and minimize errors, like Stevenson (1986) cites, it is important, first of all, defined its purpose: how, where and what is the information intend. Also, mentions the author, that is also important to recognize, measure and understand the causes of variability, to act about its and then, the results should be measured and interpreted from technical and scientific measures. Complement Shimazaki (2007) that these measures start with simple methods, such as the arithmetic mean, and advance in extremely complex calculations, now aided by computer technology.

Statistical surveys may assist the work of scavengers logistics, but due to lack of adequate procedures and technical support, was noticed the difficulty in putting into practice. To apply the results collected on this work, any error made in the evaluation of the selective materials collected percentage, may affect mainly the collector, who lives on sparing resources. If, however, there is any error of judgment in favor of the collector, who will suffer are those who will make the purchase of materials, in this study, the association or cooperative of scavengers.

3 Materials and methods

3.1 Statistical method applied to the selective collection made by scavengers

The simple and usual ANOVA hypothesis test was applied. According to Caten (2007), it essentially divides the variability between groups and within groups and compares both. This feature allows realizing a simple variance analysis for two factors with only one sample per group. Generally, the analysis is a statistical process that is used to determine if the mean of two or more samples are from the same population. In this case are formed groups of recyclable materials that have the same amount relative.

3.2 Bulk weighing method

The installation of fixed warehouses scattered throughout the city, for the delivery and commercialization of recyclable materials collected by scavengers, yonder costly, would result, according to Maccarini studies (2007), discomfort to surrounding residents. It was evident that could cause dirt and odors outbreaks, with the proliferation of vectors such as rats, cockroaches, flies, among others. Besides, what the society has not accepted much, is the agglomeration of collectors in their neighborhood. Another procedure to be performed, would be that who the collector would perform triage *in loco* in their own stand, but the space is small to accomplish this separation, which would remove this procedure too. The distances, that usually are long to transport the trolley to the store, are also determinant factors to new thoughts about alternatives.

One of these alternatives is that, instead creating fixed warehouses to receiving material, settle in mobile ones. These warehouses would be formed by a truck and receivers strategically located in the neighborhood, at points near the collection sites.

For this method realization should be implemented before the model of the selective collection made by scavengers, proposed by Maccarini (1998). This model involves the participation of the community involved, who should leave the separate garbage in front of their houses, on specific days of the week. The pickers then start collecting, and, so that, as soon as they fill the stands, take to these mobile centers of receiving recyclable materials.

The receivers will weigh throughout the bulk material from each collector, depositing them into bins within the mobile centers of receiving material (which may be a truck or similar) to then be transported to sorting centers with subsequent separation each specific item. This procedure will tend to be fast, given that will not be needed that receiver or the scavengers make a detailed screening of materials, to then know how much and what was collected. This will provide the pickers return to stretch to make more collections.

In the sorting centers, recyclable materials can be subdivided into more than 20 different types, in which each one is sold with different prices. Some with values higher than the average of other materials (aluminum, for example, is sold at an average of R$ 2,00 per kilogram, copper at R$ 7,00, while other materials ranging from R$ 0,05 to R$ 0,40 per kilogram). To avoid future troubles, these materials with much higher values, above average, must first be separated, weighed and paid apart, because, in conformity with Downing & Clark (2000), they have a large amplitude range.

To facilitate the study, in this production the recyclable materials were divided into 12 items only: waste, newspapers, paper (white), cardboard, thin plastic, hard plastic, PET, glass, ferrous metals, aluminum, copper and similars, and others. The tailings are all that can not be recycled and eventually appear on the materials collected, mainly due to lack of knowledge or education from who separates the trash at home. They include organic waste, toilet waste, pruning and weeding, among others, which should be directed to the ordinary or special domicile collection. The classified like papers, include all those white papers that were not dirty or contaminated by other residues. The thin plastic is particularly LDPE (low density polyethylene), which are the plastic bags. The hard plastics are HDPE (high density polyethylene), PP (polypropylene), PS (polystyrene), PVC (polyvinyl chloride), among others. PET (polyethylene terephthalate) is the plastic soda bottles and other containers. The glass comprises mainly canning

containers and glass bottles. Ferrous metals are the “tin plate” can and other ferrous metals. Copper and related products represent all non-ferrous metals except aluminum. The "others" are those who do not fit into any classification previously exposed, such as: rubber, furniture, electronics, clothes and rags, wood, among others.

3.3 Survey samples

Maccarini (1998) conducted studies and characterizations of recyclable materials collect performed by scavengers (Table 1). These studies provide 11 characterization data (11 samples) to be interpolated and used with other realized by Maccarini & Hernandez (2007) (Table 2) and also by data collection performed by Maccarini (2008) (Table 3).

Thus, the collected information was grouped to form three distinct data groups. The first, called "Group 1" is one whose data were obtained from 11 characterizations shown in Table 1. For practical purposes, even though these data were outdated, they were used in this study, mainly by having a large number of samples and detail level. Thus, the amount of information was increased enabling the results to be completed with the highest degree of reliability. Another reason for using these samples was because the percentages of some materials differ little in relation to data collected by Maccarini & Hernández (2007), which were also used as historical data. These were called "Group 2" (Table 2).

For more information and to make better comparisons with the existing, Maccarini (2008) made a new characterization from the materials found on a trolley collector, chosen at random, in the streets of Pato Branco city - PR. These materials were fully separated and weighed, item by item, as shown in Table 3 below. The latter was called "Group 3". Thus, the sum total of samples collected, for a total of 13, forming the three groups being studied.

It is important to emphasize that, for the three groups surveyed, among them, no one has coincidence with weekday or collection site. At first, Table 1, the data was originated from a single district of the city, and one day (Wednesday). Those raised in 2007 (Table 2) represent the average percentages of an indefinite period of days, what day of the week and place of collection, were obtained in a study by Maccarini & Hernández (2007), in the shed of the Association of Scavengers. There, the materials are mixed and homogenized. Finally, those identified in Group 3, Table 3, were on a specific day of the week (Thursday), without place of origin definition.

Table 1: Detailed characterizations, from the collections made by collectors

MATERIALS	QUANTITY (%) / collected days (group 1)												
	1st collects	2nd collects	3rd collects	4th collects	5th collects	6th collects	7th collects	8th collects	9th collects	10th collects	11th collects	**average%**	**standard deviation**
Reject	11,6	19,2	1,9	1,6	2,4	3,8	3,5	1,4	7,1	1,1	3,1	**4,43**	**5,59**
Newspaper	6,4	5,3	32,1	2,9	6,2	12,6	6,0	4,5	8,8	4,8	3,4	**10,66**	**8,29**
White paper	8,6	7,7	6,4	13,9	20,3	10,0	10,5	10,6	23,8	21,5	10,4	**11,86**	**6,01**
Cardboard	24,0	31,9	11,6	13,1	24,2	19,8	13,4	17,5	18,9	21,4	18,8	**17,80**	**5,88**
Thin plastic	5,4	4,2	2,3	3,8	6,8	4,0	2,9	5,0	3,2	4,6	3,8	**3,89**	**1,25**
Hard plastic	12,3	12,4	5,8	5,8	9,7	6,7	4,9	5,8	6,9	7,4	5,0	**7,04**	**2,73**
PET	0,0	0,0	0,0	6,3	8,2	5,8	3,8	4,9	7,2	7,5	5,7	**4,00**	**3,13**
Glass	25,8	14,8	12,9	21,9	10,4	22,6	47,8	37,8	14,2	19,7	26,3	**23,38**	**11,27**
Ferrous metal	3,3	3,8	7,1	24,6	8,6	8,7	3,7	6,5	4,6	6,3	10,1	**8,75**	**5,97**
Aluminum	1,4	0,7	1,3	0,5	2,0	1,5	1,7	0,9	1,0	1,1	0,9	**1,17**	**0,45**
Copper and related	0,0	0,0	1,1	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,7	**0,30**	**0,37**
Other	1,3	0,0	17,4	5,5	1,2	4,4	1,7	5,0	3,9	4,4	11,9	**6,71**	**5,17**

Source: Maccarini (1998).

Table 2: Detailed characterization of selective materials, held in Association of Collectors

MATERIAL	AMOUNT (%)/collection (group 2)
Reject	4,29
Newspaper	10,11
White paper	12,35
Cardboard	18,29
Thin plastic	3,75
Hard plastic	7,04
PET	5,15
Glass	22,48
Ferrous metal	8,31
Aluminum	1,29
Copper and related	0,29
Other	6,66

Source: Maccarini & Hernández (2007).

Table 3: Detailed characterization from material collected by a collector street, chosen at random

MATERIAL	AMOUNT (%) / collection (group 3)
Reject	3,69
Newspaper	5,13
White paper	13,98
Cardboard	34,52
Thin plastic	2,90
Hard plastic	5,64
PET	3,16
Glass	16,87
Ferrous metal	4,55
Aluminum	0,74
Copper and related	0,17
Other	8,63

Source: Data collected by the author in January 2008.

4 Results

4.1 Type of waste collected

The analysis of the collection percentage by kind of waste is shown in Figure 2. In this figure, the mean values appear with intervals LSD (Least Significant Differences Intervals) with 95% confidence level, confirming the F test significance performed in ANOVA, which shows significant differences between some of the percentage of collection by type of waste.

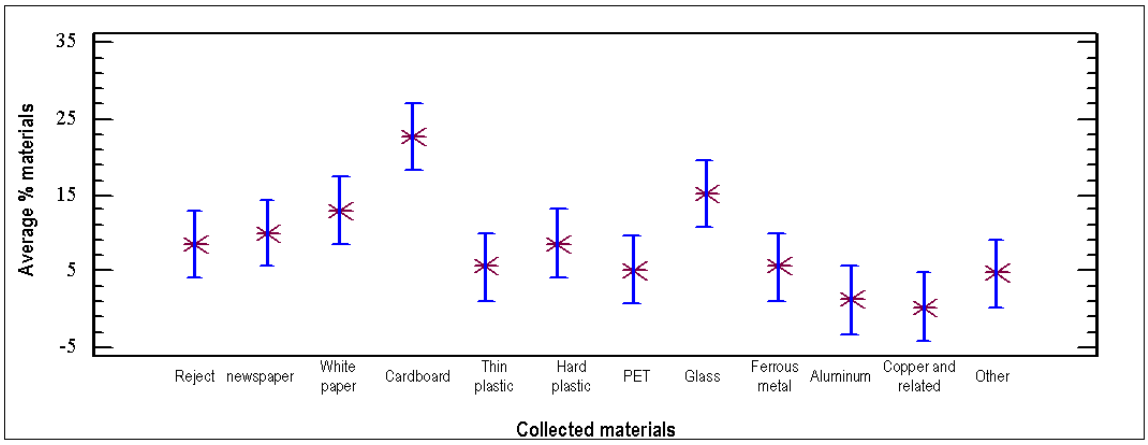

Figure 2: Results of ANOVA

The Table 4 shows multiple comparisons to determine what kind of waste has similar percentages which do not differ significantly at a level of significance of 5%. The method used was the procedure of least significant difference (LSD) of Fischer. The residues that are in the same group appear with an X in the same column. According the Table 4, may be checked the division of the waste in five groups.

Table 4: Multiple comparison multiple to determine the affinity between the materials.

	Portion (%)	Group				
		1	**2**	**3**	**4**	**5**
Copper and related	0,25	X				
Aluminum	1,19	X	X			
Other	4,60	X	X	X		
PET	5,17	X	X	X		
Ferrous metal	5,51	X	X	X		
Thin plastic	5,54	X	X	X		
Reject	8,47	X	X	X	X	
Hard plastic	8,59	X	X	X	X	
Newspaper	9,97			X	X	
White paper	12,93			X	X	
Glass	15,14				X	X
Cardboard	22,65					X

The Table 5 presents new groupings performed, in order to achieve the mean percentage of each new group, multiplied by the sales per tonne value.

Table 5: Analysis and groups formation, without repeating the type of waste.

Materials	Portion (%)	Total clusters (%)	Arithmetic mean of clusters (%)	Value of sales per tonne (R$)	Amount due to trade
Copper and related	0,25	1,44	0,72	7.000,00	R$ 50,41
Aluminum	1,19			2.000,00	R$ 14,40
Other	4,60	47,85	7,60	no set value	R$ 0,00
PET	5,17			360,00	R$ 24,61
Ferrous metal	5,51			200,00	R$ 13,67
Thin plastic	5,54			200,00	R$ 13,67
Reject	8,47			no set value	R$ 0,00
Hard plastic	8,59			260,00	R$ 17,77
Newspaper	9,97			50,00	R$ 3,42
White paper	12,93	28,07	18,89	400,00	R$ 56,13
Glass	15,14			200,00	R$ 28,07
Cardboard	22,65	22,65	22,65	180,00	R$ 40,77
			Total amount due to the sale of materials		R$ 262,92

From this survey, the new groups to be formed are:

- First group: copper and similars with aluminum;
- Second group: PET, ferrous metal wastes, hard plastic, thin plastic, newspaper and others;
- Third group: paper and glass;
- Fourth group: cardboard (which was isolated in its group).

For illustrative purposes, the result of materials commercialization per tonne, with previous separation and average arithmetic use, was R$ 234,36. Using analysis of variance - ANOVA the result was R$ 262,92, similar to the first, which is the real result. In other words, by the mean collection in a ton, the scavenger, using the proposed method, would commercialize the materials with 12.1% mean difference value

between the proposed (ANOVA) and the usual sales, in other words, from actual average (samples), with sorting and weighing each item.

4.2 Advantages of using the bulk weighing method

Below are listed some advantages from implementation of bulk weighing method, namely: (i) Due to the time savings in not having to wait to separate the materials, the collectors can return to the section to carry out new collections, (ii) As the warehouse will be strategically located near the collection site, the travel time will be reduced, because the pickers will not need to move long distances to sell the materials, (iii) If they organize themselves in cooperatives, the values in materials commercialization may be higher, due to wholesale, (iv) If there are values leftovers of trade due to errors in the estimates, these may be divided between them at the end of each month.

5 Conclusions

The study can be an initial step for the process optimization and recyclable materials receipt from the bulk weighing. This can resulted in the streamlining of materials weighing and commercialization by scavengers, in other words, is a more efficient and faster way than conventional methods.

Based on the ANOVA analysis, was found that are no significant differences in the amounts of material to the type of waste between the most of the material collected by scavengers. From Figure 2 it has been found statistically that many of these materials have little difference between them, below 5%.

The materials that have more differences in the quantities are the cardboard and glass. This means that the scavenger could deliver all materials mixed, with the exception of cardboard and glass, to then be weighed and sold without significant losses for both parties, either the scavenger or the receiver.

On the other hand, as recommended by the ANOVA test results to regroup recyclable materials into five distinct groups to commercialize them in a homogeneous way between each group, this procedure would greatly facilitate the process as a whole, because it wouldn't be necessary to separate item by item.

Acknowledgements

We are grateful to CAPES and the Araucaria Foundation, for their financial support which enabled this study to be conducted.

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