

Productivity Analysis in Recyclable Materials Sorting Operation - A Case Study at Recifavela Cooperative

Luís Henrique Rodrigues¹, Ricardo Reolon Jorge², Kevin Laita Kumamoto³

^{1,2}Professor, Engineering, Modeling and Applied Social Sciences Center, ABC University, Brazil

³Department of Production Engineering, UAM University, Brazil

Received: 15 Jul 2021,

Received in revised form: 19 Aug 2021,

Accepted: 23 Aug 2021,

Available online: 29 Aug 2021

©2021 The Author(s). Published by AI
Publication. This is an open access article
under the CC BY license

(<https://creativecommons.org/licenses/by/4.0/>).

Keywords— Waste Pickers Cooperative, Wastage, Recyclable Materials, Productivity, Added Value.

Abstract— *The reduction of waste in manufacturing processes and the productivity gain have been researched by several authors as economic competitive advantages for companies. More recently, environmental and social concerns have also been included in these studies. In this broad context, which additionally involves economic, environmental and social aspects, are the cooperatives of waste pickers (CMRs), which need to be placed on the same level where companies with productive and competitive profiles are located. Thus, the research presented in this article seeks to contribute to the advancement of this debate, considering the existence of gaps in the literature that address productivity studies in the production activities of recyclable materials sorting cooperatives. Therefore, the objectives of this study are directed to the questions that involve productivity (kg/cooperated) in the operation of screening materials, measuring the waste that occurs and which proposals for improvements can be implemented to increase productivity. This research is limited to a cooperative of collectors that adopts the sorting belt in its process. The methodology adopted is a case study, of applied nature (generating knowledge with practical application), quantitative and with exploratory data analysis. The results show that there are losses of production/waste of time of the (co-operated) operators, which could be reversed in aggregated value and, consequently, in increased productivity of the cooperative's business system in the sorting operation.*

I. INTRODUCTION

One of the main current concerns of society is the environmental issue, precisely because it is a prerogative of great importance to populations in terms of quality of life. Thus, international organizations have sought to develop symposia, seminars and global meetings that involve discussions on environmental issues (Silva, Monteiro, & Leite, 2018). In Brazil, the approval of the National Solid Waste Policy (PNRS) in 2010 represented a milestone by obliging several productive sectors to implement reverse logistics programs, a demarcation in response to one of the country's main environmental

challenges, with direct effects on the quality of life in cities (CEMPRE, 2019). At one end are consumers with the responsibility to properly package the solid waste generated. In the other, manufacturers who are unaware of the destination given by the customers to the products at the end of their useful life. Among these two extremes are the cooperatives of waste pickers, who are responsible for allocating post-consumer materials for recycling. In this context, PNRS brings a great innovation by recognizing waste picker cooperatives as key agents in the recycling chain and as potential suppliers of companies to enable reverse flows of recyclable materials (Demajorovic,

Caires, Gonçalves, & Silva, 2014). The picking of materials and the sorting of these materials for recycling are important phases for the management of municipal solid waste (de Souza, Camarotto, & Fontes, 2019)

The formation of cooperatives is a practical result of certain individuals who were marginalized, mostly homeless, who realized that by joining together they would achieve a greater amount of products to be marketed, increasing the value raised (Magni, & Günther, 2014). The recognition of recyclable material collectors by the Ministry of Labor in 2002 as a profession was an important contribution to the organization of waste picker cooperatives in Brazil. The collector is defined as someone who collects, classifies and sells recyclable materials (Besen, & Fracalanza, 2016).

The recycling cooperatives, being constituted companies, face barriers to placing their products. The participation in the recycling chain is hampered for various external and internal reasons, among them are (i) the low remuneration of the services provided, (ii) the lack of structure necessary to trade directly with the recycling industry, (iii) the quality of the materials arriving at the sorting cooperatives, (iv) low-scale production, (v) deficiencies in process management and training of cooperators 25% of waste pickers in Brazil are illiterate (Besen, & Fracalanza, 2016), (vi) inadequate organization of production resources, among others. These deficiencies have a direct impact on the low productivity of cooperatives and, consequently, on lower financial gains for co-operatives. An example of increased productivity can be illustrated in the case of the Vira-Lata Cooperative, which evolved from 0.19 tons of materials collected by cooperated in 1999 to 16.7 tons per cooperated in 2008. This significant increase in productivity is due to the purchase of new equipment, improvement of the quality of materials collected and partnerships with public and private authorities (Demajorovic et al., 2014).

Magni and Günther (2004) state that the great difficulty encountered by waste picker cooperatives, from the point of view of their management, is the conciliation between their eminently entrepreneurial economic activity and the principles of self-management. It is important to note that waste picker cooperatives are seeking efforts to achieve more efficient management for their service provision (Dias, 2016). A positive experience in this sense is evidenced by Batista, Gong, Pereira, Jia, & Bittar (2018), that mention investments of Tetra Pak Brazil in programs to increase productivity, supported by improvements in the management of cooperatives. As an example, through a group of Tetra Pak consultants, it is possible to diagnose and identify opportunities for improvement, such as layout changes, third-round production deployment, workforce

training programs, among others. Cooperatives, which were initially set up to promote the social inclusion of the homeless must evolve to an efficient and productive level of organization, so that, on the way to achieving higher productivity there is a demand to maximize production and sales results using less resources. This path necessarily involves improvement actions in order to reduce waste in the process of sorting recyclable materials from waste pickers' cooperatives. orientation by the principles and tools of lean manufacturing corroborate the improvements in productivity to be achieved, consequently, the companies that adopt these practices seek to reduce waste and activities that do not add value in manufacturing processes. (Jabbour, Jabbour, Govindan, Teixeira, & Freitas, 2013, Roosen, & Pons, 2013, Rohani, & Zahraee, 2015).

In the specific case of cooperatives, the focus is to identify which operations in the screening process are responsible for adding value and productivity gain, where there are losses due to waste and which actions are necessary to minimize this. Given that, such improvements will provide the transfer of greater financial gains to its cooperators in addition to increasing social recognition and appreciation, bearing in mind that for cooperatives there is the challenge of professionalizing their value-adding processes. Among the operations in a waste pickers' cooperative, in the processes of separating the various recyclable materials, are the activities in the sorting belt, which is the stage where the highest value is added to the final result of the cooperative and the financial gain of the cooperators. It is on the sorting belt that the materials are separated into quantities for sale to the recycling market, so this operation contributes directly to the increase of productivity, determining value to the cooperative's revenue (result). Thus, a more detailed study centered on the screening operation is essential, observing the occurrence of waste, its causes and what improvements can be applied to the process.

The case study developed in this research is applied (generating knowledge with practical application), quantitative, descriptive and based on data analysis. The data analyzed are collected through the application of filming and timing techniques and on-site observations. The specific objectives of the study refer to the following questions: (i) what is the current productivity (kg/cooperated) in the sorting operation (ii) which wastes occurred (iii) which proposals for improvements can be implemented to increase productivity.

Thus, the present case study seeks to contribute to the advancement of this social, environmental and economic debate, considering the gap in the literature in this field involving productivity studies in the production activities

of recyclable materials sorting plants. It is important to note that the case study discussed in this article is limited to a waste pickers' cooperative that adopts the screening mat in its process and does not apply to processes using stationary tables or cage benches for sorting materials. The investigation is contemporary considering that it promotes the opportunity to apply technical knowledge of production engineering in a category of organization that needs improvements in productivity for its production processes.

The results obtained in the survey are not representative of the population of waste picker cooperatives, but are important indicators for other cooperatives to carry out a detailed investigation of their sorting operations and identify the causes of the loss of productivity.

II. THEORETICAL REFERENCE

The theoretical framework in this article aimed to bring some important definitions and concepts regarding the subject under study, which later served as the starting point for the construction of the research. Based on this purpose, the topics investigated were delimited in the search for academic content on (i) the management of solid urban waste in Brazil, (ii) the participation of sorting centers (cooperatives of waste pickers) in the material recycling system, (iii) their sorting processes and (iv) the importance of productivity in the economic, social and environmental results of these recycling plants.

a. Urban solid waste in Brazil

The collectors of reusable and recyclable materials play a key role in the implementation of the National Solid Waste Policy (PNRS), with emphasis on integrated solid waste management. In general, they operate in the activities of selective collection, sorting, classification, processing and marketing of reusable and recyclable waste, contributing significantly to the recycling production chain (MMA, 2020). PNRS highlights the importance of waste pickers in the integrated management of solid waste, establishing as some of its principles "recognition of reusable and recyclable solid waste as an economic asset of social value, generating work and income and promoting citizenship" and the "shared responsibility for the life cycle of products" (MMA, 2020).

The figures for municipal solid waste generation in Brazil (RSU) show an annual total of 79 million tons in 2018. Of this amount generated, 72.7 million tons were collected, recording a 92% coverage index for the country, which also shows that 6.3 million tons of waste were not collected and consequently had improper destination (ABRELPE, 2019). In 2018, the appropriate final

disposition of RSU registered an index of 59.1% of the annual amount sent to landfills, and the difference (40.9%) is still destined to inadequate units such as controlled landfills and dumpsters (ABRELPE, 2019). This exerts influence on problems related to the correct disposal of waste, involving environmental, economic and social factors (Ramos, Castilhos, Forcellini, & Graciolli, 2013). Other important data refer to the selective collection of post-consumer materials and the process of screening these materials. Only 22% of Brazilian municipalities have selective collection installed and, in this scenario, 50% of materials selectivity is carried out by waste picker cooperatives (CEMPRE, 2019). According to the National Sanitation Information System NSIS (2016) the percentage of dry and recycled collected materials in Brazil is 2.1%, which figures as a very small percentage.

The gravimetric composition of the selective collection of solid waste, which can be recycled and offered for sale by cooperatives, is composed of 22% paper and cardboard, 13% plastic, 12% aluminum, 10% ferrous metals, 9% glass, 3% electronics, 3% other, 2% long life. In addition to these materials, there are 26% of waste that cannot be used for recycling (CEMPRE, 2019). The financial revenue of waste picker cooperatives is directly related to the productivity of the process of sorting these 74% recyclable materials. Higher productivity means higher profit and consequently a higher income distribution to the co-operated (Fattor, & Vieira, 2019).

b. Central screening: recycling cooperatives

Developing countries in particular have invested in organizing groups of waste pickers, encouraging them to form Solid Waste Picker Cooperatives (CCRS), also known as Recyclable Materials Centers (CMRs) (Magni, & Günther, 2014, Besen, & Fracalanza, 2016). It is estimated that in Brazil there are approximately 800,000 collectors of recyclable materials and that only 30,000 are organized in cooperatives (Fattor & Vieira, 2019), which represents 3.75% of the available workforce. Recyclable materials cooperatives appear as an important link in the logistics chain for sorting after-consumer products that can be reinserted into the production flow, as recycled raw material, transforming them into new products (Souza, Fontes, & Salomão, 2014, Fidelis, & Colmenero, 2018). Promoting the interface between the consumption of society and the recycling industry (Souza et al., 2014) cooperatives are presented as a public policy model to manage solid waste with recycling potential (MSWRP - *Managing Urban Solid Wastes with Recyclable Potential*) (Fidelis, & Colmenero, 2018) and are recognized by the National Solid Waste Policy (PNRS) as key agents in the recycling chain (Demajorovic et al., 2014).

Furthermore, waste pickers contribute to cities in various ways, as service providers for the selective collection of materials, as environmental agents enabling recycling and as key economic actors that feed the market with secondary raw materials (Dias, 2016).

The disposal of recyclable materials can have different destinations: regular collection, selective collection and voluntary delivery points (ENP). Once disposed of in the ordinary waste, the destination of these packages will be a landfill, while those disposed of in the waste destined for selective collection and at voluntary delivery points will be forwarded to the cooperatives of waste pickers, where they will be sorted by type of material, so that a fraction of these materials will be marketed. All else will be disposed of as waste and then sent to the same landfills to which the

post-consumer materials disposed of in the common waste were destined. Those that are marketed automatically generate revenue for collectors (Demajorovic, & Massote, 2017).

A comprehensive chain of work process operations of the sorting plants can be represented in the value flow (material flow) of Fig. 1. The operations of the sorting plants are oriented to the collection, storage, sorting and marketing of products. Production includes the entire internal flow of materials, composed of the pre-screening, screening, pressing and storage stages (Fidelis, & Colmenero, 2018).



Fig.1: Material flow in a sorting center, from collection to internal operations.

Among the operations developed, screening is the main value aggregator, an indicator of this is that the price of the material varies whether it is separate or not (Oliveira, 2010). The speed of sorting and the quality of the sorted materials determine the productivity that the cooperative will have and, consequently, the final financial gain for the cooperators. The lack of attention in this operation can be decisive for the gain by the cooperators at the end of the month (Fattor, & Vieira, 2019). For this reason, particular attention should be paid to strategies in which they can result in an increase or decrease in the value produced and, consequently, in the remuneration of waste pickers (Parreira, 2010).

Among the factors that generate inefficiency in screening, Parreira (2010) describes them in three classifications: external, internal and organizational. The external factors are the mix of the material, the amount of waste, the type and time of transport. The internal ones refer to the form of storage of the material that will be carried out the sorting, manipulation and the space intended for this operation. Regarding to the organizational, the work pace and the form of remuneration are considered (Parreira, 2010).

Properly managing a production process is crucial to achieving organizational objectives, but the lack of technical knowledge makes this management challenging and leads to results that fall short of what the organization could achieve. Associations and cooperatives of recyclable

material collectors are very relevant in the implementation of integrated waste management, however, in most cases, they have an incipient management of their processes and activities (Feitosa, & da Silva, 2018).

The area destined to the operations that add value in a cooperative of recyclable materials must be sufficient for the materials to have production flow, from the stock of the collected material to the shipment of the bales of sorted materials, as defined in Figure 1.

Thus, productivity and value added to products is directly associated with the efficiency and speed of the material flow in the process.

2.3. Productivity for recycling materials cooperatives-CMRs

The study of the system of production of goods and/or services involves its basic model composed of inputs, transformation process, and outputs. The capacity of a production process is determined by the resources it has to produce its outputs and concerns the production potential of the process (Feitosa, & da Silva, 2018). Resources (inputs) are raw materials, machinery, equipment, energy, capital, human resources, among others. The results (outputs) are goods and/or services resulting from the transformation of resources by the manufacturing processes. The higher the output with less input, the greater the productivity of the system. It has thus that productivity is usually measured by comparing the quantity of goods and services produced with the inputs used in production (Mankins, 2017).

The fraction between output (system result) and input (resources used to obtain the system result), as such, is typically expressed as an output/input rate. Simple measures of productivity reflect the production units produced per unit of a specific resource (Syverson, 2011). i.e.:

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}} \quad (1)$$

Workforce productivity, as a production resource, is the most common measure, although capital or even material productivity measures are occasionally used (Syverson, 2011).

Waste reduction in processing processes is a key point in this relationship, as it leads to increasing results. The process of sorting the cooperative recycling materials (Cmrs) adheres to this production model and considers that the results of the system are classified materials and the resource used would be the labor time of the cooperators.

Manufacturing processes contribute to the competitiveness of companies by continuously improving productivity and making the system more efficient (Rodrigues, Lourenço, & Jorge, 2019). For cooperatives this statement also applies. The establishment of sorting productivity is decisive for the results of the CMRs and for the dimensioning of sorting resources (equipment and collectors). The production capacity of cooperatives is relevant to the construction of performance indicators of screening actions seeking to increase recycling (CEMPRE,

2019). Fidelis and Colmenero (2018) state in their studies that cooperatives underuse their inputs in the generation of products, that is, they could produce more with the same inputs used, and thus be more productive. The implementation of a CMR requires a series of basic conditions of transportation, sorting, storage and commercialization of recyclable materials, as well as support for qualification of its members for the management of its business system. Managing a cooperative means managing every step of your process and setting goals (Fattor, & Vieira, 2019).

III. RESEARCH CLASSIFICATION AND METHODOLOGY

This paper has a quantitative approach in a case study, which is defined as an empirical method that investigates a given case within a real-life context through evaluations (Miguel ,2010, Y in ,2010). The methodology is also classified as applied (generating knowledge with practical application), with descriptive data analysis, as it is intended to describe the screening process and analyze the impacts of variability on the activities developed in this process. Data collection was based on the application of timing techniques and on-site observations.

Chart 1 summarizes the research classification.

Chart 1: Research Classification

Description	Specification
General Objective	Investigate the current productivity of a collectors' cooperative (kg/cooperative member) in the sorting operation. Identify the waste in the sorting operation and propose improvements that can be implemented in the sorting operation in order to increase productivity.
Classification	Applied research. It aims to generate knowledge for practical application aimed at solving specific problems (Silva & Menezes, 2001).
Objective	Descriptive research. Description of the characteristics of a given population or phenomenon using standardized data collection techniques: questionnaire and systematic observation (Silva & Menezes, 2001, Collis & Hussey, 2005, Gil, 2011).
Approach	Quantitative. Data collection and statistical analysis to describe the observed events (Silva & Menezes, 2001).
Methods	Case study. Timings and observations at the operations site (triage screen). Data was collected by records and filming.

Based on the choice of case study as an investigation approach for the present research, the search for bibliographic references began, which was not limited only

to the most recent dates, but rather to articles published by authors of relevance in the literature. The bibliographic research focuses on keywords where the contents dealt

with (i) studies of solid waste in Brazil, (ii) the importance of sorting centers (collectors' cooperatives), for the process of recycling post-consumer materials and (iii) research on the productivity of sorting processes for the final results of cooperatives.

This case study is delimited to the operations of selections of recyclable materials on the sorting belt. The timing and observations in the operations were made with the presence of the researchers at the site itself as well as filming the selection process on the screening mat. Data collection took place during May 2019.

Timings were divided into value-added time (sorting recyclable materials) and non-value-added time (waste). The value-added time represents the time of operation used to separate the various materials on the sorting belt, i.e., the time that the cooperated remove each type of material from the belt and place it in the respective big bag. The non-added value time refers to times lost by (cooperative) operators without material separation, i.e., waste. In the investigations addressed to the cooperative members working on the sorting mat, we identified four main types of waste of time in the sorting operation, which are: (i) Downtime due to lack of material on the screening belt; (ii) time performing movements that do not add value; (iii) time spent on cleaning and tidying the materials; and (iv) time expended on several other activities.

The identification of types and times wasted have a direct impact on the productivity of the sorting operation, whose resource is the cooperative's workforce. These wastes can be reduced by process improvement actions and it is assumed that the acceptance of improvement proposals by the cooperators will be more efficient using the cooperative context itself (Fidelis, & Colmenero, 2018).

IV. CASE STUDY

The case study developed was conducted at Cooperativa Recifavela, located in the municipality of São Paulo, State of São Paulo, Brazil.

The name came from a junction: Recycling and Favela, since the founders were residents of Favela da Vila Prudente, the oldest Favela in São Paulo, which was founded in 1940 on official record. Thus, they linked their origins to the identity of the cooperative. Currently, the cooperative collects three tons per month of the site, which is also where most cooperators live (Recifavela, 2020).

In 2007, in the face of pressure exerted by the government to leave the work carried out under a viaduct in the greater São Paulo, the waste pickers decided to join

the unemployed youth of Favela Vila Prudente and set up a cooperative for sorting recyclable materials. Through this initiative, the Recifavela cooperative was born on December 24, 2007. Previously the cooperative remained for 5 years under the overpass, which was the first space occupied and was an old construction site, without drinking water, electricity or toilets. The perseverance of the group resulted in an agreement with the city of São Paulo that allowed the relocation of Recifavela to a warehouse, where they were able to offer 50 jobs. Currently, the production process has two sorting belts and four presses, with daily work hours and a monthly production of 100 tons of products for recycling (Recifavela, 2020).

The cooperative processes the sorting of recyclable materials, mostly from the selective collections carried out by the city of São Paulo. The Municipal Urban Cleaning Authority (AMLURB) is responsible for the collection and management of solid recyclable waste produced (São Paulo City Hall, 2020).

In 2019, the city of São Paulo collected 80.4 thousand tons of recyclables. In the first four months of 2020 the collection of recyclable materials was 31.8 thousand tons, 16.9% more than in the same period of 2019 (São Paulo City Hall, 2020). This scenario indicates the importance of waste picker cooperatives in the correct disposal of post-consumer materials for the recycling industries, avoiding the deposition of these materials in dumps and landfills.

It is understood that the participation of Cooperativa Recifavela in the production of materials for the recycling industry represents approximately 1.5% of the recyclables collected by the city of São Paulo in 2019.

c. Characterization of the screening process

The materials that arrive at the cooperative are transported by municipal collection trucks and by trucks from Recifavela itself. The materials are received, unloaded and stored for further sorting. Of all kinds of sorting materials, three of them cardboard, glass and scrap are separated in a pre-sorting and packed in big bags, as they have an alternative flow and are not fed on the conveyor. The cardboard big bags are transported to the presses, where the material is pressed, packed in bales and stored. Glass and scrap are transported in big bags and dumped in the respective buckets (final stock).

The other materials are fed on the sorting conveyor, classified according to their type and packed in big bags. Each of the sorted products are then transported to the press, pressed into bales and stored for sale, with the exception of mixed paper and white paper, in which the materials are poured into buckets (final stock).

Moreover, of all the mass of materials that reaches the cooperative, a part of it is not classified as recyclable product, it is the waste. The waste is collected in buckets, weighed and stored, for collection by the city and destined to landfills. These wastes represent 26% of the mass, which is not used for recycling (CEMPRE, 2019), but which has added value over several stages in the screening process.

All big bags and bales, of the various sorted materials, are weighed for production management, inventory control

and monitoring of the flow of materials throughout the cooperative's process operations.

For Recifavela, the flowchart drawn in Fig. 2 details the flow of materials at each stage of the process. From the input of the collected material to the final stock of each type of sorted product, through all the internal operations of the process.

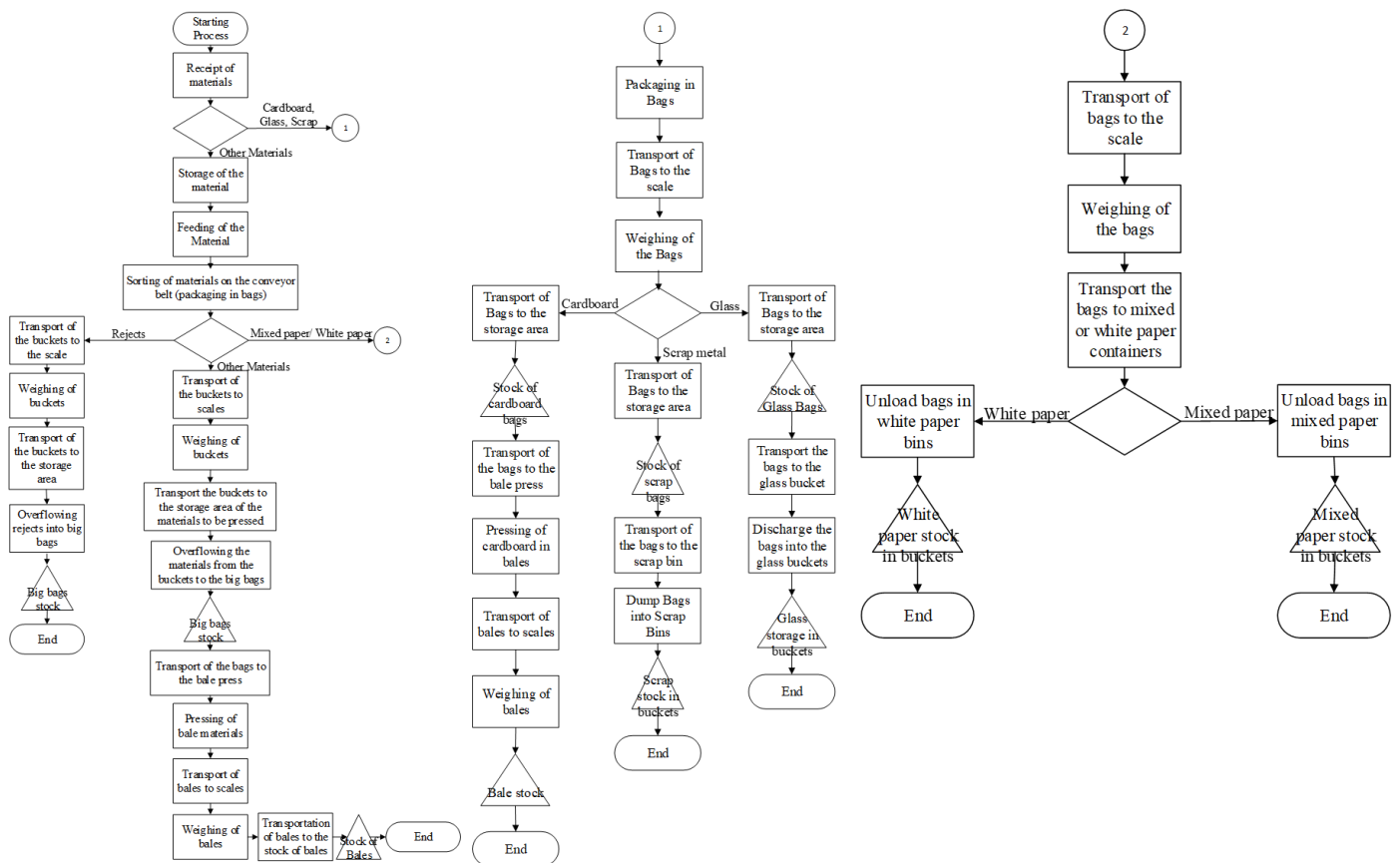


Fig.2: Flow of materials in the sorting processes of Cooperativa Recifavela. Source: Authors

It is worth adding that of the entire flowchart presented in Fig. 2, the study of this article is limited to the productivity of material sorting on the conveyor and the focus of the research is the screening process. Among the operations developed, belt screening is the main value aggregator (Oliveira, 2010). All the materials, which make up the gravimetry of the cooperative (Fig. 7), are fed on the mat to be sorted, only cardboard, glass and scrap do not pass through the mat.

4.2 Sorting operation

The sorting operation is the main activity within the cooperative's production process. It is the stage where the

material is effectively separated into the various different types to be sold (Fattor, & Vieira, 2019).

The screening operation is carried out by the cooperates positioned along a conveyor belt, basically, they separate the various types of materials, while pack them in big bags. With dimensions equal to or greater than 0.90mx0.90mx1.20m for each waste picker there are five big bags around, one for each type of material, as illustrated in Fig. 3. The movement of materials between pre-sorting, sorting, weighing, pressing and storage is done by the so-called "support", who are waste pickers that

carry out these activities manually, with the help of palletizing machines and forklifts.

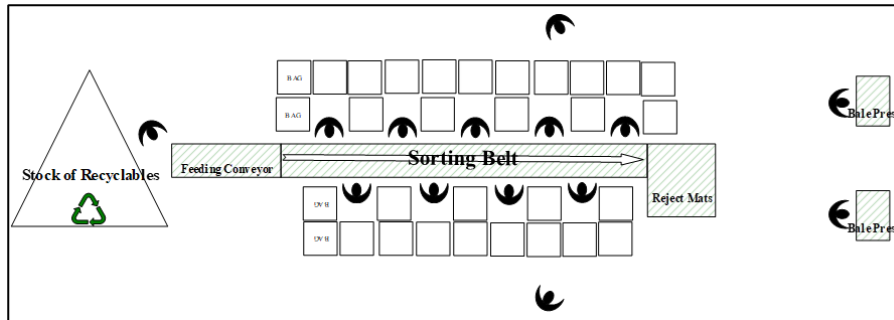


Fig.3: Layout of the sorting mat

In the screening, the value is added to the final result of the operation when the cooperators are making the move to remove the material from the mat and put it in the big bag.

Figure 4 illustrates a mat with the cooperates performing the material sorting operation. Around each

cooperate are allocated four big bags, one for each type of selected material.



Fig.4: Sorting mat. Source: Recifavela

4.3. Data collection and results

The data collected refers to the times of operations that add value to the sorting process and the waste times. According to the methodology adopted the waste times are: (i) Downtime due to lack of material on the screening belt; (ii) time performing movements that do not add

value; (iii) time employed in cleaning and tidying the materials; and (iv) time spent in several other activities.

The sorting conveyor is composed of 10 operators (cooperates) divided into five cooperates for each side of the conveyor, as shown in Fig. 5.

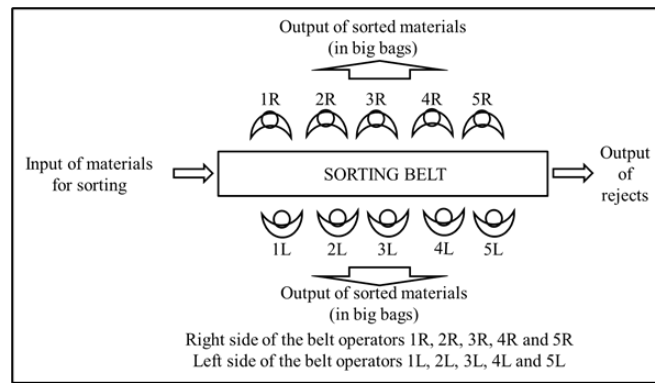


Fig.5: Distribution of cooperates on the screening conveyor. Source: Authors

For each of the positions, samples of 45 times ($n=45$) were collected at different times throughout the filming period. The summary of the timekeeping, both for the activity that adds value to the screening and for the wasted times (non-aggregated value), is presented in Table 1.

Note: The Aggregated value is the sum total of the times when operators have made movements by removing the material from the sorting belt and consigning it to the respective containers (big bag). ^bWaste: (i) lack of material on the mat to be separated, (ii) miscellaneous movement refers to movements such as tearing the bags containing materials and dragging/pulling the material on the mat; (iii) cleaning and stowing of materials in big bags; (iv) in the various activities are included parallel conversations, use of mobile, separation of material for own use.

Table 1: Value-added time and waste in the sorting operation

Cooperative operators		Value Added (VA) ^{to}	Waste ^{s b}				Non-Added Value (VNA)
			Lack of Material (i)	Miscellaneous Movements (ii)	Cleaning and Tidying (iii)	Miscellaneous Activities (iv)	
1R	Time (min)	45.00	18.50	13.82	3.45	2.30	38.07
	Percentage	54%	22%	17%	4%	3%	46%
2R	Time (min)	37.77	49.00	7.68	20.82	4.73	82.23
	Percentage	31%	41%	6%	17%	4%	69%
3R	Time (min)	44.27	19.00	8.73	2.00	3.00	32.73
	Percentage	57%	25%	11%	3%	4%	43%
4R	Time (min)	45.02	22.65	4.00	3.00	2.30	31.95
	Percentage	58%	29%	5%	4%	3%	42%
5R	Time (min)	44.54	22.18	1.00	5.00	2.28	30.46
	Percentage	59%	30%	1%	7%	3%	41%
1L	Time (min)	44.14	34.62	10.60	12.47	4.17	61.86
	Percentage	42%	33%	10%	12%	4%	58%
2L	Time (min)	44.43	34.22	5.40	7.40	3.55	50.57
	Percentage	47%	36%	6%	8%	4%	53%
3L	Time (min)	44.90	41.87	3.68	13.35	1.20	60.10
	Percentage	43%	40%	4%	13%	1%	57%
4L	Time (min)	44.45	50.55	10.72	9.50	3.78	74.55

	Percentage	37%	42%	9%	8%	3%	63%
5L	Time (min)	44.06	14.87	2.25	1.95	3.87	22.94
	Percentage	66%	22%	3%	3%	6%	34%

The average values (in percentage), of the transaction that aggregates value (VA) and the waste are represented in the graphic in Fig. 6.

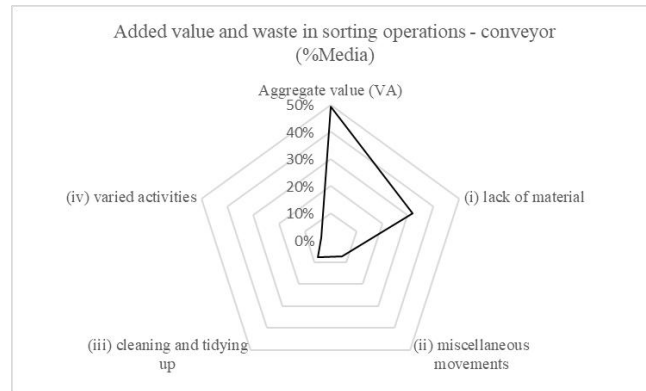


Fig.6: Added value and waste in sorting operations

To measure the amount of each type of solid residue screened in the Cooperativa Recifavela belt, the production was recorded daily during the data collection period. This information is used to calculate the gravimetric composition of the waste, that expresses the percentage of the presence of each component in relation to the analyzed

residue sample, being an information of great importance for understanding the waste and its proper management (Soares, 2011). Figure 7 graphically represents the gravimetry of the products screened in the Recifavela Cooperative.

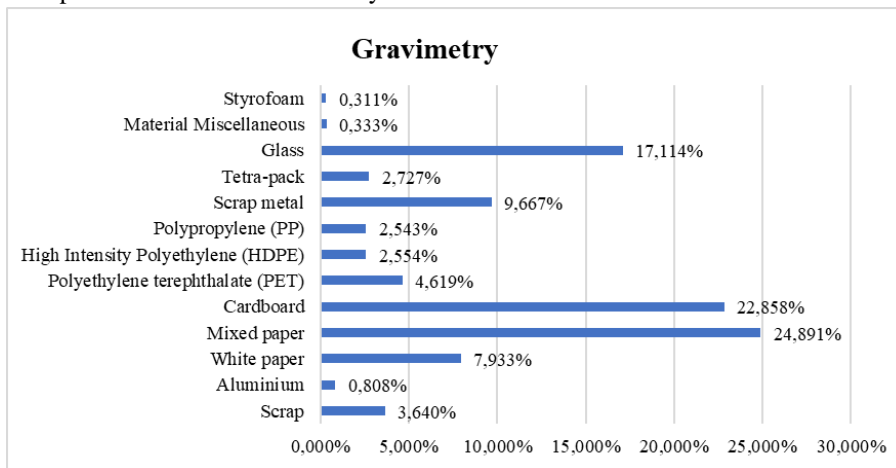


Fig.7: Gravimetry of materials screened in the belt of the Cooperativa Recifavela

The gravimetric dimensioning determines the percentage of the total mass of material that is fed on the screening belt.

The sample, with the mass of each type of recyclable material, was collected during a 30-days period, in May 2019. Pointing out that the cardboard, glass and scrap materials are not fed on the sorting conveyor (according to

the flowchart shown in Fig. 2). In this way, 50.368% of the materials passed through the mat to be separated (sorted).

The total mass produced by Cooperativa Recifavela in this 30-day period was 41,500 kg¹. Considering only the materials that were screened on the conveyor belt

¹ This value refers to the production of a sorting mat. The Cooperativa Recifavela has two mats.

(50.368% - according to Fig. 7 gravimetric), the mass produced on the conveyor represents 20,902 kg. This mass represents 49.4% of the time of aggregated value (VA), according to information presented in Table 1 and Fig. 6.

The resource used for this production was 10 cooperating operators, five operators on each side of the belt. Thus, the productivity calculated in the period is:

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}} = \frac{20.902 \text{ kg}}{10 \text{ operator}} = 2.090 \text{ kg/operator}$$

The lack of material on the conveyor belt is the most expressive waste, representing 32% loss in operational time in aggregated value (Fig. 6). Therefore, the regular feeding of materials on the belt will represent an increase of approximately 32% of the sorting operation time, equivalent to an increase of 13,540 kg of production in the period. The eviction of this waste impacts directly on the increase of productivity in the sorting operation. In this way, it is assumed that the productivity in the sorting belt becomes:

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}} = \frac{20.902 \text{ kg} + 13.540 \text{ kg}}{10 \text{ operators}} = 3.444 \text{ kg/operator}$$

The productivity gain with the elimination of waste "lack of material" is linked to the changes in the improvements in the feed operation standards of the screening belt. These operating standards shall be suitable in such a way that there is no interruption in the input of materials into the belt. Supplementarily, the cooperators responsible for the operation have to be trained and qualified for these improvements.

The study did not consider waste in various movements, cleaning and storage, and various activities, due to the fact that they represent low interference in productivity gain, and it was found that the elimination of these losses has little effect on the productivity of the system.

This research does not exhaust itself and there are several other points to be studied that directly interfere in the productivity and financial gains of recycling cooperatives, such as: (i) quality of the materials that reach the cooperatives and oscillation in the quantity of materials for screening (Souza et al., 2014), (ii) waste collection logistics - facilities for transporting recyclable solid materials provides an increase in waste pickers' financial gain (Ramos et al., 2013), (iii) production scale capacity in the other operations of the sorting process, (iv) logistics

distribution and marketing of sorted products directly to the recycling companies (Ramos et al., 2013, Fattor, & Vieira, 2019), (v) further public actions to encourage waste pickers' cooperatives, (vi) increasing the participation of companies that generate recyclable municipal solid waste, among others.

Internally to the picker' cooperative, and dealing directly with the operation of sorting materials on the conveyor belt, there are other important variables that were not considered in this study, such as: (i) belt speed, (ii) ergonomics of the cooperative members, (iii) sequential positioning of the cooperative members on the belt, and (iv) standardization of which type of material each cooperative member separates.

V. CONCLUSION AND FUTURE RESEARCH

This study is premise on the fact that the mass of collected dry and recycled materials in Brazil is very low (it represents approximately 2.1% of the total mass of recyclable materials - National Sanitation Information System, 2016). On the other hand, one of the alternatives to expand the reinsertion of these materials in the production chain is through the sorting and commercialization of these products as raw material for the industries. Recycling is a viable alternative to minimize the impacts of municipal solid waste on the environment. In this way, preventing waste from being sent to landfills, or even to unsuitable facilities such as dumps and controlled landfills, necessarily requires greater process sorting capacity in cooperatives. The increase of capacity, and consequently the search for greater productivity (less waste), in the main operation of the process of sorting of recyclable materials, is fundamentally important for the economic survival of cooperatives as well as the improvement of the quality of life of cooperatives.

Paschoalin Filho, Ghermandi, Dias, da Luz, & Cortese (2021) concluded that the low production of materials sorted for recycling is related to public management efforts to promote more active participation of citizens and greater efficiency of collection companies. In their internal production operations, waste pickers' cooperatives have limited productivity due to the lack of technological infrastructures (facilities, equipment and adequate process) and also due to poor working conditions (de Souza, Camarotto, & Fontes, 2019). Also Miranda, Fidelis, Fidelis, Pilatti & Picinin (2020) analyzed the integration of recycling cooperatives in the formal management of urban solid waste as a possibility of increasing productivity with a circular economy structure, overcoming: (i) the technological difficulties of the production resources, (ii)

the lack of technical skills of the cooperative members, (iii) the difficulties of marketing the products, (iv) the lack of attractiveness for corporate investment in raw materials, and others. In none of these papers, the researchers concentrated their studies on evaluating productivity in the operations of the process of sorting recyclable materials in the cooperatives of waste pickers. In this context, this article intended to fill this gap and revealed an opportunity to increase productivity in the sorting operation of cooperatives and the need to expand research in this field.

The study showed that in the main value adding activity (screening conveyor) there is a percentage of waste in the screening operation of 50%, which if reduced becomes a greater result of production and productivity. These identified wastes are largely concentrated in the lack of materials on the conveyor (32%), which can be shortened by operation improvement actions such as standardization of operations involving the screening and training of cooperators.

It is important to ratify that the increase in performance of the screening operation in the belt is one of the fundamental points for the sustainability, over time, of the cooperative as a business system, as well as for the improvement of the quality of life of its cooperators.

The adopted methodology used a quantitative approach that obtained data from timings and observations at the operations site (triage screen). Data collection was performed based on free and systematic observations, photographic records and filming. The work performed in this paper is classified as applied research (knowledge with practical application), with descriptive analysis of the results. The case study of this paper is limited to the operations of selecting recyclable materials on the sorting mat.

The case study presented in this article is a signal for researchers that there is a need to deepen the knowledge regarding the productivity of waste pickers' cooperatives, taking into account the importance of these organizations for the preservation of the urban environment.

It is suggested that new researches include other cooperatives in their studies. It is also necessary to investigate the development of technical training programs for members and cooperatives that involve public authorities, educational institutions and business associations. Also, knowledge projects to enable processes with more advanced technologies of production and management operations should be considered. Although waste pickers' cooperatives are a simple and humble environment, the potential for generating new scientific studies is quite evident, with the aim of enabling these

organizations for greater productivity and better representation of their social, economic and environmental importance within the solid waste recycling chain.

ACKNOWLEDGMENT

The authors thanks to Mr. Cristiano Cardoso, president of Recifavela, who allowed access to the cooperative's facilities, contributing decisively to data collection and enabling the development of this research.

REFERENCES

- [1] ABRELPE (2019) *Panorama dos resíduos sólidos no Brasil 2018/2019*. Disponível em: <http://abrelpe.org.br/download-panorama-2018-2019/>
- [2] Araújo, R. C. P. (2018) *Estudo de viabilidade econômica das centrais municipais de reciclagem (CMR's) nas regiões dos consórcios intermunicipais no Estado do Ceará*. Fortaleza: Quanta Consultoria.
- [3] Batista, L., Gong, Y., Pereira, S., Jia, F., & Bittar, A. (2018) Circular supply chains in emerging economies: a comparative study of packaging recovery ecosystems in China and Brazil. *International Journal of Production Research*. <https://doi.org/10.1080/00207543.2018.1558295>
- [4] Besen, G. R., & Fracalanza, A. P. (2016) Challenges for the sustainable management of municipal solid waste in Brazil. *The Planning Review*. 45-52. <https://doi.org/10.1080/02513625.2016.1195583>
- [5] CEMPRE. (2019) *Review 2019*. <http://cempre.org.br/upload/CEMPRE-Review2019.pdf>. Acessado em 18/06/2019.
- [6] Collis, J. & Hussey, R. (2005) *Pesquisa em Administração: Um Guia Prático para Alunos de Graduação e Pós-Graduação*. 2ª ed. Porto Alegre: Bookman.
- [7] Demajorovic, J., Caires, E. F., Gonçalves, L. N. S., & Silva, M. J. C. (2014) Integrando empresas e cooperativas de catadores em fluxos reversos de resíduos sólidos pós-consumo: o caso Vira-Lata. *Caderno EBAP.BR*. 12, 513–532. <http://dx.doi.org/10.1590/1679-39519020>
- [8] Demajorovic, J., Massote, B. (2017) Acordo setorial de embalagem: avaliação à luz da responsabilidade estendida do produtor. *ERA*. 57(5), 470-482. <http://dx.doi.org/10.1590/S0034-759020170505>
- [9] De Souza, R. L. R., Camarotto, J. A., & Fontes, A. R. M. (2019) Ergonomics and technologies in waste sorting: usage and appropriation in a recyclable waste collectors cooperative. *AISC*. 825, 851–860. https://doi.org/10.1007/978-3-319-96068-5_91
- [10] Dias, S. M. (2016) Waste pickers and cities. *International Institute for Environment and Development (IIED)*. 28(2), 375–390. DOI: 10.1177/0956247816657302
- [11] Fattor, M. V., & Vieira, M. G. A. (2019) Application of human HAZOP technique adapted to identify risks in brazilian waste pickers' cooperatives. *Journal of Environmental Management*. 246, 247–258. <https://doi.org/10.1016/j.jenvman.2019.05.128>

- [12] Feitosa, I. S. C. S., & da Silva, G. L. (2018) Análise do processo produtivo e capacidade operacional de uma organização de coleta seletiva de resíduos sólidos: estudo de caso asnov Garanhuns. *Revista Produção Online*. 18(4), 1344-1373. <https://doi.org/10.14488/1676-1901.v18i4.2945>
- [13] Fidelis, R., & Colmenero, J. C. (2018) Evaluating the performance of recycling cooperatives in their operational activities in the recycling chain. *Resources, Conservation & Recycling*. 130, 152-163. <https://doi.org/10.1016/j.resconrec.2017.12.002>
- [14] Gil, A. C. (2011) Métodos e Técnicas de Pesquisa Social. 6ª ed. São Paulo: Atlas.
- [15] Jabbour, C. J. C., Jabbour, A. B. L. S., Govindan, K., Teixeira, A. A., & Freitas, W. R. S. (2013) Environmental management and operational performance in automotive companies in Brazil: the role of human resource management and lean manufacturing. *Journal of Cleaner Production*. 47, 129-140. <https://doi.org/10.1016/j.jclepro.2012.07.010>
- [16] Magni, A. A. C., & Günther, W. M. R. (2014) Cooperatives of waste pickers as an alternative to social exclusion and its relationship with the homeless population. *Saúde Soc. São Paulo*. 23(1), 146-156. <http://dx.doi.org/10.1590/S0104-12902014000100011>
- [17] Mankins, M. (2017) *Great companies obsess over productivity, not efficiency*. Harvard Business Review. Accessed in: <http://thebusinessleadership.academy/wp-content/uploads/2019/08/Great-Companies-Obsess-Over-Productivity-Not-Efficiency.pdf>. Accessed date: 06/07/2020.
- [18] Miguel P. A. C. (2010) *Metodologia de pesquisa em engenharia de produção*. Rio de Janeiro: Elsevier.
- [19] Miranda, I. T. P., 1, Fidelis, R. 2, Fidelis, D. A., Pilatti, L. A., & Picinin, C. T. (2020) The Integration of Recycling Cooperatives in the Formal Management of Municipal Solid Waste as a Strategy for the Circular Economy—The Case of Londrina, Brazil. *Sustainability*, 12(24), <https://doi.org/10.3390/su122410513>
- [20] MMA – Ministério do Meio Ambiente. (2020) *Catadores de materiais recicláveis*. Accessed in <https://www.mma.gov.br/cidades-sustentaveis/residuos-solidos/catadores-de-materiais-reciclaveis>. Accessed date: 29 Jan 2020.
- [21] National Sanitation Information System (NSIS). (2016) *Diagnosis of urban solid waste management*. Accessed in <http://www.snis.gov.br/diagnostico-residuos-solidos/diagnostico-rs-2016>. Accessed date: 26 Jun 2019.
- [22] Oliveira, F. G. (2010) *Processo de trabalho e produção de vínculos sociais: eficiência e solidariedade na triagem de materiais recicláveis*. (Dissertação Mestrado). Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brasil.
- [23] Parreira, G. F. (2010) *Coleta seletiva solidária: agregando valor pela integração da cadeia da reciclagem*. (Dissertação de Mestrado). Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brasil.
- [24] Paschoalin Filho, J. A., Ghermandi, A., Dias, A. J. G., da Luz, E. G., & Cortese, T. T. P. (2021) Stakeholder views of source separation collection programme in East São Paulo, Brazil. *Waste Management & Research*, 39(1), 93–100. DOI: 10.1177/0734242X20972774.
- [25] Prefeitura de São Paulo. (2020) *Quantitativos: resíduos coletados no município*. Accessed in: <https://www.prefeitura.sp.gov.br/cidade/secretarias/subprefeituras/amlurb/index.php?p=185375>. Accessed date: 23/06/2020.
- [26] Ramos, N. F., Castilhos Jr, A. B., Forcellini, F. A., & Graciolli, O. D. (2013) Profile survey of waste pickers in Brazil: requirements for the development of a collection vehicle and optimized routing. *Journal of Urban and Environmental Engineering*. 7(2), 231-246. doi: 10.4090/juee.2013.v7n2.231246
- [27] Recifavela. (2019) *Nossa cooperativa*. <https://www.recifavela.com.br/sobre>. Accessed date: 26 Jun 2019.
- [28] Rodrigues, L. H., Lourenço, S. R., & Jorge, R. R. (2019) Application of a model in the evaluation of competitiveness in sustainability in factories of the pharmaceutical sector. *International Journal of Advanced Engineering Research and Science (IJAERS)*. 6(7), 144-154. <https://dx.doi.org/10.22161/ijaers.6718>.
- [29] Rohani, M. J., & Zahraee, M. S. (2015) Production line analysis via value stream mapping: a lean manufacturing process of color industry. *Elsevier Procedia Manufacturing*. 2, 6–10. <https://doi.org/10.1016/j.promfg.2015.07.002>
- [30] Roosen, T. J., & Pons, D. J. (2013) Environmentally lean production: the development and incorporation of an environmental impact index into value stream mapping. *Journal of Industrial Engineering*. <http://dx.doi.org/10.1155/2013/298103>.
- [31] Silva, T. B., Monteiro, W. R., & Leite, J. C. (2018) Application of reverse logistics in hospital material processes: case study. *International Journal of Advanced Engineering Research and Science (IJAERS)*. 5(12), 243-251. <https://dx.doi.org/10.22161/ijaers.5.12.34>.
- [32] Silva, E. L. & Menezes, E. M. (2001) *Metodologia da Pesquisa e Elaboração de Dissertação*. 3ª ed. Florianópolis: Laboratório de Ensino a Distância da Universidade Federal de São Carlos.
- [33] Syverson, C. (2011) What determines productivity? *Journal of Economic Literature* 49(2), 326–365. DOI: 10.1257/jel.49.2.326
- [34] Souza, R. L. R., Fontes, A. R. M., & Salomão, S. (2014) A triagem de materiais recicláveis e as variabilidades inerentes ao processo: estudo de caso em uma cooperativa. *Ciência & Saúde Coletiva*. 19(10), 4185-4195. <https://doi.org/10.1590/1413-812320141910.09072014>
- [35] Soares, E. L. de S. F. (2011) *Estudo da caracterização gravimétrica e poder calorífico dos resíduos sólidos urbanos*. (Dissertação de Mestrado), Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ, Brasil.
- [36] Yin, R. K. (2010) *Estudo de caso: planejamento e métodos*. (4ª ed.) Porto alegre: Bookman.