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RESEARCH PAPER

Value stream analysis of a waste picker cooperative: an approach based on sustainability and lean philosophy

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ABSTRACT

Purpose: This article aims to propose improvements to a solid waste cooperative's value stream from social, environmental, and economic aspects of sustainability and within the scope of lean philosophy.

Design/Methodology/Approach: An empirical piece of research was developed to obtain an overview of the productive process of a cooperative located in the city of Florianópolis, in Southern Brazil, starting with the application of Value Stream Mapping (VSM) in a case study.

Results: Some sustainability challenges in waste management were identified in the studied cooperative's reality, such as: Urban Solid Waste (USW) inefficient management; lack of resources to help with basic expenses, which jeopardizes the individual income earned by pickers; risks to workers when carrying out activities without personal protective equipment and instructions on how to perform tasks properly, in addition to the disorganized environment, which results in high piles of waste and puts the workers' health at risk.

Research Limitations: As limitations, it is possible to list the focus on a single material flow for better applicability of VSM and non-implementation of the improvements proposed.

Practical Implications: Results contributed to the cooperative analyzed in this study by identifying the main waste that compromise the organization's operational and sustainable efficiency.

Originality/Value: There is a research gap on the thematic axes of this study in the context of waste picker cooperatives; this article is therefore original for addressing the application of VSM with a sustainable bias in reverse logistics of solid waste.

Keywords: Pickers; Urban solid waste; Value Stream Mapping; Sustainability.

1. INTRODUCTION

The generation of Urban Solid Waste (USW) in Brazil was estimated at approximately 81 million tons in 2022, according to data from the Brazilian Association of Public Cleaning and Special Waste Companies - ABRELPE (2022). According to ABRELPE Bulletin, Southern Brazil is responsible for 10.6% of the country's total generation, and the southeast region is the most representative (49.7%).

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In view of the issue of USW generation, management, and correct disposal in the country, the National Solid Waste Policy (PNRS) was enacted in 2010, aiming to define instruments and principles for solid waste management (Brasil, 2010). The PNRS has sustainability as a fundamental principle, since it defines the expectation of using resources from the environment with the objective of meeting current human needs without compromising the future generations' life (Wang et al., 2020). This concept of sustainability encompasses three main dimensions: social, economic and environmental (Kircher, 2022). Thus, promoting waste management based on sustainability requires taking these three aspects into account.

When it comes to modern organizations, market pressure requires companies to have strategic objectives that go beyond economic efficiency and promote sustainable development. In this regard, lean philosophy and its tools have been adapted to not only improve the operational efficiency of production processes, but also identify opportunities for improvement – from the perspective of sustainability – to the organizations' value chain (Texeira et al., 2021; Tortorella et al., 2018).

Preliminary studies have proposed numerous adaptations to Lean tools – especially Value Stream Mapping (VSM) – to meet sustainable objectives in different organizations (Bait et al., 2020; Hartini et al., 2020; Hedlund et al., 2020; Lima et al., 2023; Lorenzon et al., 2019; Mubin et al., 2023; Santos et al., 2019; Texeira et al., 2021). However, despite the efforts of the authors of this study, no research was found that dealt with the application of the use of VSM in pickers' cooperatives, making this study an important contribution to the literature.

Studying the value stream of pickers' cooperatives and promoting improvements in their operation is important due to the challenges faced by selective collection, since waste sorting plants are precarious and recyclable material pickers face problems with their working conditions, in spite of these workers' relevance to segregating recyclable waste and reintroducing it into the production chain (Gall et al., 2020). Therefore, it is necessary to think about ways to improve this group's work (Jalalipour et al., 2021), and, in doing so, foster the development of the three pillars of sustainability.

Thus, the originality of the research lies in its focus on proposing improvements to the value stream of a waste pickers' cooperative, considering sustainability aspects and the perspective of lean philosophy. The authors aim to analyze the cooperative's value stream and suggest enhancements that can contribute to social, economic, and environmental sustainability.

This article is structured into five sections. The concepts that involve the listed issues are discussed below. Section 3 discusses the research methodological procedures. Finally, sections 4 and 5 present the results with their implications and discussions and the study final considerations, respectively.

2. THEORETICAL FRAMEWORK

This section discusses the essential theoretical bases for understanding the topic: solid waste, sustainability, and lean philosophy.

2.1 Urban Solid Waste and selective collection

One of the principles of the PNRS is to encourage the recycling industry, in order to stimulate the use of reused materials. However, for this process to be more assertive, it is necessary to characterize physically the composition of the solid waste generated (Yildiz et al., 2013). In this context, the Brazilian USW gravimetric composition is predominantly organic matter (45.3%), followed by plastic (16.8%), and waste (14.1%). Waste, in turn is composed of sanitary waste and other materials that were not identified or whose contamination did not allow for their separation (ABRELPE, 2020).

After characterization, the recycling process feasibility starts being analyzed, based on socioeconomic incentives, which take place in global situations where high costs are involved in the final waste disposal (Peña-Montoya et al., 2020). Nevertheless, recycling has primarily met the economic demands of the production chains without focusing on the benefits to the environment, since many materials that should go through some recovery process are discarded because of their low economic value (Melo et al., 2022). As a result, there is a great lack of structuring of the entire recycling program, mainly in terms of how it occurs in practice, and this should be the focus of public policies and not just stimulus to recycling process without preparing all individuals for participation (Jesson et al., 2014). On the other hand, the informal work carried out by waste pickers begins with the introduction of urban solid waste management as a public service (Velis and Vrancken, 2015). This contribution, however, is still ignored on several occasions, as this group is rarely associated with the solution of issues related to this management (Dias, 2016).

2.2 The triple bottom line of sustainability

The triple bottom line of sustainability refers to the three dimensions – social, economic, and environmental – that characterize sustainable development in organizations (Götz et al., 2023). The economic pillar relates to the economic aspect of sustainable development, associated with actions that facilitate and improve conditions resulting from economic activity and factors that are non-tradable and/or non-quantifiable for the environment (Hammer and Pivo, 2017). The environmental aspect is associated with the efficient and conscious use of natural resources and means of production, to secure resources for future generations. Thus, concerns of this dimension are issues such as the use of renewable energy, greenhouse gas emissions, and ecological footprint, and so on (Lorena et al., 2021). Finally, the social dimension refers to actions aimed at society, work and, above all, human capital in sustainable development (Alhaddi, 2015; Kerber et al., 2023).

Despite the individual presentation of each pillar, these three dimensions should be addressed together, given the impact that one pillar can have on the other (Lorena et al., 2021; Martine and Alves, 2015). It is important to point out that there is no single model to integrate the triple bottom line of sustainability in organizations (Schulz and Flanigan, 2016). Nevertheless, there are external factors that can drive organizations to opt for sustainable attitudes, such as consumer preference (Paula et al., 2019), the existence of regulatory frameworks, and market competition (Schulz and Flanigan, 2016). In this way, due to the diversity of factors involved, the decision was to focus on Lean philosophy, due to its objective of reducing waste and adding greater value to the production flow (Braglia et al., 2021).

2.3 Lean philosophy and Value Stream Mapping (VSM)

Lean philosophy focuses on reducing non-value-added activities fiercely, that is, waste, and relies on an extensive set of tools and techniques to meet this objective (Garza-Reyes et al., 2018). In practice, its tools have gained wide acceptance to achieve operational excellence (Braglia et al., 2019). In the scope of its application, there are several tools and techniques available and widely used in different manufacturing sectors, such as Overall Equipment Effectiveness (Braglia et al., 2019); Kanban; Just-in-time; 5S (Costella et al., 2018); Materials Cost Deployment (MaCD) (Braglia et al., 2021), and Value Stream Mapping (VSM) (Abualfaraa et al., 2020; Bhatt et al., 2020; Hartini et al., 2020).

Among the plethora of tools that Lean incorporates, VSM is considered one of the most essential (Garza-Reyes et al., 2018). In this way, VSM is the main mapping tool pointed out by the literature to identify waste (Andreadis et al., 2017; Pereira et al., 2017), facilitating the systematic identification of waste and supporting decision-making to prioritize and coordinate continuous improvement initiatives, providing a holistic view of the value streams executed to deliver a product or service to customers (Martins and Cleto, 2016; Shou et al., 2017). In addition, this tool can suggest improvements to the worker's routine, such as improving ergonomic matters and acting on their health and safety (Cherrafi et al., 2016).

In a complementary way, Lean philosophy is not applied only to industrial processes, because, among the different uses, it is possible to use it in the context of urban solid waste, even in situations where there has never been previous contact with Lean tools (Tortorella et al., 2018). Regarding its application in the sustainable USW management, there is a strengthening of the analyzed cooperative's performance, optimization and reuse of waste and, consequently, natural resource extraction and waste generation, principles present in the PNRS in an evident manner (Da Fonseca et al., 2017).

3. METHODOLOGICAL PROCEDURES

Regarding the empirical procedure adopted, this work is a case study, as it sought to analyze a particular case of a cooperative and interpret the value stream in a practical context, portraying the reality observed. The steps towards the operationalization of VSM, proposed by G. L. Tortorella et al. (2017) and F.-K. Wang et al. (2022), were taken into account to conduct this study, as summarized in Figure 1.

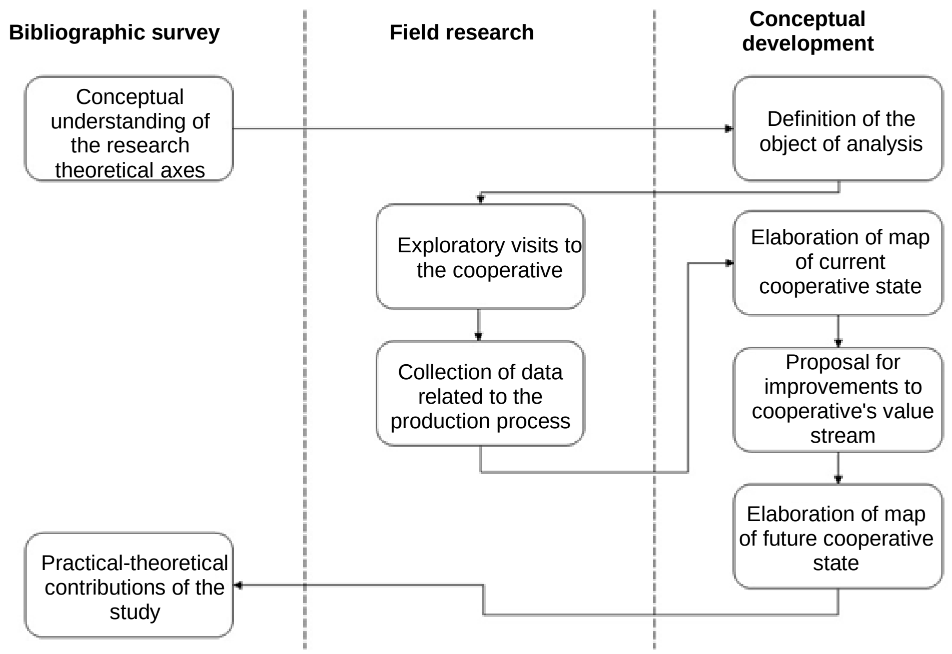

Figure 1 - Research methodological procedures
Source: Adapted from G. L. Tortorella et al. (2017) and F. K. Wang et al. (2022).

The first step consisted of developing the theoretical framework to support the discussions raised in this article about the axes of research on USW, sustainability, and lean. According to authors such as Fink (2013) and Seuring & Gold (2012), this step is essential for the development of any scientific research. The next step gave directions towards the flow to be analyzed, given that exploring different points of analysis is a very strenuous activity. In this sense, a cooperative located in the city of Florianópolis was selected, and the selection criterion was the cooperative that was most receptive to receiving visits. The name of the solid waste cooperative is not identified to preserve its image and anonymity.

After defining the cooperative to be analyzed, several visits were made to the site between June and September 2022, which took place twice a week, with a duration of two hours on average. The objective was to become acquainted with the organization, obtaining an overview of the routines and the main difficulties faced by it. During these visits, some tools such as face-to-face interviews, direct observation, photographs taken, and documents were utilized. Incorporating various data sources aided in collecting diverse sets of data. The method of cross-checks, as proposed by Pettigrew (1990), was employed to leverage the strengths of each data collection technique, and bolster the methodology, enhancing its robustness.

Pre-designed questions were utilized to facilitate the in-person interviews. The semi-structured interviews were conducted with its president and the two volunteer social workers on site who knew the cooperative’s routine. This step was undertaken to identify the challenges related both to the company’s operation and to its workers. Moreover, this collection method enabled the gathering of detailed information while still allowing for flexibility in the interview process, facilitating the exploration of unexpected insights and ideas for the next step of building the VSM.

Then, the collection of the production process data began to develop the map of current cooperative state, a VSM component. The collection was based on the observational technique and information from the interviewees. Thus, with the data collection referring to the organization's production flow, it was possible to identify points of improvement based on lean philosophy. Analyzing the identified waste and the whole context of sustainability, improvements to the cooperative's value stream were proposed and their implications for the analyzed organization and for the specialized literature were discussed, as foreseen in the methodological scheme of this study.

4. RESULTS AND DISCUSSION

4.1 Characterization of the object of study

The studied cooperative is composed of 74 workers, and opening hours are from 7 a.m. to 10 p.m., every working day. Each picker's income is determined based on the segregated material weight, considering the price offered by the cooperative. To manage internal activities, the cooperative uses "Catafácil," management software developed exclusively to serve picker organizations and assist in some processes such as material sales, rendering of accounts, reports, and specific calculations of the activity.

Material collection is mostly carried out by the Capital Improvement Authority (COMCAP), except for covenants – agreements made directly between the cooperative and large generators, such as schools, supermarkets, etc. Two small cargo bed trucks are used for collections. Most sales agreements are made with third-party companies, that is, companies that buy materials from cooperatives, carry out additional treatment and, later, resell them to industries to reapply the recycled material in their production processes, since the analyzed cooperative does not have enough structure and machinery to serve the industries directly.

To define the family of products to be mapped, data were collected regarding the representativeness of the main materials sold in three categories: price, revenue, and weight, as shown in Figure 2.

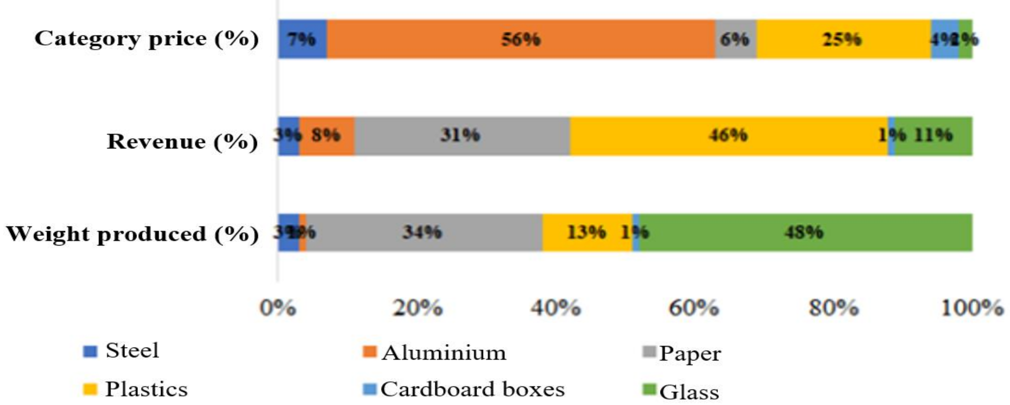

Figure 2 - Main materials traded by the cooperative
Source: Elaboration by the author.

Although aluminium has the highest sale price, plastics are the most representative element in revenue. Furthermore, glass, and not aluminium, is the material with the most relevant weight produced, but its traded value is much lower. Therefore, one concludes that proposing improvements with a focus on the plastic flow can bring a greater profitability to the cooperative members' work, exploring the economic dimension of sustainability.

Plastics are sorted into different categories, and the main ones are polypropylene (PP), polyvinyl chloride (PVC), high-density polyethylene (HDPE), and polyethylene terephthalate (PET). However, all categories go through the same production processes, and then there will be no distinction between them.

4.2 Description of the production process

Figure 3 represents the recurrent material flows in the cooperative's USW processing.

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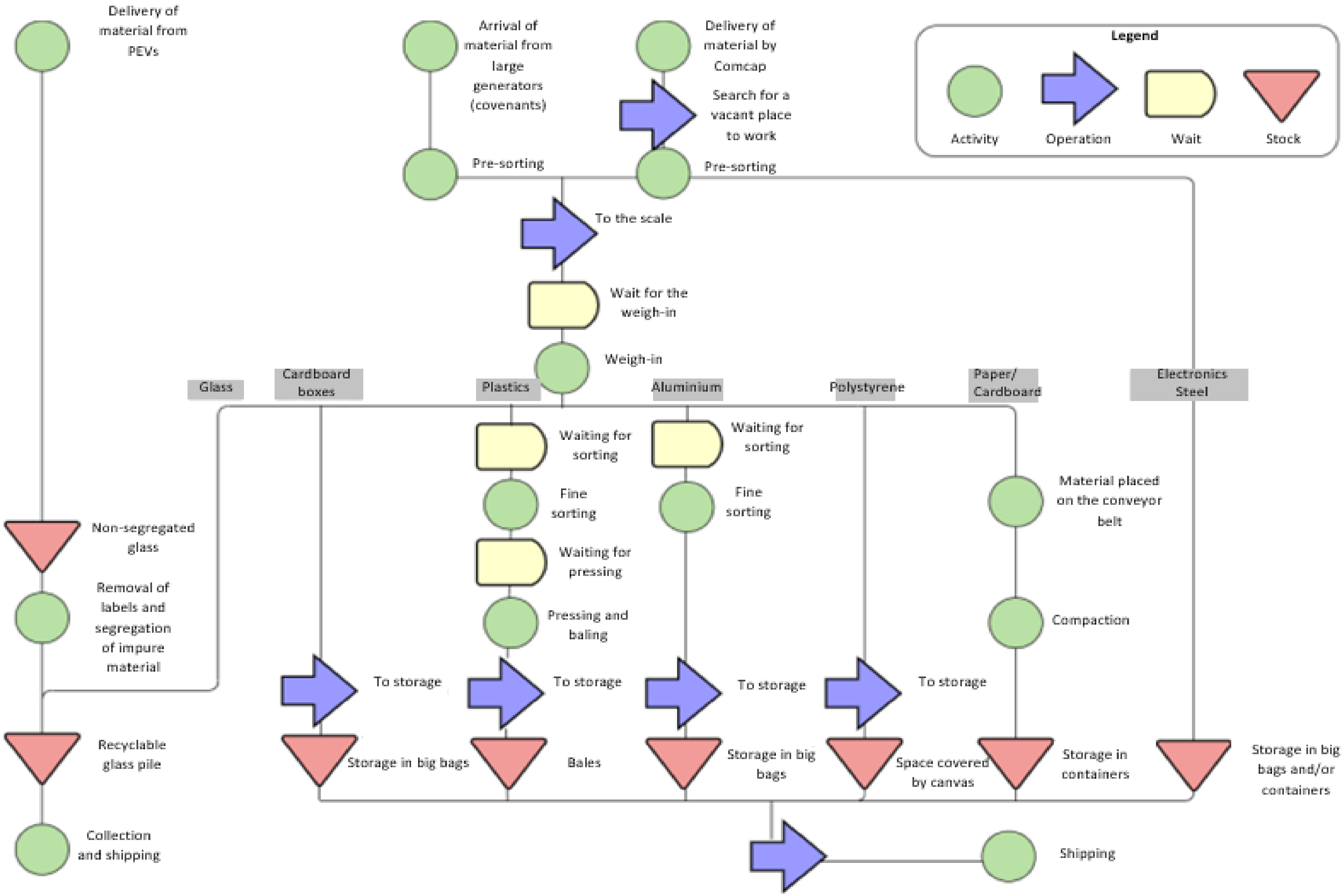

Figure 3 - Flowchart of cooperative materials
Source: Elaboration by the author.

Waste arrives at the sorting warehouse via COMPAC trucks or through large generators (covenants) collection, on a daily and weekly basis, respectively. Materials are deposited wherever available, and then the lack of process organization requires the use of a wheel loader to generate walkable space in the warehouse whenever the material amount becomes excessive.

In pre-sorting, workers do not have specific workstations, and tables are placed throughout the warehouse between the waste piles. For this task, the worker separates the waste and puts it in different containers placed around the table. It is possible to carry out the work individually or in pairs, and the number of workers assigned to this stage is variable. Some types of materials do not go through the pre-sorting stage, such as electronics, metals, cardboard boxes, and polystyrene. Polystyrene is stored in a specific place at the main warehouse entrance. Cardboard boxes are only separated into big bags for later sale. Bulk metals such as iron bars, chairs, and file cabinets are placed in a large container outside the warehouse.

After pre-sorting, the worker must take the containers to be weighed, a process in which the amount of segregated material and the worker's name are registered to facilitate the payment made by the cooperative administrative-financial sector. After weigh-in, the papers/cardboards are shredded, compacted, and stored in a container. Plastics and aluminium are taken to the so-called fine sorting and then pressed and packed in bales for later storage. Aluminium is taken to a container at the warehouse entrance, which has an internal separation table for fine sorting, and from there it is stored in a specific place.

The glass segregation process takes place outside the warehouse. If this material comes from pre-sorting, the workers throw it in containers – since there are no problems about it being broken –; however, throwing this material makes the procedure dangerous for workers. Two people are responsible for cleaning (removing the labels) or discarding the material when there are many impurities inside the recyclable container, given that the cooperative does not have the structure to sanitize the materials received. About shipping, in general the cooperative is responsible for delivering the plastics. As for other materials, third parties are responsible for collecting them and usually take all the material available for sale, leaving no stocks.

4.3 Pickers' perspectives

Based on interviews with social workers, several key findings emerged. The cooperative exhibits a high turnover rate, indicating an inconsistent relationship between the cooperative and its members, despite a large number of pickers seeking to join. The main challenge for social workers is to reduce the weekly deductions, ranging from US$13 to US$16, from the pickers' income. These deductions cover expenses such as electricity, meals at the cooperative, and Personal Protective Equipment (PPE). Social workers rely on donations from private companies and public bodies to minimize these deductions, but there is limited continuous support from the municipality.

Safety is a critical concern due to the frequent lack of PPE, resulting in frequent accidents. Additionally, the separation benches are small and in poor condition, contributing to difficulties in the working routine. The warehouse lacks proper organization, with a significant volume of material occupying considerable space. Pickers express a desire for training opportunities, such as technical or professional courses, but limited access due to the majority's low level of education.

4.4 AS-IS map of the cooperative

Figure 4 presents the map of current state of the cooperative's value stream. For this map, due to the changes that occur with the material, the stock is represented in kilograms (kg) and the number of workers involved is inside the process box. In addition, timeline is at the map bottom, estimating the time that the material takes to go through all stages; the upper part indicates the lead time and the lower part the value-added time.

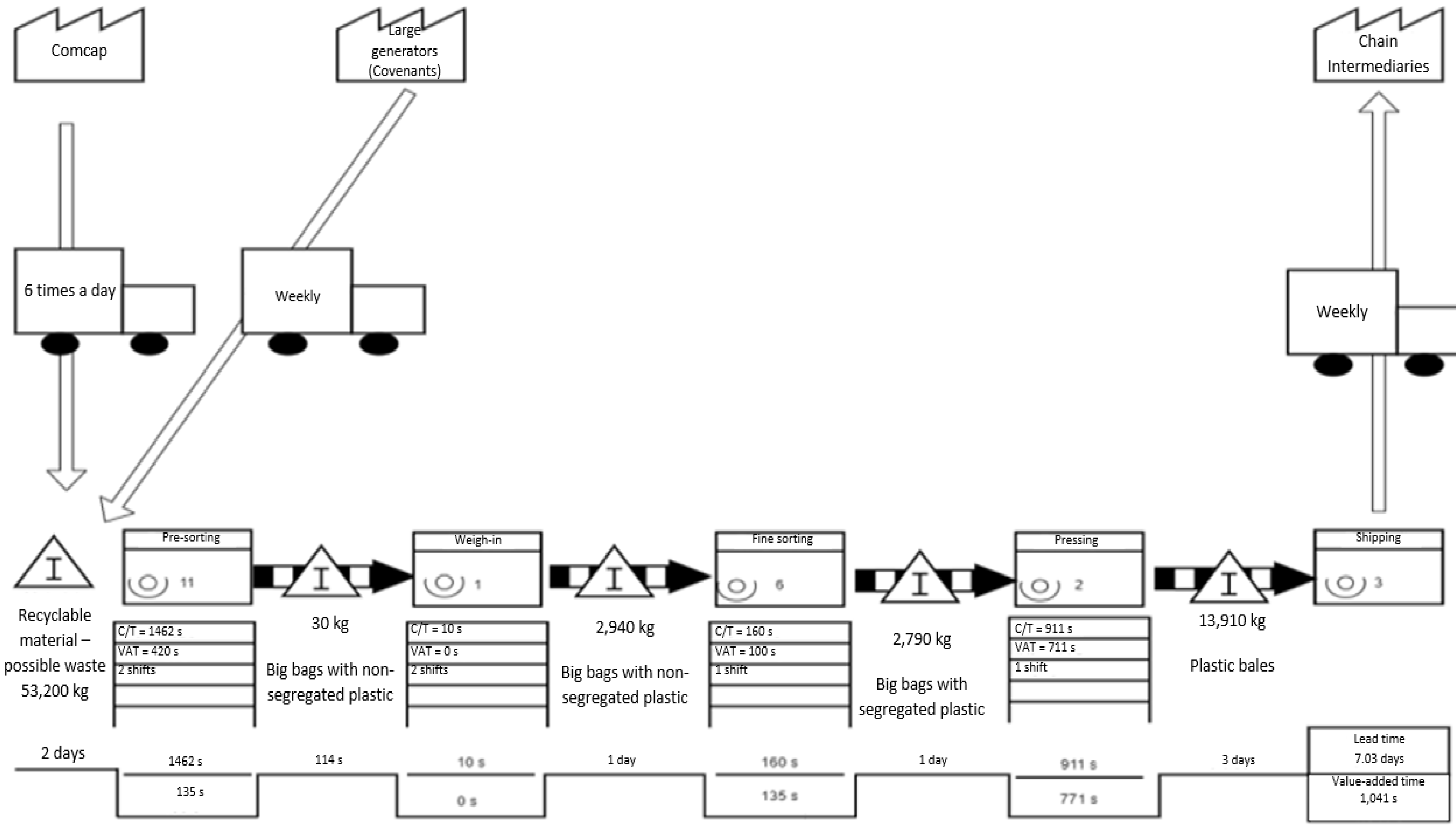

Figure 4 - Map of current cooperative state
Source: Elaboration by the author.

In VSM, the stock symbology is assigned to each location where it is identified; however, due to the large amount of stock without delimitation throughout the warehouse, it was not possible to identify all the stock points, and it is important to point out that this does not have a well-defined location. Another point of adaptation was the need to standardize how plastics are transported along the flow. In most cases, plastics are put in big bags, but it is also possible to identify this material being carried in plastic bags of household waste. In Figure 4, considering the value generation classifications, the difference between the cycle time (C/T) and value-added time (VAT), there are waste and non-value-added time, which is necessary. With that, Figure 5 defines the composition of each time according to each stage.

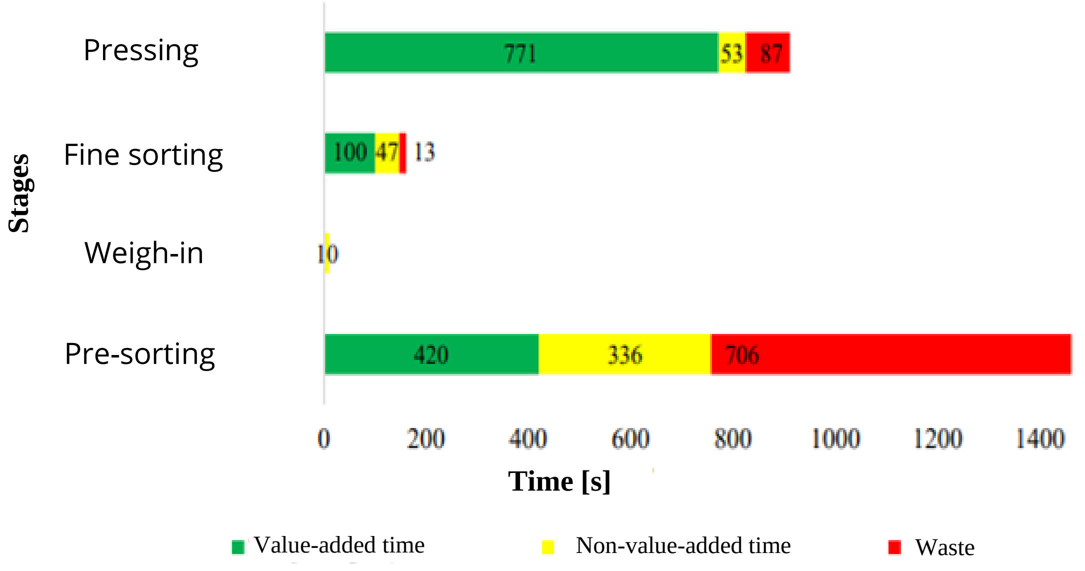

Figure 5 - Breakdown of cycle time according to value generation
Source: Elaboration by the author.

Starting the analysis after receiving the material, the pre-sorting process has several particularities, since there is no standardized way of working, generating differences in the work pace when the material is separated in pairs and when the separation is done individually. For this reason, in Figure 4, there is a representation of the situation in which all tables were occupied, but with only one worker at each of them.

In addition, rest intervals are adopted without any criteria, which also present great variation. Each worker has a different way of organizing their workplace, and each one is responsible for cleaning it. However, it is difficult to organize the place due to the large volume of stock for pre-sorting.

The next stage, that is, weigh-in, presents a waiting time relatively short, and this is because this stage is very objective. The distance between workers and the scale also varies, as the sorting tables are arranged along the warehouse.

At this stage, in addition to moving from place to place with great frequency, the workers also drag the big bags, and when the material is separated into plastic bags, those are carried on their backs, putting their health at risk. Moreover, as the cooperative members' income is according to the segregated weight, when filling the big bag with the material, the workers try to fill it to the maximum volume possible; then, when dragging it along the warehouse, some materials end up falling along the way and are not collected.

In fine sorting, waste is also related to unscheduled breaks, in addition to the fact that at this stage it is possible to find materials that are not plastics. Pressing, the last processing stage, does not occur continuously, unlike the others. In this way, the amount of material stored before this stage is high. Besides, during processing, it was noticed that those in charge take up relevant time moving the material stored in big bags to the press. Finally, as a way of highlighting the waste found along the flow, Table 1 summarizes this waste based on the main processes.

Table 1 - Observed waste

Process	Waste	Analysis	Pillars of sustainability affected
Pre-sorting	Process Stock Products	Workers spend a lot of time cleaning and organizing their workplace. Sometimes, the material thrown by them does not fall into the big bag but on the floor and then it is not collected. The excessive amount of stock arriving at the cooperative hinders the workflow.	Environmental and economic
Weigh-in	Wait Operation Products	It is possible to observe that queues are formed. Furthermore, the worker moves too much to go to the scale and in a non-ergonomic manner; this time could be used to sort more materials. Also, due to the way in which the material is taken, some of it often falls along the way and is not collected.	Environmental, social, and economic
Fine sorting	Stock Process Products	The amount of stock is too much for this process. Workers' unregulated rest intervals interfere with workflow. This stage reflects possible pre-sorting errors, such as existence of products that are not plastic.	Environmental and economic
Pressing	Wait Operation Stock	Some idle moments during pressing were observed. Workers must move around during pressing to look for more big bags when they are distant from the press. The amount of stock on hold is high for the pressing pace.	Economic and social

Source: Elaboration by the author.

When contextualizing the waste listed within the dimensions of sustainability, it is noted that the environmental pillar is affected by processing inefficiencies throughout the whole process, so that wasted materials become non-recycled waste that will be sent to the landfill. These generates higher expenses for the municipality and affects the economic pillar. Moreover, the cooperative's financial performance is also affected, since the volume of stock represents the impossibility of meeting the real urban waste generation demand, and consequently, the cooperative's revenue is not optimized. Finally, workplace disorganization and the presented ergonomic issues negatively affect the pickers' health, affecting the social pillar.

4.5 TO-BE map of the cooperative

Figure 6 presents the proposed value stream map for the cooperative, after evaluation of the issues identified.

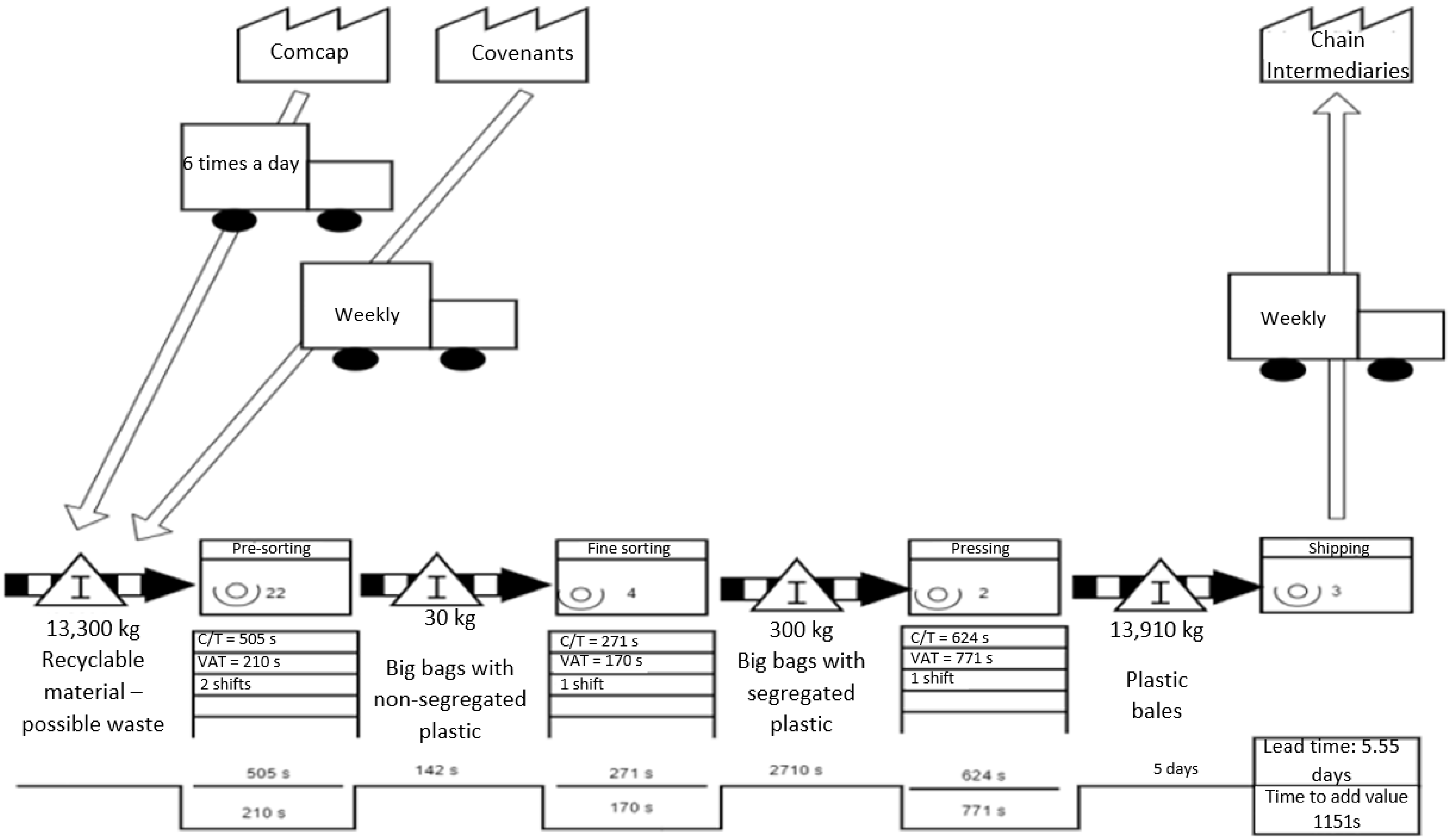

Figure 6 - Map of future cooperative state
Source: Elaboration by the author.

As a first premise, what determines the chain pace is not customer demand, but the amount of supplies available, in this case, the recycled materials sent to the warehouse. In this sense, obtaining accelerated flow throughout the process is not possible. However, the limitation of intermediate stocks and the recalibration of the planned work pace aim to generate a sense of flow, so that the work pace can meet all the recyclable material demand. According to information collected at the cooperative, around 133 tons of waste are sent per week, approximately 20% total waste. With this, it is necessary to estimate the new average incoming stock. For this, Ballou (2011) establishes Equation 1.

$$Medium\ stock = \frac{Order\ quantity}{2} + Safety\ stock \quad (1)$$

Analyzing Equation 1, we have the safety stock as an auxiliary volume to guarantee possible variations in demand and delivery (Ballou, 2011). Nevertheless, as the sustainable role of the cooperative within the municipality is to be able to process all the waste sent, there is no need to estimate a supplementary stock. Therefore, considering the daily goal of meeting the demand, the order quantity becomes equivalent to everything received in a day and the average stock represents 13,300 kg.

Bringing the focus to the plastic flow, considering the context presented in which 13% recyclable materials are plastic, 13,910 kg of plastic are processed per week, or considering five working days, 2,782 kg of plastic per day. Using the big bag with 30 kg of plastic as the standard unit, it is estimated that the cooperative should produce approximately 93 big bags with plastic per day. Analyzing pre-sorting, which is the process closest to material receipt, it takes place in two shifts; therefore, estimating the available working time as 13 hours, takt time is 505 seconds to process one big plastic bag with plastic. Considering the current cycle time in which only 11 people work in this sector, it appears that it would not be possible to meet the current demand. Nevertheless, in a scenario in which people work in pairs and all tables are occupied, in addition to reducing the related waste, it would be possible to synchronize this process through takt time. Analyzing pre-sorting, waste represents 49% cycle time; in the future situation of this stage, it is expected that this proportion will drop to 25%, given the need to consider that workers, due to the human factor, are unable to work continuously throughout the shift. Therefore, it is not possible to disregard the existence of breaks in a very manual and repetitive work, but it is admissible to foresee smaller and scheduled breaks.

Table 2 presents the main indicators of the AS-IS and TO-BE maps used to evaluate the improvements, namely the cycle time (C/T), the value-add time (VAT) and the number of shifts.

Table 2 – Main indicators of the process

Indicator	AS-IS				TO-BE		
	Pre-sorting	Weigh-in	Fine sorting	Pressing	Pre-sorting	Fine sorting	Pressing
C/T	1462 s	10 s	160 s	911 s	505 s	271 s	624 s
VAT	420 s	0 s	100 s	711 s	210 s	170 s	771 s
SHIFTS	2	2	1	1	2	1	1

Table 2 shows that the gains in added value are greater in the fine sorting process. Furthermore, the pre-sorting and pressing processes are improved by reducing the cycle time. The following are proposed actions to improve the cooperative's processes. The proposals were structured through an action plan using the 5W1H tool, which can be seen in Table 3.

With these actions, a lead time reduction is expected, so that it is possible to process a similar volume of material in a shorter time interval, making more frequent sales or forming a larger stock in the same time interval; the cooperative then can scale its sales and be able to negotiate more assertively with its customers.

In addition to the proposed improvements to the cooperative's value stream, VSM could be applied with auxiliary methodologies and approaches focused on sustainability to further capture the study sustainable bias. Garza-Reyes *et al.* (2018) used the PDCA (Plan, Do, Check and Act) cycle to increase the methodological approach in their study and evaluate the environmental performance in organizations. Furthermore, Ishak et al. (2018) argue that the sustainability metrics evaluated along the value stream captured by VSM should not only measure environmental aspects, but also pay attention to the economic and social pillars, as proposed in their research. Hartini et al. (2020) perfected the application of VSM through the Analytical Hierarchy Process (AHP) approach, to prioritize the sustainable indicators in the evaluation model.

Finally, despite the future map proposed, the waste that is delivered at the cooperative depends on the division carried out by COMCAP, in addition to the municipality generation. Therefore, in situations of increased demand, production may be insufficient even with the improvements proposed. In this sense, having the municipality involved in recycling to promote waste separation from source is essential, as it is capable of mobilizing resources and establishing communication channels at a municipal level (Storey et al., 2015).

Table 3 – Action plan for the main proposed improvements to the cooperative

Actions (What)	Related stages (Where)	Time to act (When)	Justification (Why)	Responsible (Who)	Methodology or tool (How)	Pillars of sustainability affected
Standardization of activities	Pre-sorting, fine sorting and pressing	Medium term	To determine the optimal fill level of a big bag for preventing overflow and ensure that materials are not wasted or left unrecycled.	Cooperative and co-op members	5S lean tool	Environmental and economic
Visual management	Receipt, shipping, and intermediate stocks	Medium term	To avoid some waste related to the place disorganization and the waste of materials that fall throughout the warehouse.	Cooperative and co-op members	5S lean tool	Environmental and economic
Place organization	Pre-sorting and fine sorting	Short term	To improve the flow of materials and people in the cooperative.	Co-op members	5S lean tool	Environmental and economic
Payment for hours worked	All stages. However, weigh-in does not exist anymore	Medium term	To engage workers in the overall process, fostering a collective commitment to waste reduction and the pursuit of greater efficiency.	Cooperative	It is suggested models like Torres Junior and Battaglia (2013), where remuneration is based solely on hours worked and does not vary based on the volume of work completed.	Economic and social
Workshops and kaizen events	The entire value stream	Medium term	To engage all stakeholders and foster a culture centered around continuous improvement.	Cooperative	For this, workshops on the benefits and functioning of the lean philosophy and its tools are necessary.	Environmental, social, and economic
Stakeholder involvement (universities, government, etc.)	The entire value stream	Medium term	To improve engagement and support for waste pickers.	Cooperative	By promoting environmental education and technology transfer in the sector. As well as public policies to provide essential economic and social support.	Environmental, social, and economic

5. CONCLUSION

5.1 Theoretical implications of the study and other discussions

As discussed in the introduction to this article, the literature still lacks more practical work that aims to relate lean and sustainability themes in the context of pickers' cooperatives. In this study, the tripod of sustainability served as a theoretical basis for understanding the USW management context. However, for sustainability to be inserted in the cooperatives' internal environment, integration with different society agents is paramount. In this regard, Azevedo et al. (2019) and Azimi et al. (2020) corroborate this discussion by pointing out the need for greater stakeholder involvement in USW management.

Lean thinking was used as a way to act on several organizations' waste. Thus, analyzing the contributions of lean tools to the social, environmental, and economic aspects showed the versatility of this philosophy, indicating that it is a favorable instrument for proposing improvements in an environment where social vulnerability predominates.

Previous literature has shown the application of VSM in numerous sustainability contexts, such as the use of Environmental Value Stream Mapping (E-VSM) (Garza-Reyes et al., 2018), and VSM focused on Cleaner Production (CPVSM) (Ishak et al., 2018). Despite the gap in the literature when considering the context of pickers' cooperatives, previous studies presented challenges similar to those discussed in this article, such as: the difficulty in capturing all product information in a single VSM, and the lack of strategies that consider environmental aspects (Hartini et al., 2020; Santos et al., 2019).

5.2 Practical and managerial implications

The use of value stream mapping from social, environmental, and economic aspects of sustainability can help identify waste and inefficiencies in the waste management process, enabling the cooperative to make informed decisions about how to streamline and optimize their operations while considering sustainability issues. By implementing changes based on the findings of this study, the cooperative can improve the efficiency of their waste management process, reduce costs, and increase waste pickers income and work safety. Additionally, the use of value stream mapping can facilitate communication and collaboration between different levels within the cooperative, fostering a culture of continuous improvement and teamwork.

From a managerial perspective, this study can provide valuable insights into the organization's operations and help identify areas for improvement. By using value stream mapping as a tool to analyze and visualize their waste management process, managers can identify bottlenecks, redundancies, and other areas where improvements can be made. This can help managers make more informed decisions about resource allocation, staffing, and process redesign. Additionally, the use of value stream mapping can provide managers with a framework for continuous improvement, enabling them to continually assess and optimize their waste management process over time.

5.3 Final considerations and future research

The objective of this work, considering sustainability and the lean philosophy, was to propose changes to improve the value stream of the analyzed cooperative. Through discussions within this process, the impacts of the proposed actions on the organization's sustainability were highlighted. The analysis of the cooperative's reality identified main challenges, including inefficient waste management, lack of resources for basic expenses, risks to workers' safety, and a disorganized environment leading to health concerns. Using lean tools, improvements were suggested to enhance the production process, addressing waste generation, and benefiting the environment, economy, and workers. However, to ensure the successful implementation of the proposed actions and achieve full engagement from the group, involving the identified stakeholders is crucial, given the complex nature of the waste management system and the fundamental role of all parties involved.

The limitations of this study include focusing on a single material flow to enhance the applicability of Value Stream Mapping (VSM) and the non-implementation of the proposed improvements, resulting in suboptimal exploration of VSM's full potential. Thus, the suggestion is that future research should:

- ✓ Understand the variations in waste demand and propose more effective improvements based on these factors;
- ✓ Study the impact of increased community involvement through household waste separation, as it could significantly modify the pre-sorting stage, which currently requires substantial labor;
- ✓ Incorporate metrics into Value Stream Mapping (VSM) with a greater emphasis on sustainability factors, such as analyzing environmental indicators and monitoring environmental impact. Further analysis of conditions affecting workers' health also presents potential avenues for future research.

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