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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

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Abstract: In many developing countries, the informal recycling sector is responsible for reducing the amount of waste in landfills and supplying the needs of recycling industries. In the context of municipal solid waste (MSW) management, considering that developing countries aim to implement circular economy (CE) actions, it is essential to ensure the inclusion of waste pickers (*catadores*) in an adapted CE structure. This study analyzes the integration of recycling cooperatives in the formal management of municipal solid waste with recyclable potential (MSWRP) of a medium-sized municipality in Brazil, with the objective of ascertaining the contributions of cooperatives in an adapted CE structure and, at the same time, identifying a cooperative that can be used as a benchmarking option for other cooperatives, especially in relation to their organizational and operational practices. The results indicate that from this integration, cooperatives have legal responsibility in the management of MSWRP, resulting in the professionalization of its members and increasing their productivity. The results also revealed that the implementation of the CE in developing countries is, in a sense, conditioned to the performance of the informal sector in the recycling chain and, in addition, that the inclusion of cooperatives in the formal sector of MSWRP management can improve the rates of a municipality.

Keywords: informal recycling sector; municipal solid waste management; circular economy and recycling; waste pickers; *catadores*; recycling; waste with recyclable potential

1. Introduction

Recycling has been identified as a key strategy in the management of municipal solid waste (MSW), considering the following approaches: (1) environmental focus: recycling contributes to the reduction of pollution, the preservation of natural resources, the decrease of environmental impacts, the reduction of waste destined to dumps and landfills (and, consequently, the increase of their useful lives), the saving of electric energy and so forth [1–3]; (2) economic focus: recycling enables the reduction of costs for industries (since processing recyclable material is less costly than processing natural resources), the increase in the number of individuals with active participation in the economy, the reduction of costs related to the creation and maintenance of dumps and landfills, the promotion of the recycling industry, the incentive for the implementation of micro and small recycling companies and

so forth [1,3–6]; and (3) social focus: recycling operates in the inclusion of *catador* in the labor market, in the generation of revenue, in the improvement of the quality of life and in the strengthening of the citizenship of the individuals directly involved with the collection, sorting and commercialization of municipal solid waste with recyclable potential (MSWRP) [2,5,7,8], henceforth referred to as "*catador*" or "*catadores*" in Brazil [7].

In developing countries, the informal recycling sector has actively participated in the recycling chain through the collection, classification (based on similar material characteristics) and commercialization of MSWRP [5,9–15]. Indeed, in many cases, the formal MSW management system is subsidized by the informal sector [16]. This is verified in countries of Latin America, Africa and Arabia, as well as in India, among others, where the dependence of the formal sector on the informal sector regarding the management of MSWRP is evident. In this scenario, the informal sector is responsible for reducing the amount of waste in dumps and supplying the needs of industries that use this waste as raw material [8–11,13,14,17–19]. In Brazil, for example, *catadores* are responsible for 89% of MSWRP that returns to the industries as raw material [20]. It is worth noting that the informal sector provides low-cost services to the formal sector, as *catadores* survive mainly due to the commercialization of MSWRP and the municipalities benefit from these inexpensive services [21].

Fidelis et al. [10], Gutberlet [2], Asim et al. [8], Mediana [22], Wilson et al. [7], among other authors, state that it is necessary to integrate existing informal recycling systems with formal MSW management operations, since whether municipalities attributed more importance to the work performed by informal recycling, it would be possible to improve MSW management services. In this direction, in 2010, the National Solid Waste Policy (NSWP) was instituted in Brazil, presenting as one of its principles the integration of *catadores* of reusable and recyclable materials in actions involving shared responsibility for the life cycle of products [23]. Since then, informal *catadores* or organized into associations and cooperatives have been directly involved in the management of MSW. However, few Brazilian municipalities have paid for the environmental service provided by these social actors [24].

Another important aspect regarding MSW management is related to the fact that developing countries aim to implement circular economy (CE) actions. In this context, it is essential to consider the inclusion of *catadores* in an adapted CE structure. According to Gall et al. [25], it is important to have CE business models that are adjusted to regional specificities and also socially inclusive, combining a human-centered and technology-oriented approach. It should be noted that in most developing countries the informal recycling sector has a fundamental role in the implementation of the CE, as it reintroduces the MSWRP into the production chain. In this sense, this study analyzes the inclusion of recycling cooperatives in the formal MSWRP management of a medium-sized Brazilian city, in order to identify the contributions of cooperatives in an adapted CE structure (according to Gutberlet et al. [26] and, at the same time, to indicate a cooperative that can be used as a benchmarking option for other cooperatives, especially in relation to their organizational and operational practices.

Considering the panorama exposed, this study presents significant contributions: (1) identifies an example of inclusion of recycling cooperatives in the formal MSW management in a medium-sized Brazilian city that remunerates the cooperatives for the environmental service provided; (2) demonstrates that the inclusion of recycling cooperatives in the formal system can result in significant improvements both in the management of MSW and in the quality of life of the actors involved; and (3) reinforces the possibility and necessity of including *catadores* in the MSW management, in a socially inclusive CE perspective, since in most developing countries *catadores* are responsible for waste collection and, from this standpoint, have the potential to environmentally, economically and socially transform an entire value chain.

2. Theoretical Background

2.1. General Aspects Regarding Catadores

In the context of countries with significant social inequalities, such as Brazil, India and Mexico, it is estimated that 1% of the population survives from the collection and commercialization of MSWRP [27]. In South America, estimates indicate that about 3.8 million informal or collectively organized *catadores* depend on this sector to survive [28]. In general terms, *catadores* are poor people, excluded from society due to their age, social status, low schooling or inability to be allocated to the formal labor market [2,7] and, from this perspective, the most fragile economic and social part of the recycling value chain [29]. In Brazil, research agencies diverge on the estimated number of *catadores*: 400,000 according to the *Instituto de Pesquisa Econômica Aplicada* (IPEA) [29]; 800,000 according to the *Compromisso empresarial para reciclagem* [30]; and 1 million according to the *Movimento Nacional dos Catadores de Material Reciclável* (MNCR), which also states that only a small proportion of *catadores* is structured in collective organizations (cooperatives and associations) [31].

Catadores perform a fundamental role in the management of MSWRP in developing countries, both in its collection and commercialization, providing complementary services to the formal management of MSW [10,32–35] and acting directly in the process of revalorization of residues, which are no longer considered useless waste and are now recognized as economic resources [32].

It is worth mentioning that MSW management with socio-productive participation of *catadores* is a powerful instrument for socioeconomic inclusion, because besides having the potential to restore human dignity and citizenship to a socially and economically excluded portion of the population [27], it also contributes to the objectives of sustainable development [36] and, moreover, presents the potential to transform environmentally, economically and socially an entire value chain, which begins with the performance of the *catadores*, goes through the processing industries and ends with the return of the product to the consumer market [9].

Nonetheless, *catadores* are commonly not recognized for the environmental service provided, either by society or by governmental agencies [27,32,34]. In addition, in some cases, local authorities categorize them as "offenders," which generates negative attitudes of neglect or repression of these workers [32].

The activities performed by these workers are predominantly manual and involve low technology [37]. The collection is executed in dumps, public places or residences and, for this, manually pulled carts, bicycles or tricycles, adapted cars, trunk trucks or adapted trucks are used. Subsequently, the sorting of materials is executed in sorting centers (SC), residences, valley bottoms and so forth [9].

From a labor standpoint, *catadores* have their health and safety often exposed to risks associated with the collection and sorting of waste. Among the direct risks are: biological and chemical contamination; injuries caused by sharp residues [38]; respiratory problems [12]; ergometric problems, mainly related to body posture [9]; and so forth. On the other hand, the main indirect risks are: presence of pests (rats, cockroaches, pigeons, etc.) and, consequently, the risk of disease transmission, such as leptospirosis; and lack of ventilation and high temperature in SC, which can contribute to respiratory and pulmonary diseases [38].

The recyclable waste processed by the *catadores* is mainly commercialized with middlemen, who are responsible for forwarding it to the processing industries [9,34]. This occurs either because the *catadores* do not produce the quantity of materials required by the processing industries, that is, productivity is lower than demand [34] or because they maintain a loan-commercialization relationship with middlemen, in other words, the middlemen lend equipment to the *catadores* and, in counterpart, require the exclusive commercialization of products with them [9]. In this scenario, the amount paid by the middlemen in this loan-commercialization relationship is lower than the commercial value. Although *catadores* are aware of the exploitative nature of this relationship, the middlemen are important actors in the recycling chain, as they connect individual or collectively organized *catadores* to the formal recycling industry [34].

According to IPEA, this category of workers is strengthened when united through collective organizations (cooperatives and associations) [29]. Such organizations provide structural and economic feasibility to *catadores*, allowing them to perform their activities in the recycling chain and enabling them to obtain investments and recognition of rights before government agencies at the federal, state and municipal levels [39].

The cooperatives are presented as a model of public policy able to assist the insertion of *catadores* in the formal MSW management system, since they can generate greater revenues and benefits for this category, better working conditions, social inclusion and citizenship, promoting the integration of its members with other social groups in an organized form of occupation, in addition to better operational and organizational conditions [6,40,41]. Furthermore, they are based on the guidelines of social solidarity economy (SSE), which searches forms of organization to transform models and operations through values of solidarity, cooperation and reciprocity [2,26].

In Brazil, for example, the performance of the collective organization MNCR, founded in 2001, has contributed to the fact that the activity of *catadores* is no longer seen as a result of a social problem but rather as a socio-environmental solution [42]. The MNCR has a high degree of organization and social articulation, which has allowed it to discuss with different governmental instances issues inherent to the social condition and professional activity of this category of workers [26].

Consequently, a series of regulations, norms, decrees and laws began to contemplate aspects related to the activity of the *catadores*, such as: the recognition of the professional activity of "recyclable material *catadores*", in 2002, through its insertion in the Brazilian Classification of Occupations (COB), with the code 5192-05; the creation of the Interministerial Committee of Social Inclusion of *catadores*, gathering 13 ministries of the federal government; the NSWP; the *Pro-Catador* program, with the objective of assisting and financing cooperatives in training, technical assistance, acquisition of equipment, support to commercialization networks; and so forth.

The NSWP represents a legal milestone in the inclusion of *catadores* in MSW management in Brazil. Established in 2010, it constitutes a sectoral agreement of shared responsibility in the product life cycle, reaching the public authorities, manufacturers, importers, distributors and traders [24].

Regarding the informal sector, the NSWP: (a) prohibits the use of uncontrolled landfills and obliges the government (at the federal, state and municipal levels) to elaborate solid waste treatment plans, establishing targets and recycling programs; (b) recognizes reusable and recyclable solid waste as a product that has economic and social value, since it generates work and revenue and also promotes citizenship; (c) presents, as one of its objectives, the integration of *catadores* of reusable and recyclable materials in actions that involve shared responsibility in the life cycle of the products; (d) encourages the creation and development of cooperatives and associations of *catadores*; (e) prioritizes the assignment of government resources to municipalities that implement selective collection through the participation of cooperatives and associations of *catadores*; (f) determines that the MSW management plan should integrate the activities of cooperatives and associations of *catadores*; (g) establishes that the holder of public services for urban cleaning and solid waste management must prioritize the hiring of cooperatives and associations of *catadores*; (h) authorizes the government to institute incentive measures and specific financing lines for cooperatives and associations of *catadores*, in order to assist, as a priority, the implementation of physical infrastructure and the acquisition of equipment.

However, there are still many barriers and challenges currently faced by *catadores* in Brazil, among them: sanitary and occupational health issues; improvement of revenue and technology; new methods of adding value to products; recognition for the environmental, social and economic service provided; and so forth.

Furthermore, *catadores* experience a paradoxical situation because, on the one hand, they are the actors responsible for waste management, that is, they have the task of transforming waste into a product of interest to industries, and, on the other hand, they occupy a marginal position in society, as they face discrimination both in the consumer market and in social dynamics, in addition to residing in suburban geographic spaces [29,32].

2.2. A Brief Account of the Role of Recycling Cooperatives in the CE

The CE represents a possibility of improvement of MSW management, since it applies the principle of valorization and recycling of waste in order to boost developing economies. Nevertheless, some elements still need to be enhanced, mainly related to environmental policies, effective investments, social inclusion and public awareness [43].

In general terms, the CE proposes that the value of the extracted and produced resources be preserved in circulation through integrated productive chains. The objective is to eliminate the concept of garbage (useless waste) and direct each material within a cyclical flow, enabling its trajectory "from cradle to cradle" (that is, from product to product), preserving and transmitting its value [44]. In this scenario, the CE can be presented as a positive cycle of continuous development, due to the preservation of the environment, the strengthening of natural capital, the optimization of natural resources, the management of finite reserves and renewable flows, as well as the minimization of system risks [45].

Focusing on waste, this study adopts the concept of CE based on the 3R principle: reduction, reuse and recycling. In other words, the CE has three main objectives: the reduction of the use of virgin raw materials, the reuse of processed materials and the recycling of waste [46], as an alternative to the linear economy. Unlike the latter, the CE arises in order to enable the production of goods in a closed cycle, through the flow of recycled materials and waste, aiming not to aggravate the scarcity of virgin resources and prevent the generation of new waste [47,48].

Salmenpera et al. [49] state that MSW management must be reviewed in order to stimulate and increase the circularity of the material. They also affirm that the recycling sector lacks other actors in the development and processing of waste, as it is currently the *catadores* who assume the tasks related to the extraction of resources from the MSW and their application in innovative recovery. (The results of the above-mentioned studies also elucidated that these functions do not attract traditional industry companies or waste management companies). (It is worth remembering that in developing countries the management of MSWRP is performed predominantly by *catadores*). Therefore, the development of a CE structure should consider the inclusion of these workers in this process, since they have the knowledge to deal with resource scarcity through different types of resource recovery activities based on socioeconomic needs [50].

Although recycling is the final stage of the value generation chain of the CE, whose production process is established not to generate waste, its role is extremely important at the end of the cycle, since it enables the transformation of waste into raw material [44]. According to Gall et al. [25], despite the fact that recycling is not the only element of the CE, it has a major function in the pursuit of sustainable development, as it allows to confront the multiple challenges that permeate the economic, environmental and social spheres.

As Schroeder et al. [51] assert, CE practices can be applied as a toolbox, due to the specific approaches for their implementation and for the achievement of sustainable development goals, since, in developing countries, the informal sector has an important role in the recycling chain. The authors also note that making the informal recycling system more efficient in developing countries requires greater efforts from stakeholders (public and private sectors) to train *catadores*, transfer technology and transform these activities into decent jobs.

Gutberlet et al. [26], in turn, suggests a new perspective for the CE (Figure 1) considering the ecological economy (EE) and the SSE, expanding in this way the social and political aspects of the CE concept (rendering social benefits more sustainable and less paternalistic), under a lens of the Global South and in the context of *catadores*.

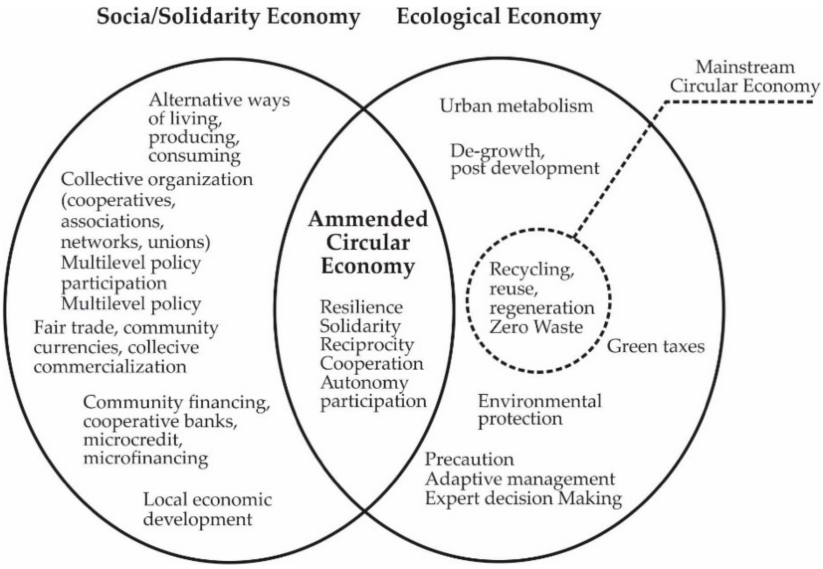

Figure 1. "An amended framework for circular economy (CE) in the Global South (and elsewhere)." Source: [26] (p. 10).

The aforementioned author Gutberlet et al. [26] also proposes that, in addition to the principles required by the EE (responsibility, precaution, resilience, adaptive management and participation), the principles of the SSE (solidarity, autonomy, cooperation and reciprocity) also need to be reflected in the daily practice of a CE for the Global South.

For all the above, the performance of *catadores* in MSW management is essential. They contribute not only to the correct classification of waste but also to the economic movement of the entire recycling chain by generating revenue, generating savings for the public sector, extending the useful life of landfills, supplying raw materials to the industrial sector and reducing the level of greenhouse gas emissions [52]. Hence, it is imperative to recognize the knowledge that *catadores*, small entrepreneurs and garbage workers have, social actors who, despite their importance, are often ignored [26].

3. Materials and Methods

The medium-sized municipality object of this study is Londrina, located in the state of Paraná, Brazil, whose estimated population for 2020 is 575,377 inhabitants [53]. In the aforementioned municipality there are seven cooperatives of *catadores*, in this study denominated Coop1, Coop2, . . . , Coop7, responsible for the total collection (100%) of MSWRP.

The data applied in this study were collected as follows: (a) the information regarding the equipment and management of each cooperative was obtained during on-site visits to the seven cooperatives analyzed; (b) the data related to the collection of MSWRP from 2014 to 2020 were provided by the *Companhia Municipal de Trânsito e Urbanização de Londrina* (CMTU), the local governmental agency responsible for the management of MSW in the municipality in focus [54]; and (c) the results of a survey applied to 135 *catadores* (out of a total of 439) were obtained from the CMTU. In order to apply this questionnaire, the total number of collectors (439), the population proportion of individuals belonging to the desired category (0.5, to obtain the maximum sample), an estimate error (of 7%) and an error margin (of $\alpha = 5\%$) were considered, resulting in a representative sample of 135 individuals, stratified by cooperative.

This study is classified as exploratory, since it aims at an understanding of the characteristics of the phenomenon studied, in order to obtain a comprehension of its causes and consequences [55]. In this sense, the analysis of the data was conducted by descriptive statistics and, for this purpose, such analysis was fragmented into three phases: (a) the first phase presents the studied cooperatives and analyzes the recycling rates of the municipality; (b) the second phase analyzes the socioeconomic

and professional profile of the *catadores*; and (c) the third phase presents a reflection regarding the analysis of the results obtained in the two previous phases.

4. Results and Discussion

4.1. The Management of MSWRP with Socio-Productive Inclusion of Catadores in Londrina, Brazil

The selective collection was implemented in Londrina in 1996, by the Municipal Secretary of Environment. At the time, this collection covered only the central region of the city, corresponding to about 20% of the total residences in the municipality. In 2001, the CTMU created the program entitled *Reciclando Vidas* (Recycling Lives), aiming to include *catadores* in the municipal scenario. In this sense, with the assistance of the Public Prosecutor's Service and by signing of a term of conduct, the *catadores* were removed from the dump, organized in associations and cooperatives and received training and professional qualification [56]. On 23 September 2009, even before the creation of the NSWP, Municipal Decree No. 829, instituted the *Londrina Recicla* (Londrina Recycles) program, establishing a new method of collection logistics by the door-to-door system, maintained until the present day, in addition to including the *catadores* of recyclable materials in the public network of selective collection [57]. Currently, the seven local cooperatives are responsible for the collection, sorting, processing and return of recyclable waste to the productive chain and, in counterpart, the local government is responsible for providing subsidies for the purchase of personal protective equipment (PPE) and uniforms, payment of the lease of the properties used in the sorting and processing of recyclable materials, financial transfer for payment of the social security of the cooperative members and payment of the MSWRP collection service. In this configuration, the selective collection covers the entire (100%) area of Londrina, including its districts and rural villages and each of the seven cooperatives serves a specific region through the door-to-door system, collecting recyclable materials on predetermined days and hours [54].

From the above, the municipality of Londrina has integrated the recycling cooperatives in the formal collection system, through the signing of service contracts with stipulation of rights and responsibilities to be observed in the management of collection, as well as setting a fine in case of non-compliance with contractual clauses.

4.2. The Recycling Cooperatives and the Recycling Rates of the Municipality

As previously exposed, in the municipality of Londrina there are currently seven recycling cooperatives responsible for the management of MSWRP. All the cooperatives have a national registration in the *Cadastro Nacional de Pessoa Jurídica* (CNPJ), constitutive act (bylaws), board of directors, minutes of their assemblies, environmental license, sanitary license, fire prevention license, operation license, pest control program (rats, cockroaches, flies, etc.) and fiscal regularity (including payment of taxes and formal issuance of invoice). In addition, all seven cooperatives provide transportation vouchers to their members, who are also insured by social security.

At first, the cooperatives perform the weekly collection of MSWRP by the door-to-door system, in accordance with the contract signed with the CMTU. Such collection is executed by the *catadores* (one driver and two or three collectors) with a truck known as a trunk or cage (vehicle with vertically elongated body by a wire mesh). The *catadores* then proceed to sort and classify the MSWRP, based on its characteristics, using, for that, sorting mats or tables (usually built by the *catadores* themselves with pieces of wood and remains of materials, without any standardization in their dimensions). In the sequence, the selected materials are pressed in order to add value for subsequent commercialization.

Nonetheless, the cooperatives report some common difficulties, such as: (i) ergonomic problems related to body posture, because during the sorting of the materials, the *catadores* called "yard" handle heavy containers (plastic bags with a capacity of 60 L or more, large bags with dimensions equal to or greater than 0.90 m × 0.90 m × 1.20 m, cylindrical-shaped plastic drums, pressed bales, etc.); (ii) complaints from buyers due to the mixing of materials, evidencing problems in sorting; (iii) resistance

of *catadores* in using PPE; (iv) some SC have inadequate ventilation, lack of luminosity and strong odor; (v) many of the sorted waste have no commercialization due to lack of buyers or have low commercial value, as the cost of the transport freight is higher than the commercial value of the product; (vi) instability in the contract signed with the municipality, since at each contract renewal there are significant changes in the form of valuation of the materials and the amount transferred to the cooperatives.

Analyzing the number of residences covered by a collector, it is verified that the cooperatives with the smallest (203 residences/cooperative member) and the largest (597 residences/cooperative member) proportion are Coop2 and Coop6, respectively (Table 1). This discrepancy is due to the fact that the distribution of the quantity of residences per cooperative is executed by the CMTU according to the following criteria: coverage area, socioeconomic issues of the neighborhoods, volume of MSW, quantity of large waste generators and affinity of the cooperative with the neighborhood served.

Table 1. Operational information of the cooperatives.

	Coop1	Coop2	Coop3	Coop4	Coop5	Coop6	Coop7
Number of residences covered	87,383	28,940	25,334	20,660	20,307	22,922	24,549
Number of types of waste sorted	30	21	19	23	14	12	16
Number of SC	4 (2 [a] e 2 [c])	2 [c]	3 [c]	3 [c]	3 [c]	2 [c]	1 [c]
Number of equipment							
Presses	14 (12 [a] e 2 [b])	4 (1 [a] e 3 [b])	3 [a]	3 [b]	4 (2 [b] e 2 [c])	2 [a]	2 [b]
Styrofoam extruder	1 [b]		-	-	-	-	-
Scales	4 [a]	1 [a]	1 [a]	1 [a]	1 [a]	1 [a]	1 [a]
Sorting mats or tables	1 [a]	-	1 [a]	-	-	-	-
Forklifts	2 (1 [a] e 1 [b])	1 [b]	2 [a]	-	1 [a]	1 [a]	1 [a]
Pallet jacks	1 [a]						
Trucks	7 [a]	3 (1 [a] e 2 [c])	2 (1 [a] e 1 [b])	3 [c]	2 [c]	2 [c]	3 (2 [a] e 1 [c])

[a] Property of the cooperative; [b] Loaned (loan-commercialization relationship); [c] Rented/Leased.

In administrative terms, Coop1 is the most organized of the seven cooperatives, as its administrative activities are performed by departments (sales, finance, production, human resources, contracts—which acts in the search for incentive notices for recycling cooperatives) composed of qualified *catadores* or specialized hired employees, whereas in the other cooperatives all the administrative functions are executed by the president of the cooperative or by the person in charge of the SC. All the seven cooperatives have a formalized board of directors but only the members of the Coop1 board of directors have active participation in its management.

Concerning the management of the SC, at Coop2, Coop3, Coop4 and Coop5 each SC has independent management autonomy. In practice, it is as if there were sub-cooperatives within a central cooperative. In this configuration, each SC defines its layout, material flow, sorting methods, remuneration of the *catadores*, quality in the sorting, standard of the building used as SC, list of buyers, amount obtained in the commercialization of the products and so forth. This structure corroborates the IPEA statement that cooperatives have different levels of organization and management difficulties, which restricts their performance in the recycling chain [4].

Regarding the commercialization of the products, some factors contribute to the distinction of the amount obtained by the cooperatives in relation to the same material (Table 2): (1) the aggregation of value to the products through the standardization of pressed bales and loads for transportation, the volume of materials commercialized, the punctuality in deliveries, the correct separation of materials by type of waste and the quality in customer service; (2) the commercialization directly with the processing industries, avoiding middlemen. In this sense, Coop1 usually obtains the commercial value on the sale of its products, because it commercializes predominantly with the processing industries, a fact that is not observed in the context of other cooperatives; (3) the differences in their governance; and (4) the ownership of the equipment used. In this direction, as Coop1, Coop3 and Coop6 have more equipment of their own property (scales, forklifts and presses), they present less dependence on middlemen that lend equipment in a loan-commercialization relationship. Due to the fact that Coop1

has a contractual department that operates in the search of incentive notices for recycling cooperatives, most of its equipment was obtained through such notices issued by the federal government and private companies [9,34].

Table 2. Monthly production and revenue of cooperatives in 2019 and 2020.

	Coop1	Coop2	Coop3	Coop4	Coop5	Coop6	Coop7
2019							
Average salary (US$)	271.72	120.56	206.69	167.72	116.58	152.75	156.05
Quantity commercialized (tonne-t)	212.425	48.684	64.736	55.091	91.225	54.605	45.956
Revenue from commercialization (US$)	21,127.40	3628.91	6243.56	3317.12	5108.45	5129.18	3196.95
Amount commercialized (US$/t)	99.46	74.54	96.45	60.21	56.00	93.93	69.57
Amount commercialized (US$/cooperative member)	173.18	78.89	195.11	114.38	164.79	138.63	88.80
2020							
Average salary (US$)	268.90	128.22	220.93	182.65	141.74	106.28	141.72
Quantity commercialized (t)	214.976	68.647	53.289	36.737	106.411	23.417	37.514
Revenue from commercialization (US$)	17,383.64	2926.59	4902.41	1851.54	4459.60	2341.56	2128.49
Amount commercialized (US$/t)	80.86	42.63	92.00	50.40	41.91	99.99	56.74
Amount commercialized (US$/cooperative member)	129.73	71.38	144.19	61.72	139.36	68.87	68.66

Source: CMTU [54].

As exposed in Table 2, in the period 2019–2020 Coop1, Coop3 and Coop6 commercialized their products for an average amount superior to US$ 93.00/t, while the other cooperatives commercialized their products for an average amount inferior to US$ 75.00. The biggest difference between the two medium amounts commercialized is 43.7% (between Coop1 and Coop5) and 42.7% (between Coop6 and Coop2).

In turn, Table 3 demonstrates the monthly amount commercialized by cooperative and by type of material in 2019 and 2020. Coop1 has the highest amount per ton commercialized, followed by Coop3 and Coop6. The percentage differences between the lowest and the highest commercialized amount in 2019 for long life packaging, metal, paper, plastic and glass materials are 35.7%, 79.9%, 12.3%, 49.8% and 79.7%, respectively. In 2020, the percentage differences for the same materials (in the same sequence) are 42.4%, 84.4%, 26.3%, 77.1%, 94.5%, respectively.

Table 3. Quantity and amount commercialized per type of material.

Long Life Packaging		Metal		Paper		Plastic		Glass	
2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Monthly quantity (t)									
Coop1	5.191	7.455	12.079	17.228	89.933	98.228	41.600	55.776	63.371	81.277
Coop2	0.239	0.888	3.004	12.700	20.246	24.598	7.299	14.561	17.896	50.213
Coop3	2.469	3.178	5.962	6.486	27.071	33.223	14.027	16.618	15.207	20.430
Coop4	0.832	0.536	2.300	2.904	14.560	13.344	5.341	4.229	32.058	34.094
Coop5	0.460	1.555	9.992	64.187	17.078	21.139	14.808	37.822	39.667	34.914
Coop6	1.833	1.041	2.498	2.483	21.450	18.582	13.476	9.636	15.370	3.385
Coop7	0.117	0.838	7.503	15.503	18.920	15.813	10.473	11.649	8.943	12.469
Monthly amount (US$/t)										
Coop1	68.49	61.83	158.42	145.58	84.66	87.00	236.50	232.29	22.20	19.74
Coop2	44.05	50.44	158.39	25.83	74.23	67.65	186.98	107.01	15.36	15.83
Coop3	44.66	42.51	41.98	34.12	84.31	80.92	246.28	247.49	9.60	9.60
Coop4	44.93	40.71	61.28	43.28	79.30	79.32	185.20	184.85	31.44	23.16
Coop5	52.70	35.62	31.86	22.78	76.70	64.15	123.53	56.60	38.96	47.98
Coop6	45.19	42.62	52.28	55.32	79.70	73.35	224.73	199.42	11.52	13.63
Coop7	44.15	43.43	40.03	30.46	79.36	80.93	125.97	117.72	7.90	2.66

Source: CMTU [54].

With regard to data related to the individual and family revenues of the *catadores*, in order to demonstrate their representativeness in the context of the Brazilian economy, the local currency (real) was converted to the US dollar, using the exchange rate of July 2020 and the national minimum wage in force in Brazil at the same time (July 2020), in the amount of R$ 1045 or US$ 200.96.

The average monthly revenue of the members of all seven cooperatives was over 50% of the Brazilian minimum wage (Table 2). With positive results, Coop1 and Coop3 achieved an average monthly revenue 35% and 3% higher than the national minimum wage in force in 2019 and 34% and 10% higher than that in force in 2020, respectively. On the other hand, with negative indexes, in 2019 Coop4, Coop6 and Coop7 and in 2020 Coop4, Coop5 and Coop7 obtained average monthly revenue corresponding to 70% of the Brazilian minimum wage. Also, Coop2 and Coop5 had an average monthly revenue close to 60% of the national minimum wage in force in 2019 and Coop6 close to 53% of that in force in 2020.

In a survey conducted by Fidelis et al. [24] with 88 cooperatives it was noted that members of 8% of them (among which Coop1 and Coop3) owned average monthly revenue above or equal to the national minimum wage. In addition, the members of 40% of the studied cooperatives presented an average monthly revenue below 50% of the national minimum wage and, even worse, the members of 8% of the cooperatives had an average monthly revenue 25% below the Brazilian minimum wage. These data demonstrate that the cooperatives analyzed in this study present better results concerning the average monthly revenue of their members if compared with the cooperatives examined by Fidelis et al. [24]. However, it is evident that the cooperative members do not have an ideal financial situation, so it is necessary to employ efforts to improve their average monthly revenue.

Still in relation to the amounts earned by the cooperatives, Table 4 presents the average monthly amount transferred by the municipality of Londrina to the recycling cooperatives as payment for the environmental service provided. The municipal government, through the CMTU, transfers the total amount of the lease of the SC, the partial amount of the social security of the cooperative members and the amount corresponding to the remuneration per residence covered, according to the contract signed with the cooperatives (the Brazilian currency was converted to the US dollar using the exchange rate of July 2020). Such financial resources are extremely important for the cooperatives, as they correspond to a portion of the average monthly revenue of the cooperative members.

According to the data presented in Table 4, the municipality of Londrina transferred to the cooperatives the amounts of US$ 1,233,890.64, US$ 1,361,257.82, US$ 1,199,216.20, US$ 1,059,500.35, US$ 1,065,370.10, US$ 1,062,400.15 and US$ 1,068,868.07 in 2014, 2015, 2016, 2017, 2018, 2019 and 2020 (projection), respectively.

In order to obtain the proportion between the average monthly revenue of a *catadores* and the amount transferred by the municipality, the ratio between the "amount commercialized (US$/cooperative member)" and the "average salary (US$)" described in Table 2 was calculated. The results indicate that in 2019, the proportion was 36.3%, 34.6%, 5.6%, 31.8%, −41.4%, 9.2% and 43.1% in relation to Coop1, Coop2, Coop3, Coop4, Coop5, Coop6 and Coop7, respectively and in 2020, the proportion was 51.8%, 44.3%, 34.7%, 66.2%, 1.7%, 35.2% and 51.6%, concerning Coop1, Coop2, Coop3, Coop4, Coop5, Coop6 and Coop7, respectively. The positive results demonstrate that the cooperative is able to afford all its financial obligations using just the amount received for the environmental service provided and the surplus is distributed among the cooperative members. The only cooperative that had to complement the amount transferred by the municipality with the revenue obtained by the commercialization of its products was Coop5, in 2019. It is also worth mentioning that the higher results indicate a better management of the cooperative in relation to the available resources and, moreover, a lower quantity of loaned equipment (loan-commercialization relationship) (Table 1).

Another important factor related to the revenue of the cooperatives is the productivity of the *catadores*. As stated by the IPEA, the cooperatives that collect and process over 1800 kg/*catadores*/month of MSWRP have high efficiency [4]. Based on this reasoning, in 2019 and 2020 only Coop7 would have been considered inefficient (Table 4), since the other cooperatives were very close to this objective.

Table 4. Summary of the amount transferred to the cooperatives.

	Year						
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Coop1 (monthly average)							
Number of cooperative members	186	167	187	159	133	122	134
SC Lease (US$)	4559.39	3917.66	3051.56	4959.83	6541.15	6541.15	6541.15
Social Security (US$)	4156.30	3729.26	609.89	3166.74	3143.24	2918.61	3069.97
Amount per residence (US$)	0.08	0.10	0.22	0.26	0.28	0.28	0.28
Total amount in relation to the residences (US$)	30,376.49	29,288.70	20,917.07	22,555.27	24,655.09	24,655.09	24,655.09
Total production (t)	374.936	363.319	397.714	289.447	234.212	212.425	234.144
Production (kg/*catadores*)	2015.78	2175.56	2126.81	1820.42	1760.99	1741.19	1747.34
Coop2 (monthly average)							
Number of cooperative members	96	68	55	32	51	46	41
SC Lease (US$)	6187.43	3722.39	3268.95	2994.05	2166.33	2166.33	2166.33
Social Security (US$)	1391.59	1020.94	867.10	483.89	629.48	656.29	929.47
Amount per residence (US$)	0.08	0.11	0.22	0.26	0.28	0.28	0.28
Total amount in relation to the residences (US$)	17,541.42	13,881.82	12,321.19	8092.80	8165.41	8165.41	8165.41
Total production (t)	217.597	171.700	146.334	39.961	49.052	48.684	93.660
Production (kg/*catadores*)	2266.64	2525.00	2660.62	1248.78	961.80	1058.35	2284.39
Coop3 (monthly average)							
Number of cooperative members	25	28	40	37	40	32	34
SC Lease (US$)	1385.51	1568.14	2071.96	2710.26	1896.40	1896.40	1896.40
Social Security (US$)	419.14	471.94	704.58	697.92	726.03	704.47	789.28
Amount per residence (US$)	0.12	0.11	0.22	0.26	0.28	0.28	0.28
Total amount in relation to the residences (US$)	3614.90	5799.74	7249.56	6509.82	7147.98	7147.98	7147.98
Total production (t)	44.592	71.725	80.118	75.933	77.975	64.736	71.881
Production (kg/*catadores*)	1783.68	2561.61	2002.95	2052.24	1949.38	2023.00	2114.15
Coop4 (monthly average)							
Number of cooperative members	29	38	38	31	33	29	30
SC Lease (US$)	1999.36	2159.31	3051.56	3218.67	1546.53	1546.53	1546.53
Social Security (US$)	455.19	604.27	609.89	585.51	608.10	475.52	555.23
Amount per residence (US$)	0.12	0.11	0.22	0.26	0.28	0.28	0.28
Total amount in relation to the residences (US$)	16,031.57	9078.44	8268.92	5081.41	5829.21	5829.21	5829.21
Total production (t)	35.150	112.622	108.978	81.775	57.710	55.091	47.119
Production (kg/*catadores*)	1212.07	2963.74	2867.84	2637.90	1748.79	1899.69	1570.63
Coop5 (monthly average)							
Number of cooperative members	65	33	47	33	33	31	32
SC Lease (US$)	2580.19	2389.24	3946.74	4015.30	1520.10	1520.10	1520.10
Social Security (US$)	934.31	373.06	576.31	436.03	422.96	401.56	484.48
Amount per residence (US$)	0.08	0.15	0.22	0.26	0.28	0.28	0.28
Total amount in relation to the residences (US$)	11,191.41	6467.85	10,098.50	5674.91	5729.61	5729.61	5729.61
Total production (t)	147.918	70.902	126.620	101.063	85.493	91.225	135.917
Production (kg/*catadores*)	2275.66	2148.55	2694.04	3062.52	2590.70	2942.74	4247.41
Coop6 (monthly average)							
Number of cooperative members		43	45	28	35	37	34
SC Lease (US$)	-	1401.87	1780.12	2109.27	1837.64	1837.64	1837.64
Social Security (US$)	-	319.26	472.05	437.63	549.13	607.39	429.25
Amount per residence (US$)	-	0.08	0.22	0.26	0.28	0.28	0.28
Total amount in relation to the residences (US$)	-	12,594.12	6715.78	5015.96	6926.49	6926.49	6926.49
Total production (t)	-	27.558	97.102	58.052	51.852	45.956	49.473
Production (kg/*catadores*)	-	640.88	2157.82	2073.29	1481.49	1242.05	1455.09
Coop7 (monthly average)							
Number of cooperative members		17	27	25	37	36	31
SC Lease (US$)	-	2223.29	2903.07	3331.63	1715.85	1715.85	1715.85
Social Security (US$)	-	752.39	809.38	483.50	556.66	624.26	669.42
Amount per residence (US$)	-	0.10	0.22	0.26	0.28	0.28	0.28
Total amount in relation to the residences (US$)	-	11,674.46	9640.51	5731.32	6467.44	6467.44	6467.44
Total production (t)	-	144.819	146.301	84.272	58.313	54.605	33.388
Production (kg/*catadores*)	-	8518.76	5418.56	3370.88	1576.03	1516.81	1077.03
Total amount transferred to the cooperatives (annual)							
SC Lease (US$)	200,542.52	208,582.73	240,887.53	280,068.13	206,688.02	206,688.02	206,688.02
Social Security (US$)	88,278.51	87,253.32	55,790.37	75,494.61	79,627.23	76,657.28	83,125.19
Total amount in relation to the residences (US$)	945,069.61	1065,421.77	902,538.31	703,937.61	779,054.86	779,054.86	779,054.86
Annual production (t)							
Total annual production	9842.311	11,551.748	13,237.989	8766.030	7375.287	6872.648	7986.966

According to the SI Units, 1 metric ton corresponds to 1000 kg. Source: CMTU [54].

The "total production" indicator presented in Table 4 corresponds to the totality of materials commercialized by the cooperatives, disregarding rejects. It should be noted that, after sorting, many MSWRP are destined to landfills, either because of the low commercial value of the product, the high cost of transportation, the small quantity of manufacturing industry of some types of materials

(for example, plastic packaging with laminate: packaging of some chocolates, snacks, candies, etc.) or even the great distance of manufacturing industries.

In terms of the quantity of MSWRP collected, the cooperatives experienced their peak in 2016 but a serious political crisis in Brazil, followed by an economic crisis, resulted in a decrease in the commercial value of the materials and, consequently, prevented some *catadores* from remaining in the cooperatives, increasing the number of informal *catadores* (not linked to cooperatives). It is worth mentioning that even before these crises, Londrina already had informal collectors. Such informal *catadores* are known as "garbage pirates," since they act previously to the cooperatives, selecting and collecting the materials with higher added value, which creates conflicts between these two categories. The informal *catadores* do not desire to join the cooperatives, because the cooperative members have their remuneration taxed. On the other hand, the cooperative collectors are legally supported, including by the social security, while the informal *catadores* do not have any government help, besides their working conditions are very precarious and inferior to those provided by the cooperatives. Although there is no official information concerning the number of informal *catadores*, it is estimated that they collect about 600 tons of MSWRP per month.

In this context, Figure 2 presents the quantity of MSWRP commercialized by recycling cooperatives (the quantities for 2020 are projections calculated from data collected between January and August of the mentioned year) and reveals fluctuations along the years analyzed in this study. Some factors contributed to these fluctuations, among them: (i) the great variability in the number of cooperative members, due to the flow of admissions and dismissals of *catadores*; (ii) the interruption, by the municipal supervisory agency (CMTU), at the end of 2016, of the supply of 100 L green garbage bags, discontinuing an old local custom (until then, the *catadores* collected MSWRP and concomitantly distributed new green garbage bags to the population) and, therefore, generating a decrease in the separation of MSWRP in the covered residences; and (iii) the increase in the number of informal *catadores*.

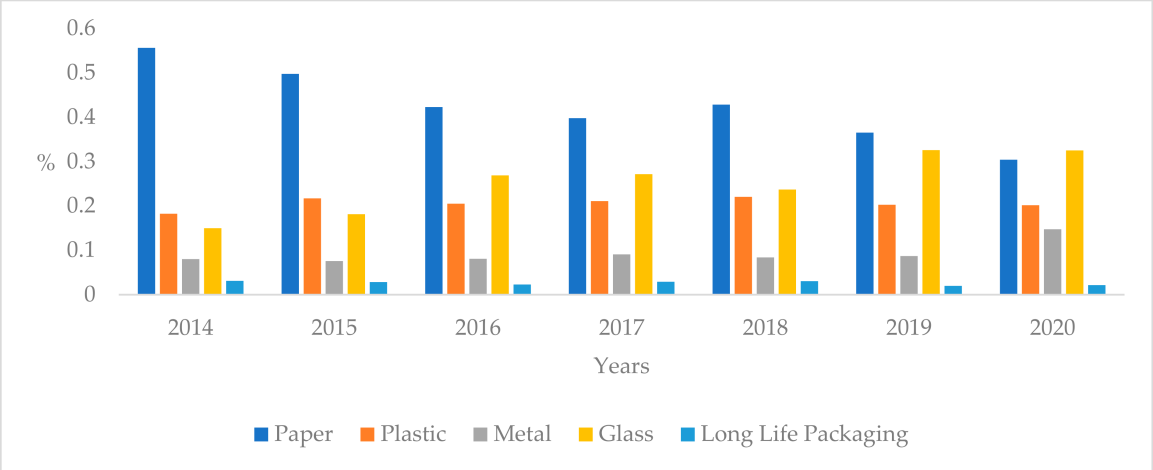

Figure 2. Quantity of municipal solid waste with recyclable potential (MSWRP) commercialized by the cooperatives. Source: CMTU [54].

Moreover, as presented in the Figure 2, the largest volume of MSWRP concerns paper, followed by glass, plastic, long-life packaging (Tetra Pak) and metal. The long-life packaging are carton containers used for milk, soups and other liquid products. The commercial value of each type of material fluctuates over time and the greater the quantity of material to be commercialized, the greater will be the cooperative's ability to negotiate with the manufacturing industries or middleman.

Analyzing the quantities commercialized per type of material and per cooperative, described in Table 3, it is noted that the proportions remain close to the rates presented in Figure 2, with few exceptions. In 2019, Coop4 and Coop5 commercialized more glass than paper and Coop7 commercialized more

plastic than glass. In 2020, the most commercialized material by Coop5 was metal, while Coop7 commercialized more plastic than glass.

It is important to emphasize that the quality of the sorting performed by the cooperative is directly related to the quantity of types of waste commercialized (Table 1). Coop1 is the cooperative that presents the best quality on waste sorting and classification (resulting in 30 different types), followed by Coop4, Coop2, Coop3, Coop7, Coop5 and Coop6. The greater the amount of different waste commercialized, the smaller the number of rejects destined to landfills.

Fidelis and Colmenero [9] studied the performance of all seven cooperatives in their operational activities in the recycling chain. According to the authors, Coop1 stood out in all performance rates, so that its organizational practices (waste collection and processing method, method for obtaining financial resources, budget planning, sales method, expenses control, among other actions) can be used as reference model for other cooperatives.

4.3. The Profile of the Catadores Organized in Recycling Cooperatives

Regarding the actors involved in the management of MSWRP, this section presents the socioeconomic and professional profile of 135 *catadores* linked to one of the seven cooperatives object of this study. The line "interviewed" in Table 5 indicates the percentage of *catadores* interviewed in each cooperative. The column "% total" illustrates the sum of the percentages of the cooperatives in relation to each variable. The columns "Coop1 (%)" to "Coop7 (%)" demonstrate the percentage of each variable in relation to the corresponding cooperative.

According to the data analyzed (Table 5), the majority of the *catadores* are female, corresponding to 71.11% of the total number of members, whereas 28.89% are male. In addition, there are a large number of single *catadores* (35.56%), of which 57.36% have more than 2 children and 34.88% have more than 3 children.

The data also revealed that most *catadores* (76.87%) are between 21 and 50 years old. However, when analyzing the beginning of their professional life it is noted that 63.7% of them started working before the age of 15 and 26.7% started even before the age of 9. This fact can be directly related to the low schooling of the *catadores* (Table 6). In this regard, it is observed that 63.70% of the interviewees have low education (no schooling and incomplete elementary school), while 89.63% were unable to complete high school (considering the interval between no schooling and incomplete high school).

In terms of revenue, 68.5% survive only from the activity as a *catadores*, while 31.4% have some financial supplement, such as pension, retirement or government assistance. It is worth mentioning that all the interviewed *catadores* have housing: 59% have bought, donated or borrowed homes; 32.8% have financed or rented/leased homes; and 8.2% live in informal settlements. Moreover, the portion of *catadores* who own cars corresponds to 21.8%.

With regard to the activities performed in the cooperative, 71% of the *catadores* work directly in the processing of materials (yard, sorting and general services) and 11.11% operate in the collection (driver and collectors), with many members of the board of directors accumulating activities in the administrative and operational sectors, as declared in the questionnaire.

In addition, the data exposed that 56.6% of the cooperative members have been working as *catadores* for more than 3 years, of which 37% and 12.3% have been working for more than 10 years and 15 years, respectively. However, it is noted that many of them worked informally for a period, since only 41% reported being linked to some cooperative for more than 3 years. Furthermore, 37.31% of them have already switched cooperatives, indicating a high turnover of the *catadores* among the recycling cooperatives.

Table 5. Socioeconomic profile of *catadores* organized in cooperatives.

		Cooperatives						
	% Total	**Coop1 (%)**	**Coop2 (%)**	**Coop3 (%)**	**Coop4 (%)**	**Coop5 (%)**	**Coop6 (%)**	**Coop7 (%)**
Interviewed	100%	14.07%	17.04%	11.11%	11.11%	27.41%	7.41%	11.85%
Sex								
Female	71.11	11.85	16.30	8.89	5.93	13.33	6.67	8.15
Male	28.89	2.22	0.74	2.22	5.19	14.07	0.74	3.70
Function								
Administrative	4.44	0.00	1.48	0.74	0.74	1.48	0.00	0.00
Collection	10.37	2.22	0.00	2.22	0.00	2.96	0.00	2.96
Board of directors	7.41	0.00	0.74	0.74	1.48	2.96	0.74	0.74
Driver	0.74	0.00	0.00	0.00	0.00	0.74	0.00	0.00
Press/Forklift operator	5.93	1.48	0.74	0.74	1.48	0.74	0.00	0.74
Yard	13.33	1.48	2.22	0.74	1.48	5.93	0.74	0.74
General services	5.93	0.00	1.48	1.48	2.22	0.74	0.00	0.00
Sorting	51.85	8.89	10.37	4.44	3.70	11.85	5.93	6.67
Age								
18–20	5.22	0.75	0.00	0.00	0.00	3.73	0.00	0.75
21–30	23.88	2.99	1.49	2.99	3.73	6.72	2.24	3.73
31–40	26.87	2.24	5.22	3.73	2.24	9.70	1.49	2.24
41–50	26.12	2.99	8.21	2.99	4.48	2.24	1.49	3.73
51–60	14.18	2.99	1.49	1.49	0.75	5.22	0.75	1.49
61–70	3.73	2.24	0.75	0.00	0.00	0.00	0.75	0.00
Schooling								
No schooling	12.59	3.70	2.96	0.74	0.74	1.48	2.22	0.74
Incomplete Elementary School	51.11	5.19	10.37	6.67	5.19	14.07	2.96	6.67
Complete Elementary School	10.37	1.48	0.00	0.74	0.00	3.70	2.22	2.22
Incomplete High School	15.56	2.96	0.74	2.22	1.48	6.67	0.00	1.48
Complete High School	8.89	0.74	2.22	0.74	3.70	1.48	0.00	0.00
Complete Higher Education	1.48	0.00	0.74	0.00	0.00	0.00	0.00	0.74
Civil status								
Single	35.56	7.41	6.67	4.44	1.48	9.63	2.22	3.70
Married	44.44	2.22	8.15	3.70	7.41	15.56	1.48	5.93
Divorced	14.81	2.22	1.48	2.96	2.22	2.22	2.96	0.74
Widower	5.19	2.22	0.74	0.00	0.00	0.00	0.74	1.48
Number of children								
0	15.50	0.00	0.78	2.33	1.55	10.08	0.00	0.78
1	9.30	0.00	1.55	0.78	2.33	3.10	0.00	1.55
2	17.83	4.65	1.55	2.33	0.78	3.88	0.78	3.88
3	22.48	1.55	3.88	0.00	3.10	7.75	3.10	3.10
More than 4	19.38	1.55	6.98	3.10	1.55	3.10	0.00	3.10
Has vehicle								
No	78.20	9.02	14.29	9.02	6.77	23.31	6.02	9.77
Yes–Financed	2.26	0.75	0.00	0.00	0.00	1.50	0.00	0.00
Yes–Paid	19.55	4.51	3.01	2.26	3.76	3.01	0.75	2.26
Housing								
Rented/Leased	24.63	2.99	2.99	2.24	4.48	4.48	3.73	3.73
Informal settlement	8.21	0.00	0.75	0.75	0.75	5.22	0.00	0.75
Borrowed	12.69	0.75	2.99	2.24	0.75	5.22	0.75	0.00
Donated	4.48	0.75	1.49	0.00	0.75	0.00	0.75	0.75
Financed	8.21	2.24	0.75	0.00	0.00	1.49	0.75	2.99
Owned	41.79	7.46	8.21	5.97	3.73	11.19	1.49	3.73
Has other source of revenue								
No	68.46	10.77	12.31	4.62	6.92	23.08	3.85	6.92
Yes	31.54	2.31	5.38	6.15	3.85	5.38	3.08	5.38

Source: CMTU.

The quality and safety of the work are important factors for the *catadores*. Nevertheless, only 46.7% of them affirmed to have received some type of training related to the use of PPE, customer service, cooperativism, management, body posture, relaxation, traffic legislation, handling and risk of materials, personal hygiene, social economy solidarity and so forth. Another issue that deserves to be highlighted is that 45.7% of the *catadores* have some health problem, of which 39.5% and 8.5% have diabetes/hypertension and/or respiratory problems, respectively.

Table 6. Professional profile of *catadores* organized in cooperatives.

		Cooperatives						
	% Total	**Coop1 (%)**	**Coop2 (%)**	**Coop3 (%)**	**Coop4 (%)**	**Coop5 (%)**	**Coop6 (%)**	**Coop7 (%)**
Age at which started working (years)								
5 to 9 years old	26.7	3.0	3.7	2.2	4.4	5.9	4.4	3.0
10 to 14 years old	37.0	8.9	8.1	3.0	4.4	7.4	1.5	3.7
15 to 17 years old	19.3	1.5	2.2	3.0	1.5	7.4	0.7	3.0
Over 18 years old	14.8	0.7	2.2	2.2	0.0	6.7	0.7	2.2
How long have been working as a catadores								
Less than 6 months	13.18	0.00	0.78	0.78	0.00	10.08	0.00	1.55
6 months to 1 year	3.88	0.00	0.00	1.55	0.00	1.55	0.78	0.00
1 year to 3 years	23.26	0.78	6.20	1.55	3.10	7.75	0.78	3.10
3 years to 5 years	13.18	0.00	2.33	0.78	2.33	3.88	0.00	3.88
More than 5 years	43.41	12.40	6.98	6.20	3.88	5.43	6.20	2.33
Membership time in the cooperative								
Less than 6 months	25.37	0.00	3.73	2.99	2.24	12.69	1.49	2.24
6 months to 1 year	10.45	0.00	0.75	2.99	0.00	3.73	2.99	0.00
1 year to 3 years	23.13	0.75	5.22	0.75	4.48	5.97	2.99	2.99
3 years to 5 years	16.42	0.00	4.48	0.75	2.24	4.48	0.00	4.48
More than 5 years	24.63	13.43	2.99	2.99	2.24	0.75	0.00	2.24
Has worked in another cooperative								
No	62.69	14.18	8.21	6.72	7.46	16.42	2.24	7.46
Yes	37.31	0.00	8.96	4.48	3.73	11.19	5.22	3.73
Another family member works as a catadores								
Yes, spouse and children	18.37	3.1	1.0	2.0	2.0	9.2	0.0	1.0
Yes, spouse, children and other relatives	6.12	0.0	0.0	1.0	0.0	4.1	0.0	1.0
Yes, other family members	37.76	6.1	5.1	3.1	4.1	9.2	3.1	7.1
No	37.76	0.0	7.1	5.1	5.1	15.3	0.0	5.1
Proud of the profession of "catadores"								
Yes	85.07	14.18	12.69	10.45	8.96	21.64	5.97	11.19
No	0.75	0.00	0.00	0.00	0.00	0.75	0.00	0.00
Regardless	14.18	0.00	4.48	0.75	2.24	5.22	0.75	0.75
Experienced prejudice for being a catadores								
No	60.45	5.97	10.45	7.46	4.48	23.88	0.00	8.21
Yes	39.55	8.21	5.97	3.73	6.72	3.73	7.46	3.73
catadores -community relationship								
Great	10.45	0.00	2.99	2.24	0.75	1.49	0.75	2.24
Good	52.99	8.96	5.97	7.46	4.48	14.93	5.97	5.22
Bad	14.93	2.99	3.73	1.49	2.24	2.99	0.00	1.49
Terrible	2.99	0.00	0.00	0.00	0.75	1.49	0.00	0.75
Regardless	18.66	2.24	4.48	0.00	2.24	6.72	0.75	2.24
Received some kind of training								
No	53.28	0.00	9.84	1.64	3.28	30.33	5.74	2.46
Yes	46.72	13.93	6.56	8.20	6.56	0.00	0.82	10.66
Has health problem								
No	54.26	0.00	9.57	3.19	6.38	26.60	1.06	7.45
Yes	45.74	8.51	9.57	5.32	3.19	11.70	3.19	4.26

Source: CMTU.

4.4. Summary of Results

The *catadores* associated to the recycling cooperatives analyzed in this study have a profile similar to that mentioned in the literature [7,31,33]: they are poor people, have many children, started working at a young age, earn low revenue, have low schooling and face difficulties to be allocated in the formal labor market (Tables 1 and 2). Their activities are predominantly manual and involve low technology [9,32,34,37]. Moreover, they have only essential equipment for the performance of their activities: presses for compacting waste, whose purpose is to add value to products; trucks for collection; scales and forklifts for the internal displacement of waste. However, some of this equipment is rented/leased (increasing operational costs) or lent by middlemen in the loan-commercialization relationship (resulting in the reduction of the amount obtained in the commercialization of the products) (Table 1).

Some common difficulties were reported by the cooperatives, such as: ergonomic problems related to body posture during the collection and processing of MSWRP; complaints from buyers due to the mixing of materials (sorting issues); resistance of *catadores* in using PPE; some SC have inadequate ventilation, lack of luminosity and strong odor; many of the sorted waste have no commercialization; at each contract renewal there are significant changes in the form of valuation of the materials and the amount transferred by the municipality to the cooperatives.

Furthermore, the cooperatives do not have many fiscal incentives, a fact that burdens their activity, impacts negatively on the revenue of members and renders difficult the organization of *catadores*

in cooperatives. This issue also has repercussions on the industrial sector, as few products made from recyclable materials are exempt or have reduced taxation, which indicates that Brazilian legislation does not seriously encourage the use of such materials. Additionally, investments in recyclables are less attractive in some regions of the country, a fact that explains the geographical concentration of industries (73% of the recovering industries are in the South and Southeast regions, while 27% are in the North, Northeast and Center of Brazil) [58] and the increase in the costs of commercialization of recyclable materials in regions less attractive in terms of recycling.

Despite the difficulties reported by the analyzed cooperatives, the living and working conditions of their members, although not ideal, are much better than those presented by *catadores* from other regions of Brazil [24]. In this context, the members of Coop1 had an average monthly revenue 34% higher than the minimum wage in force in the period 2019 and 2020; the majority of the cooperatives presented monthly revenue of approximately 70% of the Brazilian minimum wage; and no cooperative obtained an average monthly revenue below 50% of the minimum wage, a sad reality observed in many other cooperatives in Brazil [24] (Table 2). According to a study based on data from 16 cities in the state of Espírito Santo, Brazil, 82% and 17% of the cooperatives of *catadores* operated with very low and average efficiency, respectively [59].

Another important fact is that 91.8% of the *catadores* have decent housing (with access to water, electricity, sewage, etc.) (Table 6), unlike the reality of so many other collectors who generally reside in suburban geographic spaces [29,32]. It is also worth noting that the profession of "*catadores*" is common to several members of the same family (62.3%) and that only 0.75% of them declared to be ashamed of their profession, which demonstrates that such workers are aware of their importance in the management of MSWRP. However, there are still issues related to the prejudice experienced by these workers, as 39.6% stated to have already suffered some prejudice and 17.9% affirmed to face difficulties in their relationship with the community (Table 6).

At the moment, although the seven cooperatives meet the collection needs of the municipality, some of them do not efficiently optimize their inputs in products [9], so there is still a great potential to be explored. Therefore, in case of future exploitation of the total potential offered by the municipality in terms of recycling, problems may arise. According to CMTU [54], in 2018 (the data for 2019 and 2020 are not complete) the municipality generated 128,977,746 tons of MSW, while and the cooperatives collected approximately 18% (7,375,287 tons) of the total MSWRP produced by the municipality. In Brazil, it is estimated that 31.9% of the MSW generated is composed of MSWRP [60], in the case of Londrina, 31.9% of 128,977,746.

It is noteworthy that the municipal supervisory agency (CMTU) is committed to reducing the number of informal *catadores* by including them in existing recycling cooperatives (there is no official information concerning the number of informal *catadores* but it is estimated that they collect about 600 tons of MSWRP per month). Notwithstanding the fact that the municipality of Londrina has 100% of its urban and rural area covered by MSWRP collection, the system is still underused, since, according to the CMTU, about 30% of the MSW collected and destined to landfills could be recycled. This may be associated with the environmental education of the local population, which does not perform the correct separation and destination of MSW.

In a sense, recycling is the reverse channel of reverse logistics, since it aggregates value to the product after its consumption and prevents the life cycle of the product from ending with its final consumer, thereby promoting environmental and economic awareness, as well as social responsibility of consumers [61,62]. Therefore, it is undeniable that *catadores* perform a fundamental role in the management of MSWRP in developing countries, acting directly in the process of revalorization of residues, which are no longer considered useless waste and are now recognized as economic resources [32]. Moreover, this category of workers has the potential to transform environmentally, economically and socially an entire value chain, which begins with the performance of the *catadores*, goes through the processing industries and ends with the return of the product to the consumer market [9].

In the context of developing countries that aim to implement CE actions, it is essential to ensure the inclusion of *catadores* in an adapted CE structure, as stated by Gutberlet et al. [26], considering the EE and the SSE, expanding in this way the social and political aspects of the CE concept (rendering social benefits more sustainable and less paternalistic), under a lens of the Global South and in the context of *catadores*.

According to Gall et al. [25], it is important to have CE business models that are adjusted to regional specificities and also socially inclusive, combining a human-centered and technology-oriented approach. The author also highlights that the quality of post-consumption plastic waste collected by informal collectors authorizes its processing with other materials that are comparable to state-of-the-art recyclates (in terms of composition and basic engineering properties) and states that whether the right model of cooperation was found, it could bring socio-economic improvements for people who work and live in the informal sector.

Regarding the above and although the problems reported by the cooperatives, the MSWRP management system implemented in Londrina, Brazil, can be considered as an example of the inclusion of recycling cooperatives in the formal recycling system. It is important to highlight that the formalization of the *catadores* in collective organizations was essential in this context, because the cooperatives became legally responsible for the management of MSWRP (with the imposition of fines in case of non-compliance with legal and contractual obligations), fact that encouraged the professionalization of the *catadores*. Strategies for the inclusion of collective organizations of *catadores* in waste management in a CE can be achieved by promoting the economic sustainability of these organizations through improved governance tools [63].

The factor responsible for this improvement is the recognition, by the municipality, of the environmental service provided, through its remuneration. In this sense, when municipalities give more importance and recognition to the work performed by *catadores*, there are improvements in MSW management services and in quality of life and work of these workers [7,8,10,22,31].

Coop1 stood out in comparison to the other cooperatives and can be indicated as a benchmarking. Its organizational practices, methods of collecting and processing waste, method of obtaining financial resources, budget planning, sales method, expenses con, among other actions, can be used as a reference model for other cooperatives. This cooperative has a sales department that commercializes directly with processing industries and the amount obtained by selling its products is according to the market value, a fact that is not observed in the context of other cooperatives. Due to the fact that Coop1 has a contractual department that operates in the search of incentive notices for recycling cooperatives, most of its equipment was obtained through such notices issued by the federal government and private companies.

It is important to mention that the path followed by Coop1 was long. It was founded in 2009 and received assistance to build its organizational identity: financial and managerial support from the municipality of Londrina; and support from researchers at the State University of Londrina and the Federal Technological University of Paraná.

For example, the extension project financed by the Araucaria Foundation, an institution linked to the government of Paraná, performed in 2010/2011, aimed to provide technological and commercial support for Coop1. This project included two researchers of the Federal Technological University of Paraná, three recently graduated professionals (two from the administration area and one from the law area) and two trainees from the administration area. This project executed an operational diagnosis of the cooperative (to verify the processes that should be improved) and proposed layouts for the SC (to optimize the internal flow of materials), a report proposing training courses and a logistical report (indicating the existing failures in the collection process and proposing new routes). In addition, at that time only Coop1 was formalized as a cooperative in the municipality.

For the aforementioned, Coop1 has adapted its knowledge and academic and professional supports to build its own identity, considering the cultural issues of its cooperative members and their know-how, enabling improvements in its governance.

Nonetheless, the municipality of Londrina faces challenges in the management of MSWRP. Due to the lack of professional training, formal education and financial resources and also due to cultural issues inherent to the *catadores* themselves, there are problems in the relationship between the cooperatives, which difficulties the intercommunication and exchange of experiences between them.

5. Conclusions

Based on the assumption that in most developing countries the informal recycling sector is responsible for the collection and destination of MSWRP and therefore has a fundamental role in the implementation of the CE, this study analyzed the inclusion of recycling cooperatives in the formal management of MSWRP of a medium-sized Brazilian city, in order to identify its contributions in an adapted CE structure (according to Gutberlet et al. [26]) and, at the same time, to indicate a cooperative that can be used as a benchmarking option for other cooperatives, especially in relation to their organizational and operational practices.

The *catadores* associated to the recycling cooperatives analyzed in this study have socioeconomic characteristics similar to *catadores* in developing countries, that is, they are poor people, have low schooling, face difficulties to be allocated in the formal labor market, have many children and started working at a young age. Their activities are predominantly manual and involve low technology but they have essential equipment for the performance of their activities: presses for compacting waste, whose purpose is to add value to products; trucks for collection; scales and forklifts for the internal displacement of waste. Some of this equipment is rented/leased (increasing operational costs) or lent by middlemen in the loan-commercialization relationship (resulting in the reduction of the amount obtained in the commercialization of the products).

The living and working conditions of their members are much better than those presented by *catadores* from other regions of Brazil. In this sense, the members of Coop1 had an average monthly revenue 34% higher than the minimum wage in force in the period 2019 and 2020; the majority of the cooperatives presented monthly revenue of approximately 70% of the Brazilian minimum wage; and no cooperative obtained an average monthly revenue below 50% of the minimum wage, a sad reality observed in many cooperatives in Brazil. Another important fact is that 91.8% of the *catadores* have decent housing (with access to water, electricity, sewage, etc.) and 85% of the *catadores* declared to be proud of their profession.

Therefore, the waste management system implemented in the studied municipality can be considered as an example and despite the difficulties it demonstrates that it is possible to include the recycling cooperatives in the formal recycling system. With the formalization of the cooperatives and the payment for the environmental service provided, these collective organizations became legally responsible for the management of MSWRP, with the imposition of fines in case of non-compliance with legal and contractual obligations, fact that encouraged the professionalization of the *catadores*.

This environmental service performed by the cooperatives presents important contributions: the reduction of pollution; the preservation of natural resources; the decrease of environmental impacts; the increase of the useful life of landfills; the reduction of municipal expenses with the collection and processing of MSWRP; the inclusion of *catadores* in the labor market; the generation of revenue; the supply of raw material for the processing industries; and so forth.

According to the data analyzed, Coop1 stood out in comparison to the other cooperatives and can be indicated as a benchmarking. Its organizational practices, methods of collecting and processing waste, method of obtaining financial resources, budget planning, sales method, expenses control, among other actions, can be used as a reference model for other cooperatives. This cooperative has a sales department that commercializes directly with processing industries and the amount obtained by selling its products is according to the market value, a fact that is not observed in the context of other cooperatives. Due to the fact that Coop1 has a contractual department that operates in the search of incentive notices for recycling cooperatives, most of its equipment was obtained through such notices issued by the federal government and private companies.

It is worth mentioning that Coop1 was the first cooperative with legal formalization and included in the formal collection system of the municipality. It counted on the financial and managerial support of the municipality, besides the support of research institutions that provided technological and marketing support to exercise the activity. Coop1 has adapted its knowledge and academic and professional supports to build its own identity, considering the cultural issues of its cooperative members and their know-how, enabling improvements in its governance.

Consequently, based on the practices used by the municipality, the formalization of cooperatives and the payment of the environmental service provided, it became possible to include *catadores* in the management of MSW in a socially inclusive CE perspective, since they are responsible for the collection and destination of MSW in most developing countries and has the potential to move environmentally, economically and socially an entire value chain.

In this scenario, for a socially inclusive CE approach in the management of the MSW, developing country governments must recognize the environmental, economic and social service provided by the informal recycling sector, through: (1) the implementation of public policies aiming to insert the informal recycling sector in actions involving shared responsibility for the life cycle of products; (2) encouraging the formalization of the informal recycling sector in collective organizations, such as associations and cooperatives; (3) the inclusion of cooperatives and associations of *catadores* in the formal structure of government financial incentive programs for the management of MSWRP, at the federal, state and municipal levels; (4) the inclusion of cooperatives and associations in the MSW management plans; and (5) the fair payment for the environmental service provided.

In view of the aforementioned, this study provided an overview of the MSWRP theme, emphasizing that the implementation of the CE in developing countries is, in a way, conditioned to the performance of the informal sector in the recycling chain, as well as noting that the inclusion of cooperatives and associations of *catadores* in the formal sector of MSWRP management can increase the recycling rates of a municipality, in addition to improving the living and working conditions of the *catadores*.

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