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REVERSE LOGISTICS MODELS FOR THE COLLECTION OF WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT: THE BRAZILIAN CASE[1]

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ABSTRACT

In 2010, the legislation regarding the Brazilian Policy of Solid Waste (BPSW) was introduced in Brazil. It is the legal framework for solid waste management that differentiates what is recyclable and from what is not. The BPSW features innovations such as Reverse Logistics (RL) which determines that manufacturers, importers, distributors and retailers must perform the collection of used packaging and products like batteries, light bulbs, electronics, etc. The aim of this paper is to propose a framework that helps indicating which would be, among the National Collective and Clearing House models used in European countries, the most suitable scheme for reverse logistics of Waste Electrical and Electronic Equipment (WEEE) according to the Brazilian reality. For this purpose, the paper analyses the existing literature and various relevant practices used in Europe. Moreover, data regarding the Brazilian environmental legislation and the characteristics of each state were used to evaluate the possible use of the European reverse logistics models. The framework helps to define the Brazilian case in three stages and suggests that the most suitable model for Brazil is the National Collective. This decision is urgent since it has been proposed that many European countries should also implement this model instead of the currently employed. Finally, a structured framework is proposed, facilitating the decision-making process to be carried out by various stakeholders such as the Brazilian Federal Government, municipal authorities, industries, recyclers and service providers. In this way, the WEEE management and logistics organization would be easier in the Brazilian territory.

Keywords: Reverse Logistics, Recycling, Framework, Model, WEEE, Brazil

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1 INTRODUCTION AND BACKGROUND

In August 2010, the legislation regarding the Brazilian Policy of Solid Waste (BPSW) was introduced by the Brazilian government. It is the legislation on solid waste management that differentiates what can be recycled and what is not susceptible to reuse [1]; [2]; [3]. On one hand, [4] describes the reduction of solid waste generation as one of the significant aspects for sustainability assessment. On the other hand, reverse logistics represents the ability for organizations to respond the requirements of markets and customers by remaining sustainable over time [5]. Consequently, the following question arises from the presently described research: what is the actual difficulty for companies in meeting the requirements of the BPSW?

The BPSW features innovations such as the aforementioned Reverse Logistics (RL), and fixes that manufacturers, importers, suppliers and retailers must perform the collection of used packaging. Diverse types of products such as batteries, pesticides, exhaust tires, lamps, light bulbs and electronic devices are regulated by this legislation. Additionally, some of the objectives and the proposal of the BPSW are acknowledged below [6]:

- Its objective is monitoring the generation, reduction, reuse and treatment of solid waste, in addition to the assurance of an environmentally appropriate final disposal of not-reusable items, a reduction in the use of natural resources (water and energy, for example) in the production processes of new products, intensification of environmental education actions, an improvement of recycling within the country, encouraging social inclusion through the generation of work and benefits for recyclable material collectors.
- Its proposal is to spread the principle of shared responsibility throughout the products' life cycle including manufacturers, importers, suppliers, traders, customers, public cleaning systems and solid waste management services. The BPSW indorses actions such as shared assignments, both for public and private institutions, as well as for the society in general. It also proposes reverse logistics as one of its fundamental principles, constituting a set of actions to facilitate the return of waste to its generators, then it will be properly treated or recycled into new products.

- Among the main challenges imposed to manufacturing firms by the BPSW, the thirty-third article with its third, fourth, fifth, sixth and eighth sections must be highlighted. These stipulate the disposal of pesticides, their wastes and packaging; batteries, exhaust tires, lubricating oils with their wastes and packaging; fluorescent, mercury and sodium vapor and mixed-light lamps; electronic and electrical devices and their components. In these sections, it is stated that: (1) “manufacturers, importers, suppliers and traders [...] are required to take all necessary actions to guarantee the application and operationalization of reverse logistics schemes under their responsibility”; (2) “customers must consent the return of used products to traders and suppliers and their corresponding packaging”; (3) “traders and suppliers must arrange the flow return of products to manufacturers/importers”; (4) “manufacturers and importers have to provide an environmentally suitable place for collected or returned goods and packaging, in this manner non- reusable items are appropriately discarded”; (5) “excluding customers, all those belonging to reverse logistics systems will have to make accessible, detailed and updated data on the implementation of actions under their responsibility to the competent municipal institutions and other concerned authorities”.

Separately, the markets uncertainty and the strong competition between firms are becoming a major challenge for business management [7]. Firms are being required to adopt reverse logistics practices due to the laws regarding collection and disposal of solid waste, the increased concern about corporate image and environmental aspects and the obtention of economic benefits [8]. Apart from this, thegreatest challenge that organizations have faced in order to fulfill the BPSW requirements and sustain a competitive position in the market is to establish a link between customers and suppliers in order to track their products across the supply chain. The reverse logistics process beginswith the classification of products used or returned in different categories, then they must be prepared for reparation, remanufacturing, recycling, reuse or final disposal, depending on the decision as to its value. The mainactivities involved in this process are identification, collection, inspection, classification for reuse or disposal [8].

The operationalization of the related reverse logistics legislation in Brazil is reflected in two fronts, the first refers to companies that should comply with the new requirements of tracking and disposal of waste from the process of packaging, moreover, the second is related to old products to be replaced. A new approach to the supply chain includes reverse logistics, accounting end-of-life (EOL) products leading to an integrated approach of both direct and reverse supply chains simultaneously in a closed loop. This new approach is also known as closed-loop supply chain (CLSC) [5]; [9]; [10]; [11].

In addition, for [12] the use of the third-generation Enterprise Resource Planning (ERPs), would not only help in meeting the legislation, but also could allow the optimization of enterprise resources, such as time, financial resources and employees.

As regards to the choice of which collection model should be adopted in Brazil, this issue represents an urgent decision because there must be a previous definition of the general implementation guidelines before companies can build their collection structure independently [2].

In Europe, the problem was similar and there are two models already adopted in thirty countries: the Clearing House model and the National Collective scheme. These can be compared, analyzed and used as a basis for the proposition of a more suitable model to the current conditions in Brazil.

The main purpose of this article is to study these two models used in European countries, highlight their advantages and disadvantages and propose a model to facilitate the decision-making in the Brazilian case. To accomplish this objective, various specific goals were set:

- Conducting a literature review involving WEEE collection models in the European Union: analyzing the National Collective scheme and theClearing House model, their definitions, characteristics and objectives;
- Proposing an integrated framework for managing the reverse logistics on the disposal of electrical and electronic products and their components at the end of their lifetime.

In summary, this article adopts a qualitative approach with the objective of describing the complexity of the problem stated, without involving manipulation of variables and experimental studies [3]; [9]; [10]; [13]; [14]. This work is organized into five sections. Section II presents a general view of the WEEE collection systems in the European Union, Section III describes a critical analysis of the European WEEE collection systems, Section IV proposes a WEEE reverse logistics model for Brazil, Section V draws the conclusions, followed by the bibliography used.

2 WEEE COLLECTION SYSTEMS IN THE EUROPEAN UNION

To deal with the environmental problems related to the management of WEEE, some EU member states began to develop in the 1980s and 1990s national legislations in this regard. Later on, a clear need of a harmonized European legislation appeared on these waste streams in order to overcome certain difficulties related to the presence of different national policies on the management of WEEE. Given these premises, the European Directive 2002/96/CE

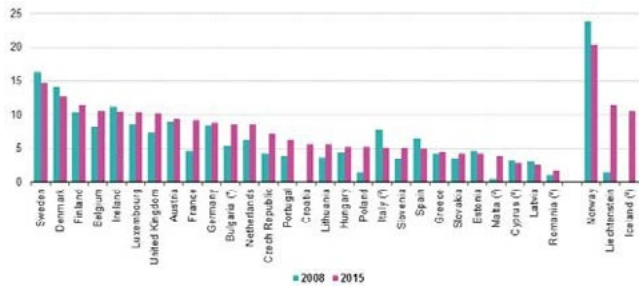
[15] entered into force in 2003 to prevent and limit the flow of waste electrical and electronic equipment sent to the landfill by the means of reuse and recycling plans. This directive was reviewed with the publication of the Directive 2012/19/EU (came into force in 2012) because of the intensification of this kind of waste [16].

This part addresses the issue of collection and recycling outlined in the WEEE European Directive by conducting an analysis of the design and the operating characteristics of the WEEE collection systems (also called schemes) operating in 28 nations of the European Union. The WEEE directive of 2012 currently sets a minimum collection target of 4 kg per year per inhabitant for WEEE coming from households. The newest directive also has introduced higher collection objectives that were applied since 2016 and others that will be applied from 2019 onwards. Nevertheless, as it is noticed by the European Commission “some member states will be able to derogate from the new targets for a limited time, where this is justified by a lack of necessary infrastructure or low levels of consumption of electrical and electronic equipment (EEE)”. Since 2018, the directive is extensive to

all categories of EEE and the categories of waste have changed definition and numeration, they were reorganized from 10 categories to the current 6.

In this sense, Fig. 1 illustrates a summary of the European situation and the amount of WEEE collected by country in kg/inhabitant for the years 2008 and 2015.

Fig. 1 | WEEE collected by country in 2008 and 2015 [17]



As shown in Fig. 1, Norway, Sweden, Denmark, Finlandand Belgium present the best rates of collection. Romania and Latvia are achieving very low rates during these years. Insummary, most of the European countries have improved their collection rates of WEEE from 2008 and after the implementation of the new directive.

A. *The WEEE directive and its implementation*

To face appropriately the environmental problems associated with the WEEE in Europe the Directive 2012/19/EU [16] imposes a separate collection which must be guaranteed by appropriate systems so that users can easilydiscard their electrical and electronic appliances.

Nevertheless, the directive gives freedom for companies to choose any of the following options: implementing their own individual recovery system or participating in collectiveschemes for collection or shared systems composed by multiple companies associated in order to obtain the benefitsderived from economies of scale. Nowadays, in most of the European countries the recovery systems are of the second type. Empirical studies have shown that individual schemes end up supporting much higher costs than the collective schemes because they hardly reach economies of scale in collection and processing of products [18]. Furthermore, collective schemes can be divided into two main models [19]:

- National Collective scheme.
- Clearing House model.

Table I outlines the current configuration of the collection systems in the EU member states and others, highlighting a ratio of 2:1 in support of the Clearing House model.

Table I | Collection models in eu member states and others [20]

Model	Nation
ClearingHouse	Austria, Bulgaria, Croatia, Czech Republic, Denmark, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Poland, Portugal, Romania, Slovakia, Slovenia, Spain and United Kingdom.
National Collective	Belgium, Cyprus, Estonia, Greece, Hungary,Luxembourg, Malta, Netherlands, Norway and Sweden.

B. *The National Collective scheme*

In a country where the National Collective scheme (NC) is implemented one or more schemes may operate. It should be noted that in this final case they are not competing between them, because they are in charge of the collection of diverse categories of WEEE. Thus, they can manage the collection points in the best way to maximize logistics efficiency. However, every scheme must report its performance yearly (defined as an amount of WEEE collected and a percentage of waste recycled) to the ministry in charge of the environment. This institution will report the data to the European Commission.

It is noteworthy that, these kinds of systems are usually formed by non-profit organizations or associations of manufacturers. Each scheme is responsible for the collection, transport and processing of WEEE from the manufacturers and/or their partners. Frequently, the collection systems collaborate with carriers and logistics operators for transport and recycling companies for waste treatment.

Despite the use of a National Collective system, it is possible for a manufacturer to make the decision of implementing its own collection structure. In that case, the manufacturer must ensure that their products once wasted follow a well-organized and differentiated return flow from those used by the other manufacturers: a good example are the products gathered in collection points set up by manufacturers or by their dealers. If the product is discarded in common locations, where the WEEE is stored by its category regardless of the brand, it is the manufacturer who chooses to implement its own recovery scheme and must guarantee that it can furnish any public collection point. Therefore, a complex and large recovery network is necessary. For this reason, most manufacturers who do not have a well-established and independent return flow of their products take part in collective schemes.

C. *The Clearing House model*

The schemes operating in the Clearing House model willcompete between them as they can gather the same WEEE categories. In this scenario the schemes are responsible for the collection, transport and processing of the products and must deal with logistics operators and recyclers. This model is accompanied by a national register with the following functions [16]:

- To define and manage the allocation mechanisms of collection points to the various players according to impartiality criteria and being consistent with the collection scheme fee, using as a reference their market shares.

- To ensure that the systems meet their responsibilities and address the WEEE assigned.
- To report annually to the ministry of environment or the European Community the environmental performance achieved.

If a manufacturer implements its own system of recovery,it must enroll in the national register and will be subject of the same allocation mechanism used for the collection points.

Frequently manufacturers are associated with one of the schemes and are required to declare the kilograms of finished products (for each category) that are planning to sell in the domestic market during the present year. Then, the schemes provide grouped data to the national register and this will be capable to calculate the market share of every collective scheme by category of product. The responsibility of collection of WEEE must respect the market share of each system [21]; [22]. However, the actual amount of WEEE collected in the year may deviate significantly from the quantities placed on the market by the manufacturers registered. Usually, this variance is mainly due to the presence of historical waste and orphan products.

Nevertheless, the modus operandi of the NationalCollective scheme and the Clearing House model are profoundly different. To provide a sufficiently complete explanation of these two systems and to conduct a comparative analysis later, two variables were compared in Table II: how the collection points are assigned and the method used for the division of the territory.

Table II | Weee collection systems classification [20]

Model	Assignment of collection points	Land subdivision
National Collective	Absent or by category	Unified managementof the nation
Clearing House	Periodic	By zone
		By site
	Immediate	By site

Within the Clearing House model, the assignment ofcollection points is made by the national register and can be periodic or immediate. In the first case, there are two different ways to divide the territory by zone and by site, respectively.

3 THE REVERSE LOGISTICS MODELS USED IN EUROPECOMPARED

This section of the article presents a framework includingthe characteristics of the two main models employed in the European Union for collecting and recycling WEEE [20]. The framework is sketched below, then a brief explanation will be outlined by examining the items listed in Table III:

Table III | Main variables used to compare different collecting models [20]

Variables	National Collective(N)	ClearingHouse(C)
1 - Logistics efficiency	High	Low
2 - Level of complexity	Low	High
3 - Impartiality	Absent	Present
4 - Level of competition betweenschemes	Absent	High
5 - Overall effectiveness of the collectingsystem	High	Low
6 - Overall efficiency of the collectingsystem		
6.1 - Economies of scale	Yes	No
6.2 - Small size of the nation'spopulation	Appropriate	Not appropriate
6.3 - Producers with well-established and independent return flow for eachproduct	Appropriate	Not appropriate

1 - Logistics efficiency: the logistics efficiency is higher in the National Collective model, where the scheme is responsible for the collection of all WEEE or certain categories of them, covering the whole national territory.

2 - Level of complexity: the National Collective scheme is easier to implement than the Clearing House model because of the number of partakers involved in the recovery and treatment of the WEEE, it also requires a national register.

3 - Impartiality: in the National Collective model, the problem of impartiality between schemes does not exist.

4 - Level of competition between schemes: the presence of many firms competing entails higher efficiency rates and consequently, a reduction of costs for the collection and disposal of WEEE. Thus, the Clearing House model should be more competitive.

5 - Overall effectiveness of the collecting system: the National Collective schemes usually exceed by far the objectives and minimums imposed by the community legislations.

6 - Overall efficiency of the collecting system: the examination of the general efficiency is done by analyzing the following characteristics:

6.1 - Economies of scale: when there are many collection schemes competing in a Clearing House environment, the market share of the collecting companies decreases. So, regarding this extent, it is better to apply a National Collective model.

6.2 - Small size of the nation's population: in small or lightly populated nations it is easier to apply a National Collective model. A Clearing House system is not suitable in small nations where the quantity of WEEE to recover probably does not justify the extra costs of infrastructures and duplication of functions, logistics costs and extra management generated by the allocation mechanisms of the collection points and the fragmented management of the territory.

6.3 - Manufacturers with a well-established and an independent return flow for each product: the National Collective model is more suitable because every product will be collected by a single firm [23]; [24].

4 MODEL PROPOSITION FOR WEEE COLLECTION IN BRAZIL

Brazil is a continental country with large differences among its states. Some of them have wealth and, regarding their magnitude, are similar to some European countries, however, others, despite their large extension, they are very poor. For this reason, it may be difficult to define one of the models as appropriate or suitable for all states. Thus, the proposal of this paper was divided into three levels (Fig. 2).

The first level refers to the entire country, which should set the guidelines for WEEE treatment, establishing the responsibilities for every state in relation to the processing of products in disuse, ensuring the collection and the allocation of the various categories of waste and depending on the recycling methods available.

Fig. 2 | WEEE Framework proposed for Brazil

A. 1st Level - Definition of guidelines - Federal scope

In 1998, the Brazilian government determined by law (9605/98, 11445/07 and 12305/10) the National Policy on Solid Waste (BPSW) that defines among others that municipalities are responsible for the integrated management of solid waste. Still, the BPSW sets the shared responsibility for the life cycle of products, involving manufacturers, importers, distributors, traders, consumers and holders of public services for urban cleaning and solid waste management.

Moreover, in the Decree 7404/10 the notion of reverse logistics is defined as an economic and social instrument characterized by a set of actions, procedures and means to enable the collection and recovery of solid waste to the business sector for reuse in its cycle or other productive cycles, or another environmentally appropriate disposal. The same decree provides the adoption of reverse logistics applications by a steering committee to be created for this purpose.

In terms of legislation, Brazil is prepared for the treatment of solid waste, however, among other causes, because it is a continental country there is a lack of coordination for the implementation of these policies.

Then, this rule has led to an increase in public services and industrial production limited by the expected growth of the Gross Domestic Product (GDP) and, on that basis, the supply of products and its high generated profit margins, made companies realize that there was no incentive to increase production. It was a sum of "relax" of companies due to the high profitability of the productive activity and the uncertainty of the population about their purchasing power what caused an extension in the life cycle of products. Even after the opening of the market due to globalization, there is still a strong demand of used products.

On the other hand, the market is changing rapidly and recently, even the poorer classes are beginning to have more and more access to new technological products. This increases the problem because the possibility of buying new products will shorten their life cycle and therefore increases the speed of disposal of used devices.

Moreover, the identified practices in literature on the operation policy of solid waste in European countries show that there must be a real involvement of the municipalities and that the cost associated with the collection and disposal of waste should be shared with manufacturers, importers and users of the electrical and electric products.

So, the proposal of this study is that the legal premises associated with BPSW should be clearly transmitted to the states and municipalities enabling their own organization to effectively put the law into practice. Monitoring can be developed by using performance indicators related to the level of disposal and reuse of disused products. Currently it is estimated that the percentage of WEEE processed in Brazil is about the 2%, the rest has been accumulated in houses or discarded with other municipal waste generated.

B. 2nd Level - Decision of the model to be adopted – States scope

As previously reported, the European reality is divided between two models clearly defined for the treatment of theirWEEE. Their relevant factors were used to support the model and to select the process to be adopted. The National Collective or the Clearing House model should be chosen according to the characteristics of each state using the pointslisted in the previous section (Table III).

To identify the trend for the adoption of one of the two models in Brazil the criteria set out in Table III were appliedwithin the twenty-six Brazilian states and the Federal District. Moreover, to develop each proposal, various documents and academic works were consulted regarding: the characteristics of the country and its legal framework [1];[2]; [3]; [6], the concerning WEEE issue in Brazil [25]; [26];

[27]; [28]; [29], additional general views and case studies analyzing reverse logistics encompassed in the Brazilian market [30]; [31]; [32]; [33] and the routes of recycling firms, which are critical given the recent growth in WEEE generation and their inefficiency in general [34].

The results (Table IV) showed that there is a great suitability of all states with the National Collective model; seven states were appropriate to the two models (six with preference on National Collective and one with preference on Clearing House). However, the clear majority shows that the National Collective model can be a key decision that, although respecting the autonomy of the states, it is the best choice for national management purposes.

C. 3rd Level – Operationalization – Cities scope

On this third level, the operational, the scope are the cities, that will be in charge of the effective collection of WEEE. It was considered that the models utilized in Spain and Italy as well as their accumulated experience could serveas a basis for the formulation of this level.

Even though in these two countries the collection systemis organized with a Clearing House model and in Brazil the most adequate one is the National Collective model, in the third level the effective difficulties of primary collection are not different among countries, independently of the collection model adopted. Therefore, it may be possible to use these experiences as a foundation for the Brazilian model.

To illustrate how the collection system works in a third level, the Spanish and Italian cases will be explained. The Spanish regulation [35] is similar to the Italian Directive [36]as they are in the same EU framework and both implement the Clearing House model. These regulations promote and give priority to the development and design of EEE in order to facilitate collection, disassembling, recycling and encourage the use of recycled materials.

Table IV | Analysis of the situation of each Brazilian state

			Brazil																								
			North						Northeast									Midwest			Southeast				South		
	Distrito Federal (DF)	Amazonas (AM)	Roraima (RR)	Amapá (AP)	Pará (PA)	Tocantins (TO)	Rondônia (RO)	Acre (AC)	Maranhão (MA)	Piauí (PI)	Ceará (CE)	Rio Grande do Norte (RN)	Pernambuco (PE)	Paraíba (PB)	Sergipe (SE)	Alagoas (AL)	Bahia (BA)	Mato Grosso (MT)	Mato Grosso do Sul (MS)	Goiás (GO)	São Paulo (SP)	Rio de Janeiro (RJ)	Espírito Santo (ES)	Minas Gerais (MG)	Paraná (PR)	Rio Grande do Sul (RS)	Santa Catarina (SC)
Variables	**National Collective (N)**	**Clearing House (C)**	**N**	**N**	**N**	**N**	**N C**	**N**	**N**	**N**	**N C**	**N**	**N C**	**N**	**N C**	**N**	**N**	**N**	**C N**	**N**	**N**	**N C**	**N**	**N**	**N**	**N**	**N**
1 - Logistics efficiency	High	Low	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
2 - Level of complexity	Low	High	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
3 - Impartiality	Absent	Present	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
4 - Level of Competition between schemes	Absent	High	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
5 - Overall effectiveness of the collecting system	High	Low	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
6 - Overall efficiency of the collecting system																											
6.1 - Economies of Scale	Yes	No	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
6.2 - Small size of the nation's population	Appropriate	Not appropriate	N	N	N	N	CN	N	N	N	CN	N	CN	N	CN	N	N	N	C	N	N	CN	C	C	N	C	C
6.3 - Producers with well-established and independent return flow for each product	Appropriate	Not appropriate	C	N	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	N	N	C	N	N

In both countries, the electrical and electronic equipmentusers can deliver used devices for reuse or dispose them as waste, in this second case WEEE manufacturers will beconsidered. The management of WEEE should give priority to efficiency and the reprocessing operations of WEEE. The responsibility of the users ends with the delivery of WEEE on local collection points, distributors, waste managers or delivering in the EEE producer's collection networks.

In Italy and Spain, WEEE collection is always oriented to recycling as much as it is possible, for those cases where it is not possible the accomplishment of this objective, a proper treatment must be given.

In Spain [35], the collection process of these discarded products and parts is made by:

- Distributors: they will accept for free the waste from consumers when these buy a new equivalent product.
- Local entities: carrying door to door collecting and bymeans of municipal collection points. This category includes other entities with municipal authorization.
- Manufacturers: through individual or collective systems (establishing collective schemes) they will gather the WEEE as well as the historical waste.
- Waste managers (including non-governmental organizations) authorized.

Furthermore, in Spain there is an electronic database for managing the WEEE collection coming from all channels and actors foreseen here. All operators involved in the collection and management of WEEE will incorporate data on the electronic platform and will keep them updated, whenever they made pickups, inputs or outputs of WEEE at their installations, or every time they change any other information that is incorporated into the platform. The database allows to know the situation or traceability at each stage of the waste. Each operator may only have access tothe necessary data corresponding to its activity.

Similarly, in Italy [36], the management WEEE collection in different levels belongs to:

- Distributors: the preliminary collection is organized by them in their territory. The collection is made for free with the purchase of new devices.
- Collection points: created and managed by municipalities and authorized companies. They are open to all users that can deliver domestic WEEE freeof charge. Collection points carry out the gathering ofWEEE from one or more municipalities and receive WEEE from distributors.
- Manufacturers: through individual or collective systems as it works in the Spanish case.

In addition, the organization of these agents is made by a coordination center under the supervision of the Italian Ministry of Environment. Its principal function is to coordinate and ensure the correct transfer of information provided by the manufacturers to the preparation facilities for reuse, treatment and recycling [36]. These objectives are achieved through the provision of a database. In 2007, Italy introduced, in addition to Legislative Decree 151/2005, a national WEEE management system where responsibility for the management of electronic waste was given to manufacturers, leading to changes in the system by introducing further responsibilities, activities, tasks and attributes [37].

It is worth noting that the identification of the WEEE with e-reading labels or similar instruments is mandatory in Spain since the electronic platform is operating and, consequently, this guarantees the traceability of waste. In Italy, the identification of WEEE is also mandatory and the regulation makes also possible the utilization of radio-frequency identification (RFID) systems.

Based on the Italian and Spanish experience, the third operational level where the WEEE collection occurs must bedeveloped and defined in these aspects:

- Which level of responsibility should be given to manufacturers and importers of electrical and electronic products?
- Which is the level of responsibility of the cities for the WEEE collection?
- How can the problem of low volumes in small cities that do not reach economies of scale be solved? and how can they eventually attract companies interested in collecting and recycling waste?

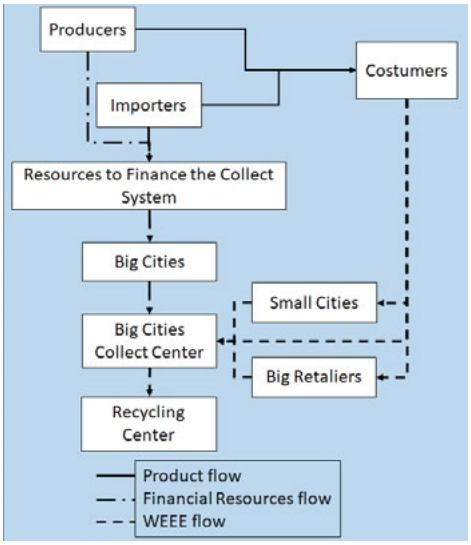
In fact, the answers to these questions can be verified in the cited models in which companies' products contribute in proportion to their market share, financing the arrangement of collection points in large supermarkets or specialized stores and routing for processing and reuse. Additionally, this funding should be used to build and maintain the structure created in cities with a population greater than one hundred thousand inhabitants, which are about 310 Brazilian municipalities.

The challenge is to solve the problem in the other 5260 municipalities that apparently do not present a volume that justifies the creation of physical structures and processing systems of WEEE collected.

The Italian experience can be adopted for this scenario. In Italy, there are agreements between small and larger towns to concentrate the collection. Therefore, a periodic collection system is arranged, in which trucks gather the products in disuse on pre-established dates.

In summary, Fig. 3 shows the proposed model for the third level in Brazil.

Fig. 3 | Third level of collection



5 CONCLUSIONS

The three-level model proposed for Brazil in this article constitutes an important contribution in addition to the previously planned ways for the collection and destination of WEEE in this country. From observation, it was elucidated that in some European countries the adopted models were not the most indicated for their characteristics and since the time for decisions was over, initiatives were adopted deliberately corresponding to the Clearing House model in general, however the best choice would have been National Collective schemes. In summary, the later the decision- making occurs, the greater are the chances of implementing the Clearing House model for collection.

In the Brazilian case, the great majority of its states has the characteristics that suit the National Collective scheme. Thus, discerning about implementing a National Collective model, it should be possible to leave aside the second level and adopt the National Collective scheme throughout the country and in each state because the initiatives are still incipient, facilitating the adoption of a national policy. The decision of the National Collective model has advantages regarding cost reduction in the implementation and process management. However, as mentioned before, the implementation of the National Collective scheme should respect the limits of each state, and therefore, the legal requirements should be clearly transmitted from the national government to the states and municipalities, enabling their own organization to enforce the law and effectively implement it.

In this study, it is suggested that only seven states could adopt both Clearing House and National Collective models (1:6 preference ratio respectively), but the vast majority should adopt the National Collective model, leading to the conclusion that it would be best to define a national policy for the collection and treatment of WEEE, otherwise it will be necessary in the future to implement the only possible model even if the Brazilian characteristics are not the most appropriate.

This study was based on the data available at the time of the research and there are both local and international pressures regarding the collection and treatment of WEEE since the sustainability issue is becoming more and more international and those countries which are more environmentally friendly are encouraging other nations to respect the environment and join forces against pollution. For this reason, local initiatives may be developed and can change quickly the current situation in Brazil.

This work contributes to the contemporary knowledge in the field of WEEE collection and reverse logistics, however this issue needs to be deepened and studied at the moment of the decision-making because WEEE management usually needs the adoption of immediate actions to solve the problem of waste and these have effect at the same time in the establishment of a model for collection.

Finally, this study hopes to stimulate interest in other researchers and representatives of the Brazilian government to address this issue as soon as possible since a great concern was observed in many countries where the problem can be considered solved and the reuse of WEEE generates financial savings besides protecting the environment.

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