UFSM

ReA UFSM
Revista de Administração da UFSM

ISSN 1983-4659
OPEN ACCESS

Rev. Adm. UFSM, Santa Maria, v. 16, n. 3, e2, 2023 https://doi.org/10.5902/1983465974238
Submitted: 17/02/2023 • Approved: 30/06/2023 • Published: 03/08/2023

The Reverse Logistics operation of solid waste pos-consumption of electronic products for domestic use in Brazil

A operação de logística reversa de resíduos sólidos pós-consumo de produtos eletrônicos de uso doméstico no Brasil

Jandir dos Santos Alós [I], **Gabriel Sperandio Milan** [I], **Luciene Eberle** [II]

[I] Universidade do Vale do Rio dos Sinos, São Leopoldo, RS, Brazil
[II] Universidade de Santa Cruz do Sul, Santa Cruz do Sul, RS, Brazil

ABSTRACT

Purpose: The general objective of this research is to present a framework aimed at structuring the operation of the RLS – Reverse Logistics System in the context of the post-consumer solid waste of products electrical and electronics segment in Brazil.
Design/Methodology/Approach: Exploratory research qualitative, operationalized through individual interviews with a semi-structured approach, with fourteen respondents, in addition to documentary research.
Findings: The cost for the operation of this structure must also be treated as a critical point for the success of this system, mainly due to the lack of a vision focused on the circular economy of EEE – Electrical Equipment and Electronics.
Implications for theory and practice: The study addressed some research gaps in relation to post-consumer reverse logistics. Regarding practical implementations, the development of a framework for the operacionalization of RLS stands out, and the evidence of this research concerns the lack of alignment, on the part of manufacturers and importers on issues related to EEE reverse logistics issues.
Originality/Value: An emphasis on an advanced view of how to treat the solid waste consumer electronics segment (EEE) in Brazil.

Keywords: Operations management; Reverse logistics; Post-consumer electronic equipment waste; Waste reduction

RESUMO

Objetivo: O objetivo geral desta pesquisa é apresentar um framework voltado para a estruturação da operação do SLR – Sistema de Logística Reversa no contexto do segmento de resíduos sólidos pós-consumo de produtos eletroeletrônicos no Brasil.
Desenho/Metodologia/Abordagem: Pesquisa exploratória qualitativa, operacionalizada por meio de entrevistas individuais com abordagem semiestruturada, com quatorze respondentes, além de pesquisa documental.
Conclusões: O custo para operação desta estrutura também deve ser tratado como ponto crítico para o sucesso deste sistema, principalmente pela falta de uma visão voltada para a economia circular de EEE – Equipamentos Elétricos e Eletrônicos.
Implicações para teoria e prática: O estudo abordou algumas lacunas de pesquisa em relação à logística reversa pós-consumo. Em relação às implicações práticas, destaca-se o desenvolvimento de um framework para implementação do RLS, e a evidência desta pesquisa diz respeito à falta de alinhamento, por parte dos fabricantes e importadores, nas questões relacionadas à logística reversa de EEE.
Originalidade/Valor: Ênfase em uma visão avançada sobre como tratar os resíduos sólidos do segmento de eletroeletrônicos (EEE) no Brasil.

Palavras-chave: Gestão de operações; Lógica reversa; Resíduos de equipamentos eletrônicos pós-consumo; Redução de resíduos

1 INTRODUCTION

Regulations aimed at improving the return on products in general, reducing their impact on the environment and other aspects, justify the growing interest in the opportunities and risks of post-consumption reverse distribution channels (Işildar, Rene, Hullebusch, & Lens, 2018; Dias, Bernardes, & Huda, 2019). Electronic waste refers to all items of EEE – Electrical and Electronic Equipment and its parts that have been disposed of as waste or garbage without the intention of reuse. Electronic waste is also known as WEEE – Waste Electrical and Electronic Equipment or electronic scrap (Baldé, Forti, Gray, Kuehr, & Stegmann, 2017; Yoshida & Yoshida, 2019).

Nowadays, the task of developing reverse logistics and closed-loop supply chains in both developed and developing industries is a necessity in our organizations and society. The growing interest in reverse issues can be clearly seen in the large number of publications. The classic supply chain approach is not responsible for end-of-life products. Therefore, reverse logistics, when inserted in this context, seeks to cover

products at their end of life, in a more ecological and sustainable manner (Govindan & Soleimani, 2017; Xin et al., 2021).

As defined in the legislation itself, reverse logistics is an instrument of economic and social development characterized by a group of actions, procedures and means designed to enable the collection and return of solid waste to the business sector, for its reuse, whether in its cycle or in other production cycles, or for another destination, provided that it is environmentally adequate (Slomski, Slomski, Valim, & Vasconcelos, 2018: Xin et al., 2021).

In Brazil, the National Solid Waste Policy, established through Federal Law 12305/2010 (Lei n. 12.305, 2010), requires that manufacturers, importers, distributors and traders of electronic products and their components, structure and implement an RLS – Reverse Logistic System, in order to operationalize the return of EOL – End-of-Life products by consumers in Brazil (https://www.gov.br/mma/pt-br, retrieved January 02, 2020).

Therefore, the guiding question of this research is: What is the best way of structuring the operation of the RLS – Reverse Logistics System in the context of post-consumer solid waste of products, more specifically from the EEE – Electrical Equipment and Electronics, from the domestic electronics segment in Brazil? Accordingly, this research had the general objective of presenting a framework aimed at structuring the operation of the RLS – Reverse Logistics System in the context of post-consumer solid waste from products in the household electrical and electronics segment in Brazil. In addition, the following specific objectives were established: (i) identify the political-legal and sectorial motivations for structuring the RLS in the context under study; (ii) verify the role to be played by the main actors in the chain; (iii) raise the difficulties inherent in the implementation of the reverse logistics structure; and (iv) propose directions in order to enhance the implementation of the proposed framework.

For this purpose, a qualitative research of an exploratory nature was implemented, based on the application of a Basic Script of Questions with the main

representatives of the actors involved in the context of the SLR – Reverse Logistics System under study and with specialists in the area. Also, documentary research was used in representative institutions of the sector. It is important to point out that two focus groups were held due to the participants' scheduling conflicts.

Initially, the article presents a theoretical review about the definition of reverse logistics and reverse logistics post-consumption electric and electronic products (EEE). Next, the research method that guided the collection and analysis of information is presented. The following section presents the results of the study, with content analysis of the interviews carried out. Finally, there are the conclusions, emphasizing the implications of the study, in addition to its limitations and suggestions for future research.

2 THEORY

2.1. Definition and relevance of reverse logistics

Reverse logistics is defined as the process of planning, implementing and controlling the efficient and economical flow of raw materials, work in process, finished goods and related information from the point of consumption to the point of origin, with the objective of recovering value or providing proper disposal (Soleimani & Kannan, 2015; Prakash & Barua, 2016). Otherwise, Guide and Van Wassenhove (2009) comment that reverse logistics concerns the design, control and operation of a system to maximize value creation throughout the entire product life cycle with dynamic recovery values of different types and return volumes over time, adding value to products (Vieira, Guarnieiri, Silva, & Alfinito, 2020; Javed, Firdousi, Murad, Jiatong, & Abrar, 2021).

The reverse flow of products and materials has been studied since the 70s and started to be explored more intensely in the 80s and 90s, with the emergence of different concepts of "reverse logistics" (Valle, Menezes, Reis, & Rebelo, 2009). To meet the growing pressure to incorporate environmental and sustainability factors due to legislation and growing public awareness, companies are rethinking their supply chain

network strategy to take control of the reverse flow of products (Mathiyazhagan, Rajak, Paniraghi, Agarwal, & Manani, 2020).

However, the interest in reverse logistics varies depending on the product characteristics, the industrial sector, the company's position in the supply chain, existing legislation, customer requirements, risks to the company's image, and the attitude of corporate responsibility. Thus, the theme acquires increasing relevance in the implementation of business programs with different strategic objectives, considering that managers have better knowledge about the values involved with the return of products and a better perception of the possibility of turning a problem into an opportunity, either as a source new profit centers, either as a source of cost reduction or as a safeguard for business reputation (Leite, 2017). Therefore, the establishment of the RLS – Reverse Logistics System as its main virtue to strengthen the recycling market in Brazil, which can bring benefits that go beyond the expected environmental impact (Agência Brasileira de Desenvolvimento Industrial [ABDI], 2013).

2.2. Reverse logistics of post-consumption electronic products

The post-consumption reverse distribution channels are constituted by the reverse flow of a portion of products and constituent materials originated in the disposal, when its original utility ends, and which somehow returns to the production cycle. Three subsystems are distinguished: reverse channels for reuse, remanufacturing and recycling (Leite, 2017). The return of the product to the production cycle, in the form of input or raw material, adds economic and environmental value (Slomski et al., 2018).

Reverse logistics is an essential part of sustainable management of supply chain operations as it helps to reduce the amount of waste sent to landfills, extracting maximum value from products in EOL or post-consumer use. It is indicated in the case of electronic return, as there is a constant increase in the number of electronic wastes, due to the rapid growth of technology. The growth of reverse logistics chain management is not only the result of legal pressure, but also driven by social

initiatives from non-governmental organizations and consumers around the world (Chagnes, Cote, Ekberg, Nilsson, & Retegan, 2016; Mathiyazhagan et al., 2020).

It should also be noted that each consumer electronics product has a different shelf-life profile, meaning that each category of e-waste has different amounts of waste, economic values and potential health and environmental impacts if improperly recycled. Consequently, the logistical collection processes and recycling technology differ for each product category, as do consumer attitudes towards disposing of EEE also vary (Baldé et al., 2017; Işildar et al., 2018).

WEEE is composed of different materials (plastics, glass, electronic components), more than twenty types of heavy metals and other materials. Their separation, processing and recycling have a certain complexity, cost and impact greater than those more well-known examples of waste (ABDI, 2013; Nilsson, 2019; Dias, Bernardes, & Huda, 2019).

2.3. Relationship between reverse logistics and sustainability

Products discarded in the environment bring what is called pollution, a fact that generates costs for society in terms of expenses for final disposal and, for companies, as a cost of negative repercussions on their corporate image (Leite, 2017; Julianelli, Caiado, Scavarda, & Cruz, 2020). In a deeper analysis, it reveals a cost that goes beyond these two dimensions, that is, the ecological costs, generated by the impact of the products on the environment.

Some authors even reflect on the ecological revaluation of post-consumer goods, such as the elimination or mitigation of this sum of costs generated by impacts on the environment, which are caused by the harmful action of products that are dangerous to human life or by the excesses of these goods. In this way, it is possible to add ecological value to the end-of-life good through reverse logistics, in order to recover the value corresponding to these costs, a value that is not always tangible (Bakhiyi, Gravel, Ceballos, Flynn, & Zayed, 2018; Mathiyazhagan et al., 2020).

In the sustainability context, when he says that the concern with ecology and the environment has grown along with the population and industrialization, which will provide new opportunities for the logistics area. Therefore, it is essential to establish the analysis of the PLC – Product Life Cycle, taking into account its environmental impacts. That can help the company to rethink product designs and seek alternative raw materials that are easier to be recycled or reused, for instance. The revaluation of products after the end of their useful life has been important both for environmental aspects, because it is concerned with the final destination of waste, as well as for social and economic aspects, by allowing many people and companies to enter this field of activity, as collectors, recycling plants, second-hand product market, among others, giving rise to the reverse logistics process (Dias et al., 2019).

Traditionally, reverse logistics was designed within the lifecycle of the product development process and was adopted as an environmental approach, as its processes are likely to be triggered when something goes wrong, for example, the product has an after-sales failure; the customer has changed his mind about purchasing the product; excess stock that has not been sold; an order sent incorrectly and when the product becomes damaged during use (Campos, Paula, Pagani, & Guarnieri, 2017).

3 RESEARCH METHOD

To achieve the objectives of the study, participatory research was developed through a qualitative exploratory approach (King, Horrocks, & Brooks, 2019; Malhotra, 2020). For data collection, the technique of in-depth individual interviews was used, with semi-structured approach, through the application of a Basic Questions Guide, which was used to conduct the interviews to be carried out. Individual in-depth interviews were recorded electronically and transcribed (Ribeiro & Milan, 2004; King et al., 2019), using a software for processing qualitative data, the NVivo software.

In addition to in-depth individual interviews, documentary research was used (Malhotra, 2020), which allowed the collection of relevant information. Thus, public

documents were accessed, such as laws, standards and reports made available by institutions representing the sector, such as, for example, ABDI – Brazilian Agency for Industrial Development (ABDI, 2013), ABREE – Brazilian Association for Recycling of Electrical and Electronics and Household Appliances (www.abree.org.br/, retrieved June 16, 2021) and ABINEE – Brazilian Association of the Electric and Electronic Industry (www.abinee.org.br, retrieved June 15, 2021).

In the content analysis implemented (Bardin, 2016), the analysis categories were defined *a priori*, that is, the analysis categories are directly related to the specific objectives: political-legal and sectorial motivations for the structuring of the RLS, the role to be played by the main actors in the chain, intrinsic difficulties in the implementation of the reverse logistics structure in the context under study and directions in order to enhance the implementation of the proposed framework.

To validate the collected contents and, mainly, the proposed framework, the data triangulation procedure was adopted (Myers, 2019). Data triangulation was operationalized, at the end of the data collection process, by conducting two focus groups (Malhotra, 2020), in a remote (virtual) environment, also by means Microsoft Teams® (Jackson & Bazeley, 2019), as in the case of in-depth individual interviews.

4 RESULTS AND DISCUSSION

4.1. Profile of the participants

The starting point for the questionnaire application was the two Management Entities Green Eletron and ABREE, which by Decree nº 10240/20, are responsible for structuring, implementing and operationalizing the reverse logistics system for electronic waste. From its membership base, some manufacturers with presence in the world market were also selected. All the interviewees, on the part of the manufacturers, are their representatives before the MEs – Management Entities; moreover, they had an active participation in the construction of the Sector Agreement, which was the basis for Decree No. 10240/20.

Therefore, fourteen individual in-depth interviews were carried out, according to the availability of the interviewees, from November 2020 to March 2021, with an average duration of 1 hour and 10 minutes per interview, and the contents, in audio and video, were recorded for later analysis and interpretation of the data, with the due consent of the interviewees, formalized through the prior submission of the TCLE – Term of Free and Informed Consent. It should be noted that, in order to preserve the identity of the interviewees, a coding was used (Interviewees A to N). The profile of the fourteen interviewees is presented in Table 1, highlighting that the company representatives have already experienced reverse logistics initiatives.

Table 1– Participants' profile and duration of the interviews

Continue...

Interviewers	Age	Line of Work	Company Time (years)	Position	Segment
A	36	Manufactures Association	6	Sustainability Manager	Reverse Logistics of EEE
B	45	Non-governmental Organizations	10	Director	Solid Waste
C	43	Research, Development and Analysis Institute	3	Environmental Manager	EEE Waste
D	35	Logistics and Reverse Manufacturing	10	Strategic Project Manager in Circular Economy	EEE Waste
E	45	Logistics and Reverse Manufacturing	18	Chief Executive Officer	EEE Waste
F	31	Environmental Public Agency	7	Environmental Engineer	Solid Waste
G	40	Manufactures Association	4	Executive Manager	Reverse Logistics of EEE
H	53	Manufacturing	4	Corporate After-Sales Manager	Electronics in General
I	49	Logistics and Reverse Manufacturing	5	Vice President of Business Development	EEE Waste

Table 1– Participants' profile and duration of the interviews

Conclusion

Interviewers	Age	Line of Work	Company Time (years)	Position	Segment
J	53	Institute of Social and Environmental Communication	20	Chief Executive Officer	Solid Waste
K	42	Social and Environmental Research Institute	1	Chairman	Urban Public Policies
L	50	Manufacturing	20	Sustainability Coordinator	Electronics in General
M	27	Manufacturing	5	Environmental Engineer	Electronics in General
N	39	Manufacturing	9	Environmental Engineer	Electronics in General

Source: Research data

4.2. Political, legal and sectorial motivations for structuring the RLS

Among the most commented empirical evidence and that prevailed among the political-legal and sectorial motivations identified, the PNRS – Política Nacional de Resíduos Sólidos (National Policy on Solid Waste) emerged, cited by more than half of the interviewees (Interviewees B, C, D, F, G, I, K, L and N). According to Interviewees G, I, K and L, the political-legal motivation is a legal framework explained through the PNRS, which is the guiding policy for any urban solid waste in the country. It brings guidelines for both urban solid waste that is held by city halls and municipalities, in municipal management, which handles the management of urban waste, as well as the responsibilities that affect the private sector, in line with the notes by Mathiyazhagan et al. (2020) who point to the growing pressure from legislation to incorporate environmental factors in waste treatment.

The second most cited reason for structuring the RLS is the influence of existing laws in other countries, that is, international legislation, as it was possible to observe

from the statements of Interviewees A, B, H and N, when they said that Brazil follows the trail of more developed countries. Abroad, mainly in Europe, there are already well-established systems, as is also the case in Japan. Brazil could not remain on the sidelines of this movement, whether due to pressure from society, or pressure from entities, in order to have an effective RLS. The government needed to send a message to society, to the market, even if some adjustments will have to be made. In relation to this issue, many countries are advancing, structuring and operating a very rigorous system. Something had to be done about it (Interviewee H).

The third motivation identified concerns issues related to the environment, especially with regard to the inappropriate disposal of materials and dumps. Many interviewees reported this as an important motivation, as stated in the speeches of Respondents B and N, who brought the information that when you look at the issues of the municipalities, and go back to the old dumps, there are many municipalities that still have this type of destination (dumps).

In addition, electronic products are increasingly presenting a shorter lifespan, as pointed out by Slomski et al. (2018). In the old days, consumers bought a television and stayed with it for twenty years, they bought a video cassette and used it for many years. As technology changes are more frequent, the life cycle of products is shorter. The waste generated by this type of product is complex (Interviewee N).

Another motivation for structuring the RLS concerns the circular economy, as mentioned above by Interviewee C, who highlighted the case of HP in Brazil. In addition, Interviewee D pointed out that it is necessary to observe that the circular economy shows that it is not just a matter of remedying a problem, but it is a matter of maintaining resources, in terms of their rational use, and to keep stocks of raw materials and various materials available, as there may be shortages at any time and companies must be prepared. In this sense, Ding, Wang, e Chan (2023) point out that reverse logistics operations are interrelated with the product life cycle.

Among the least cited motivations, the political scenario emerged, that is, the differences between entities and even the political situation in the country (Table 2):

Table 2 – Political-legal and sectorial motivations for structuring the RLS

Identified Motivations	Interviewees
National Solid Waste Policy	B, C, D, F, G, I, K, L and N
International Laws	A, B, H, J and N
Environment	B, E, D and N
National Scenario of RLS Structuring in Other Segments	C and L
Circular Economy	C and D
Political Scenario	M

Source: Research data

4.3. Role to be played by the main actors in the chain

The contributions of the interviewees were relevant. the first actor identified is the public power, in its federal sphere. We will only call it the **federal government**, which in turn plays a fundamental role in the RLS – Reverse Logistics System, as it has the responsibility to control the implementation of the Decree No. 10240/20, as a regulatory agent, mainly inspecting manufacturers and importers, by means its control bodies (Interviewees D, H, K and M).

The next actor identified are the holders of public services for urban cleaning and solid waste management, that is, the municipal governments, which currently already carry out the collection of various WEEE. When it comes to the role of municipal governments in this process, there are different views, whether from the point of view of responsibility or convenience (since they already carry out selective waste collection, for example) or from the point of view of effectiveness (in terms of collection of materials) and from a financial perspective.

Interviewees A, F and G highlighted that one of the main responsibilities of **manufacturers and importers** should be the environmentally correct disposal of 100% of the WEEE received. However, it was observed that one of the biggest concerns among

the interviewees is in non-formal environmental education, which deals with Decree nº 10240/20. Consumers need to be communicated and educated about this, and the responsibility to inform lies with the industry, the issue of awareness, where society can find points for disposal, which is important for achieving the goals (Interviewees B, E, G and L). These results are in line with the notes by Carvalho and Leite (2016). The authors point out that in Brazil, initiatives to solve the electronic waste problem are still incipient.

Regarding the **MEs – Management Entities**, for Interviewee G, they have the role of managing the reverse logistics process from the beginning to the end of the chain. Such entities must observe from the collection of EEE to its final destination, which must be an environmentally correct destination. More than that, the MEs are responsible for the dissemination strategy of this system (RLS), aiming to sensitize consumers to join this cause (Interviewees E, F and M), together with the other actors.

Within the list of the main actors in the context of structuring an SRL, we have the **carriers,** which are synonymous with logistics, material handling, cargo consolidation for transport and reverse logistics. The transport of WEEE, at various points in this chain, interacting with various actors, highlights its position, mainly due to the high cost to which its operation is linked (Interviewees A, D, E and I).

Another actor present in an RLS are the **collectors' cooperatives and associations**. Although they were mentioned a few times, Interviewee C reinforced that an important actor is the local associations of waste pickers, since by enabling them to carry out the activity, it is possible to increase their capillarity of collection, separation and destination of WEEE, since the delivery points voluntary will likely be insufficient, given the demand generated by the population. However, the goals stipulated in the legislation must be met and these cooperatives and associations of collectors have a high capacity to collect WEEE. In this way, the MEs need to create an effective link with the cooperatives or associations of collectors.

Finally, but as already mentioned, one of the actors most cited by respondents was the **consumer**. It is responsible for initiating the reverse logistics of an EEE. He has

the obligation to return used equipment (products) to the appropriate delivery points established in the system (RLS) (Interviewee A). For Interviewees B, F, G, L, and M, the consumer has an essential role in delivering the waste, and if they do not have this engagement, the process will not even begin. As the first actor in this chain, he has the obligation to segregate, store, and remove data or private information stored in EEEs and dispose of these products and/or their waste at the indicated collection points. Perhaps this is one of the biggest challenges of an RLS.

Table 3 shows the identified actors and the roles to be played in the chain, or more specifically, in the RLS to be operationalized.

Table 3– Actors identified and roles to be performed in the context of the RLS

Continue...

Identified Actors	Roles to be Performed
Federal Government	Control the implementation of Decree Nº 10.240/20, as a regulatory agent; Create public policies to facilitate the implementation of the RLS; and Inform society and effectively participate in formal environmental education for consumers.
City Halls	Participate in campaigns in partnership with the Management Entities, aiming at the collection of EEE, mainly with regard to the communication of this system (RLS); and Enable medium and long-term agreements with the Managing Entities, providing a structure (ecopoints, collections, etc.), in addition to inserting an effective EEE screening system into the current flow of selective collection.
Manufacturers and Importers	Participate as associates in the collective RLS, aiming at its sustainability and compliance with the goals established for the sector; Communicate to its consumers about the RLS, indicating the correct destination flow for their products, in the post-consumption period; Develop products that aim to facilitate your repair, upgrade or reverse manufacturing process; and Incorporate recycled raw materials into its production cycle and those of its suppliers.
Distributors and Merchants	Provide physical space for installing EEE reception points, as well as forwarding them to the RLS flow; Inform your business partners and consumers about the existing EEE RLS; and Make reverse logistics feasible, through the consolidation of EEE, aiming to reduce costs with their transport.
Managing Entities	Search for new members, working in partnership with the government, in the creation of public policies to make the RLS viable; Structuring, implementing and managing the RLS operation; Define, together with its members, the non-formal communication strategies of the RLS to those involved; and Develop partnerships with other actors, especially city halls, reverse manufacturing companies and waste picker cooperatives.

Table 3– Actors identified and roles to be performed in the context of the RLS

Conclusion

Identified Actors	Roles to be Performed
Reverse Manufacturing	Develop processes for better use of WEEE, aiming at circular economy and waste reduction; Increase your efficiency in EEE disassembly operations; and Ensure the control of the processing flow and destination of WEEE, aiming to report the correct values to the Managing Entities, corresponding to the RLS (by weight).
Carriers	Carry out the correct transport of EEE and WEEE; and Participate in the development of strategies and actions, aimed at reducing costs with the operationalization of transporting these materials, within the RLS.
Recyclers	Transforming WEEE into recycled raw materials; Increase its scope of action, covering all types of materials, aiming to reduce costs with the export of WEEE; and Develop effective processes, as well as their structure in terms of equipment, for the recycling of WEEE.
Collectors Cooperatives	Structure its activities within the minimum operating requirements, for its effective participation in the RLS; and Seek partnerships, either with industry or commerce, but mainly with Managing Entities, aiming at the environmentally correct disposal of collected EEE.
Consumers	Return the equipment (products) used at the appropriate delivery points, established in the system (RLS); Segregate, store, remove data or private information stored in EEE and dispose of these products and/or their waste at the indicated collection points; and Be aware of your role within this context, especially not discarding EEE in the common garbage.

Source: Research data

4.4. Intrinsic difficulties in implementing an RLS

In the current scenario, it is possible to identify the intrinsic difficulties in the implementation, and even in the performance of an RLS, especially when considering the history verified in the city of São Paulo (SP), Brazil, as well as the experience and opinion of people who are ahead of organizations, institutes, associations, and NGOs – Non-governmental Organizations involved in this context. Accordingly, the difficulties raised were divided into three groups in order to facilitate their understanding. The first group of difficulties is related to structural, operational, and behavioral issues. The second group concerns financial issues, while the third group comprises political aspects.

The first of the structural difficulties are related to the goal of installing 5,000 points of delivery (collection) of waste in the country by 2025, covering at least the 400

largest Brazilian municipalities, with annual and growing goals, deadlines and concrete actions. In the fifth year of implementation, it is expected that the weight of waste or products collected will reach 17% (Interviewee D).

The next structural difficulty identified is related to the lack of structured recyclers and the complexity of WEEE. Interviewee A even commented that the total cost of the operation will be higher, especially if there is no recycler in the region, being necessary to carry out the collection and direct it to other states for the final destination.

The third structural difficulty, although of an operational nature, concerns the work of collectors' cooperatives, technical assistance not having the revaluation of the product, which is fundamental for sustainability (Dias et al., 2019), and the cannibalization of products. In this perspective, Interviewee D commented that it is necessary to think about the informal sector, how to include cooperatives and waste pickers in the reverse logistics chain (or system). In addition, many products end up being discarded through technical assistance, who try to fix them and when it is not possible, they need to discard them, and the cannibalization of these products will not be accounted for within the RLS (Interviewee M).

Structural difficulties of a behavioral nature concern the lack of engagement of consumers, one of the main actors of the RLS, which is also directly connected to the next difficulty identified, that is, the forms of communication of the RLS. Interviewee I reinforced his concern about how to reach consumers, sensitizing them to dispose of their EEE, not only middle and upper-class consumers, but also people from the poorest classes of the population, that is, how to reach a "favela" and educate people, keeping in mind that that will take a lot of effort. Therefore, it is necessary for the consumer to be educated and engaged and, unfortunately, this is still not perceived in the country (Interviewee C).

Financial difficulties pose a threat to this operation, that is, the high cost of an RLS can compromise the entire process. Interviewee C noted that MEs need to receive associates, and that companies need to understand that they have an obligation to do

reverse logistics, as MEs need to put delivery points into operation, hire local labor, and homologate companies. Besides, the cost of the operation will obviously increase a lot in the coming years and for it to be distributed in a fair way, there would need to be this inspection by all actors, especially importers (Interviewee A).

The third group refers to political difficulties, which can affect RLS implementation and performance. The first concerns the lack of government incentives, through tax reduction/exemption, as a way of maintaining the financial sustainability of the system. Interviewee M commented that the government should take part on this responsibility, especially when working on something related to environmental sustainability and environmental factors (Mattos & Santos, 2022), as it is known that the industry pays high charges and that, in the end, it will impact consumers.

The second political difficulty identified, is the lack of quality education in schools, which is the responsibility of the government (Interviewee M). Interviewees I and K highlighted the importance of investments in education, with the aim of creating awareness in civil society regarding innovation, labor qualification and working on the repair or reuse of products and/or materials, that is, not direct disposal.

The next political difficulty is related to the participation of municipalities in the RLS. For Interviewee F, this is still a field that needs to be further explored. This synergy between municipal collection and reverse logistics deserves further reflection, as municipal governments could take the EEE to a warehouse or a consolidation center maintained by the MEs, for example. From this point on, the MEs themselves would be responsible for the environmentally appropriate sorting and disposal of this waste. Such a partnership with city halls would be a way to reduce costs, since delivery points have a high cost of structuring and management, even more so due to the capillarity of city halls (Interviewee E).

Two other aspects that have been highlighted as difficulties in the implementation and performance of an RLS are the lack of a greater participation of the retail sector and a vision aimed at the circular economy (Ding, Wang, & Chan, 2023). For Interviewees M

and N, the retail sector should be playing a more active role, because their participation is fundamental. It is necessary that they provide product collection points and even develop an effective communication about the RLS, because consumers have a direct contact at the time of purchase and collection points should be in visible places and easy access.

Regarding the circular economy, Interviewee D highlighted the need to rethink the design of products so that they can be more easily decomposed and/or reincorporated in productive processes. This buying and selling model is no longer a model that fits within the circular economy. It is necessary to think more about products servitization, finally, another barrier to be broken.

It was possible to identify a new threat to the domestic EEA RLS in Brazil, the Covid-19 pandemic, may cause the postponement of the environmentally correct destination targets of REEEs, defined by Decree 10240/20. The pandemic has disrupted some initiatives. There was even a meeting, a workshop, with several municipalities participating, in which MEs tackled the issue of municipalities remuneration: to what extent the municipality needs to be remunerated and to what extent it would not need to be remunerated (Interviewee F). Table 4 presents the main difficulties raised for the implementation and performance of an RLS.

Table 4– Difficulties identified for the implementation of an RLS

Continue...

Difficulty Groups	Difficulties Identified	Interviewees
Structural	Lack of consumer engagement.	A, D, E, F, H, I, J, K and N
	RLS forms of communication.	B, C, E, F, H and K
	Performance of collectors' cooperatives, technical assistance and the cannibalization of products.	C, D, L, M and N
	Installation of 5,000 delivery points (receipt or collection) of WEEE.	B, D, G, J and N
	Lack of structured recyclers and the complexity of WEEE.	A, C and K

Table 4– Difficulties identified for the implementation of an RLS

Conclusion

Difficulty Groups	Difficulties Identified	Interviewees
Financial	High cost of an RLS.	A, C, D, E and J
Policies	Lack of education of the Brazilian population in relation to social and environmental issues.	I, J, K, L and M
	Lack of government incentives with tax reduction/exemption.	H, J, K and M
	Vision aimed at the circular economy.	D, K, L and M
	Covid-19 pandemic and its impacts on society and the economy.	C, F, J and K
	Participation of city halls in an RLS.	E, F and J
	Greater participation of the retail sector.	H, M and N

Source: Research data

4.5. Framework and guidelines proposed in the implementation of an RLS

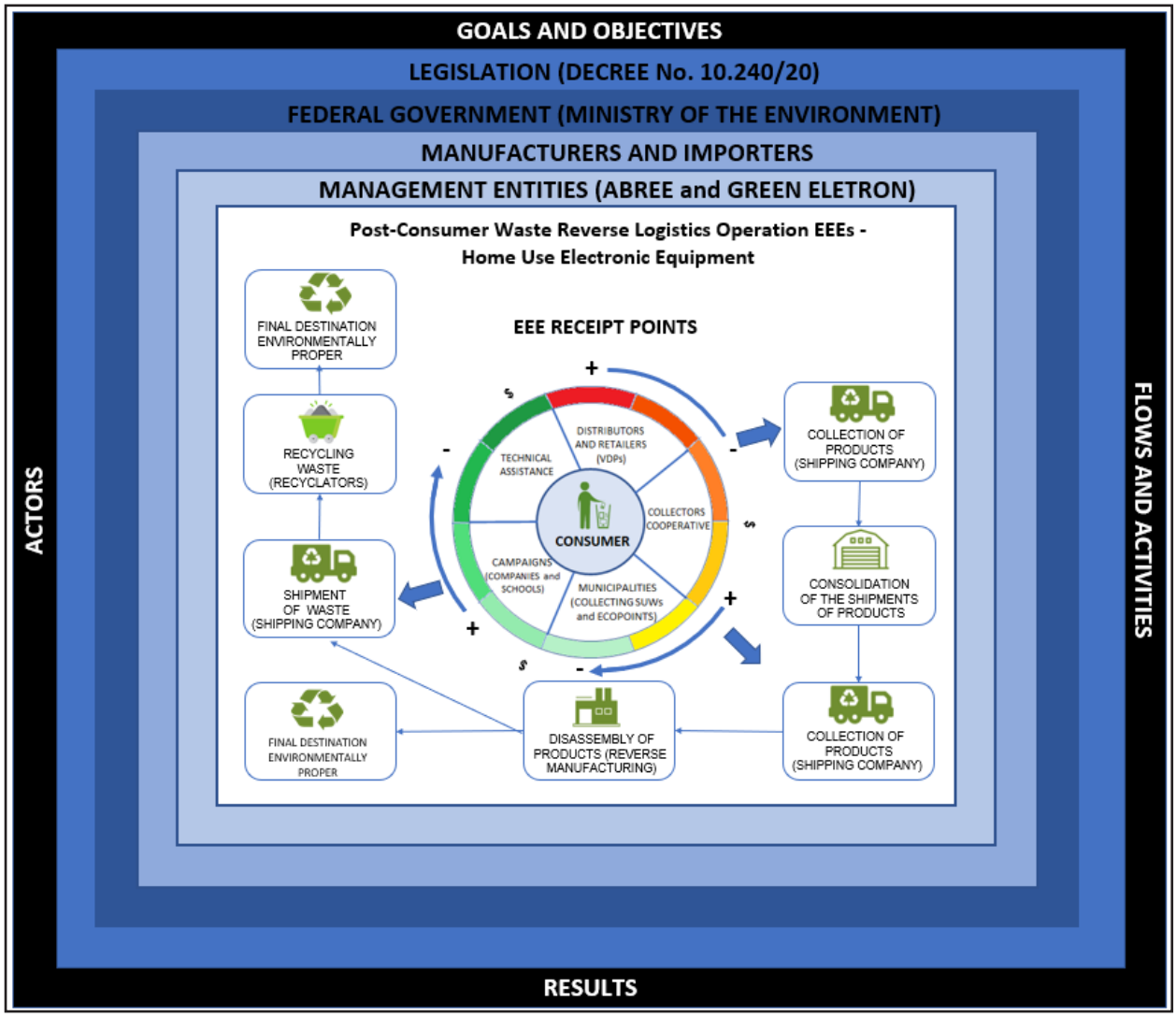
Aiming to achieve the general objective of the research, which was to present a framework aimed at structuring the operation of the RLS – Reverse Logistics System in the context of solid waste after consumption of products of the household electro-electronic segment in Brazil, follows Figure 1.

Its construction process observed the main contributions made by the interviewees, primarily having considered the role of the main actors of this RLS, as well as the major difficulties identified, which, in turn, could impact its operationalization and sustainability. Another fact that was taken as a premise for the construction of this framework refers to the fulfillment of Decree 10240/20, that is, amendments in the law for the operationalization of this RLS are not being considered.

The analysis and understanding of this framework should initially be performed by the main actor of this chain, that is, the **consumer**. Thus, it is possible to emphasize the need to develop the most diverse forms of receiving EEEs, so that there is an increasing volume of REEEs being recycled, from their capture (collection) through **distributors and retail**. Besides the consumers, other actors must be involved: the

VDPs – Voluntary Delivery Points, the waste pickers' cooperatives, which represent a large portion of this collected volume and need to be inserted in this context, and the municipalities with their capillarity in the collection of the USWs – Urban Solid Waste, whereas ecopoints make it possible to receive medium and large EEEs. Another form of collection of EEEs is in the campaigns carried out in companies and schools. Finally, the manufacturers and importers' networks of technical assistance are also relevant actors, due to their capillarity, but mainly due to the low cost of this operation, compared to the other collection points.

Figure 1– Proposed framework for structuring the RLS operation



Source: Research data

Notes. VDPs – Voluntary Delivery Points and SUWs – Solid Urban Waste.

When it comes to consumers, their position at the heart of this framework has outstanding representativeness. As it was possible to observe during the development of the research, consumers have always been referred to as key elements for the start of this flow and the critical path to reach the goals stipulated by Decree 10240/20.

Following the logic that EEEs will be delivered by consumers at any of the points mentioned, it is possible to observe that the transport of these EEEs or REEEs can start at different times and that it is directly related to the cost that this process can incur, since the greater the number of movements, the greater will be its overall logistical cost. The blue arrows in Figure 5, directed to transport activities, represent the various moments in which these EEEs or REEEs can be initially transported, and the closer to their final destination point, the less impact it will have on costs for RLS as a whole.

This RLS will become more financially efficient as the steps to be taken by REEEs to their final destination are reduced. From this analysis, it can be inferred that the better trained the actors responsible for the points of receipt of the EEEs, the greater are the opportunities for cost reduction, since it will be possible to eliminate or reduce the later stages, avoiding their movement among the following actors in this chain. Moreover, the same happens in reverse manufacturing companies, because in some cases they do not only separate or disassemble the EEEs, but also recycle some waste, reinserting it into their production chain. Another critical success factor for this RLS is the distances to be traveled between each of these actors. In this way, their engagement and development should be prioritized, aiming to increase their capillarity, reducing transport costs.

As it is possible to observe in the framework, all the RLS structure operationalization of the solid waste after consumption of products of the EEEs segment of domestic use in Brazil is under the responsibility of the ME – Management Entities. For the sustainability of this process, there are manufacturers and importers, as actors who should preferably associate with existing MEs, conducting internal audits, aiming to ensure the reliability of this RLS. Finally, there is the Federal Government, represented

more objectively in the figure of the MOTE – Ministry of the Environment, which should oversee this whole system, evaluating the data sent by the MEs, in addition to promoting public policies enabling the operation of this RLS, under Decree 10240/20.

Then, in Table 5, some proposed directions are presented, aiming to enhance the implementation of this framework, which were the result of the interviews conducted, as well as the international cases researched and the data collection as a whole, from the literature review. It should be noted that the perceptions of the interviewees during the two focus groups were also considered.

Table 5– Proposed directions to enhance the implementation of the framework

Continue...

Proposed Directions	Description of Directions
Use of Technologies	The first great ally of this RLS is the use of technologies, which in addition to reducing costs, may create a data system that will allow to identify and map the WEEE flow, generating reliability in the collected data. These technologies range from the use of smart collectors or VDPs, which through sensors can trigger a collection action, to the reading of a QR Code printed on EEE, informing the nearest disposal points or how to proceed with their disposal in an environmentally correct manner.
Incentives to Consumers	Consumers should be encouraged to dispose of their EEE, not only motivated by environmental and sustainability issues, but also by actions that can provide incentives to this movement. In this way, manufacturers, importers and MEs need to establish programs of benefits to customers and/or consumers, when exchanging their old products for new products of the same brand. Retail should use this RLS to increase the flow of customers and/or consumers in their stores, aiming to sell new products, at the time they are discarding their EEEs in VDPs. The government should stimulate the economy through energy efficiency programs, granting discounts for new products, mainly for the classes with low purchasing power.
Communication Plan	National consumer communication campaigns should be widely publicized, with strong appeal, either at the initiative of the government (Federal, State and Municipal), or at the initiative of industry and importers, through partnerships with their MEs, so that they can clarify and encourage the correct disposal of EEEs, showing that there is a way to do the right thing. It should also be evaluated, after the completion of this first five-year cycle, the application of penalties to consumers who fail to comply with the correct disposal of their EEEs.

Table 5– Proposed directions to enhance the implementation of the framework

Conclusion

Proposed Directions	Description of Directions
Participation of Importers and the Use of Recyclable Raw Materials	Regarding the RLS financial sustainability issues, it is necessary that the Federal Government, through the MOTE – Ministry of the Environment and the Ministry of Economy, immediately implants EEE importation control, aiming to ensure the isonomy of this system, in which importers must prove their participation in some RLS, so that they can receive their import licenses. In addition, another important step would be the government establishing the use of recycled raw materials in the manufacture of new products, setting gradual targets, with the intention of fostering the circular economy.
City halls and Schools	The MEs and municipal municipalities should continue strengthening their partnership and creating operational strategies, either through campaigns or through the screening of EEEs from the collection of USWs. It would also be appropriate to involve society and even create a new Generation through the development of programs aimed at schools and actions such as recreational competitions, which are an excellent channel for receiving EEEs. Finally, another initiative aimed at boosting this flow could be the establishment of specific days for the collection of these EEEs, so that the selective collection of recycled materials could take place, as already carried out in some locations.
Projects to Encourage Recycling	Waste picker cooperatives, which need to be approved by MEs. In this context, two bills are awaiting approval of the Senate: Bill 7535 from 2017, which has incentives to promote the recycling industry, creating a fund to support actions aimed at recycling and an investment fund for recycling projects, and PL 3592 from 2019, which grants tax credit to legal entities that acquire scrap or other waste for the manufacture of new products.

Source: Research data

5 CONCLUSIONS

The main contribution of this article is the development of the framework for the implementation of the RLS, based on the literature and the evidence evidenced in the collection of information. One of the main findings of the research, which strengthens the managerial implications of this research concerns the lack of alignment, specifically by manufacturers and importers, on issues related to the issues of reverse logistics of EEE. For example, the marketing area of these organizations should be aligned

with these issues, in order to generate value for the brand and not just consider this an RLS that only impacts costs for organizations, being able to use it as a context for projects involving customers and/or consumers and society in actions related to social and environmental aspects related to their brands.

Along with the legal area, the Legislative Power, and the Government, it would also be opportune to create law projects that would encourage and increase consumption, stimulating the country's economy and, at the same time, generating social inclusion, based on the occupation of many people or recycling cooperatives involved in the collection and recycling of materials or waste, with strong support for achieving the RLS goals.

In this context, it is important to highlight that the investment or even the reduction of taxes for waste picker associations could have a positive impact on this process, preventing the EEE from being directed to the same urban solid waste collection system, which does not it is adequate, either in environmental terms or in socioeconomic terms.

Another relevant split in the study, the sustainability of the EEE Reverse Logistics System (RLS), as well as the achievement of the goals defined in Decree Nº 10.240/20, directly depends on the cost that the operation will generate for manufacturers and importers.

Regarding the limitations of the research, it is worth commenting that large EEE were not considered for the construction of the proposed framework, since they do not have the same characteristics for the operationalization of the RLS. Another limitation of the research is in the business model that Decree Nº 10.240/20 deals with when it comes to household equipment, that is, EEE that is obtained or sold through the so-called B2B – Business to Business, was not considered in this study, from the negotiations of companies or manufacturers, which allocate their EEE to an existing reverse logistics.

As a possibility for future studies, it is suggested to develop a study and the proposal of a framework for the implementation of an RLS for large equipment, which, in turn, depend on a specific model for collection, causing a high transport cost compared to small EEE, in addition to the type of waste not being of great value for commercialization. In this same sense, a study to assess investments in ecodesign, carried out by companies, is guided as a strategy to encourage the circular economy, aiming at obtaining tax exemptions that can encourage this production model. Besides, it is suggested the development of a quantitative research to evaluate the consumer's knowledge about post-consumption reverse logistics as well as his behavior from this subject or context.

Finally, and not least, it would be interesting that other studies were dedicated to the investigation not only of how the actors involved in an RLS could monitor their performance, but also analyze the performance of RLS already implemented in the country and abroad, making a comparative on aspects such as economic-financial sustainability, operational efficiency and results generated for the most diverse audiences involved (for example, consumers and society in general and City Halls).

REFERENCES

Agência Brasileira de Desenvolvimento Industrial. (2013). *Logística reversa de equipamentos eletroeletrônicos: análise de viabilidade técnica e econômica*. Brasília: ABDI.

Bakhiyi, B., Gravel, S., Ceballos, D., Flynn, M. A., & Zayed, J. (2018). Has the question of ewaste opened a Pandora's box? An overview of unpredictable issues and challenges. *Journal Environment International*, *110*(1), 173-192. doi: https://doi.org/10.1016/j.envint.2017.10.021

Baldé, C. P., Forti, V., Gray, V., Kuehr, R., & Stegmann, P. (2017). *The Global E-waste Monitor 2017: Quantities, Flows and Resources*. Bonn, Geneva, Vienna: UNU, ITU, ISWA.

Bardin, L. (2016). *Análise de conteúdo* (Rev. e aum.). Lisboa: Edições 70.

Campos, E. A. R., Paula, I. C., Pagani, R. N., & Guarnieri, P. (2017). Reverse logistics for the end-of-life and end-of-use products in the pharmaceutical industry: a systematic literature review. *Supply Chain Management: An International Journal*, *22*(4), 375-392. doi: https://doi.org/10.1108/SCM-01-2017-0040

Carvalho, M. R. B., & Leite, J. C. (2016). Reverse logistics and selective waste collection: environmental education as an auxiliary tool on the process of recycling of domestic eletronic waste. *Business Management Dynamics*, *5*(12), 22-41.

Chagnes, A., Cote, G., Ekberg, C., Nilsson, M., & Retegan, T. (2016). *WEEE recycling: research, development, and policies*. Amsterdam: Elsevier.

Dias, P., Bernardes, A. M., & Huda, N. (2019). Ensuring best e-waste recycling practices in developed countries: an Australian example. *Journal of Cleaner Production*, *209*(1), 846-854. doi: https://doi.org/10.1016/j.jclepro.2018.10.306

Ding, L., Wang, T., & Chan, P. W. (2023). Forward and reverse logistics for circular economy in construction: a systematic literature review. *Journal of Cleaner Production*, *388*. doi: https://doi.org/10.1016/j.jclepro.2023.135981

Govindan, K., & Soleimani, H. (2017). A review of reverse logistics and closed-loop supply chains: a Journal of Cleaner Production focus. *Journal of Cleaner Production*, *142*(1), 371-384. doi: https://doi.org/10.1016/j.jclepro.2016.03.126

Guide, V. D. R., Jr., & Van wassenhove, L. N. (2009). The evolution of closed loop supply chain research. *Operations Research*, *57*(1), 10-18. doi: https://doi.org/10.1287/opre.1080.0628

Işildar, A., Rene, E. R., Hullebusch, E. D. V., & Lens, P. N. L. (2018). Electronic waste as a secondary source of critical metals: management and recovery technologies. *Resources, Conservation and Recycling*, *135*(1), 296-312. doi: https://doi.org/10.1016/j.resconrec.2017.07.031

Jackson, K., & Bazeley, P. (2019). *Qualitative data analysis with NVivo* (3rd ed.). Thousand Oaks: Sage Publications.

Javed, H., Firdousi, S. F., Murad, M., Jiatong, W., & Abrar, M. (2021). Exploring disposition decision for sustainable reverse logistics in the era of a circular economy: applying the triple bottom line approach in the manufacturing industry. *International Journal of Supply and Operations Management*, *8*(1), 53-68. doi: https://doi.org/10.22034/IJSOM.2021.1.5

Julianelli, V., Caiado, R. G. G., Scavarda, L. F., & Cruz, S. P. M. F. (2020). Interplay between reverse logistics and circular economy: critical success factors-based taxonomy and framework. *Resources, Conservation and Recycling*, *158*. doi: https://doi.org/10.1016/j.resconrec.2020.104784

King, N., Horrocks, C., & Brooks, J. (2019). *Interviews in qualitative research* (2nd ed.). Thousand Oaks: Sage Publications.

Leite, P. R. (2017). *Logística reversa: meio ambiente e competitividade* (3a ed.). São Paulo: Saraiva.

Lei n. 12.305, de 02 de agosto de 2010. Institui a Política Nacional de Resíduos Sólidos; altera a Lei no 9.605, de 12 de fevereiro de 1998; e dá outras providências. Retrieved from https://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/l12305.htm

Malhotra, N. K. (2020). *Marketing research: an applied orientation* (7th ed.). New York: Pearson.

Mathiyazhagan, K., Rajak, S., Paniraghi, S. S., Agarwal, V., & Manani, D. (2020). Reverse supply chain management in manufacturing industry: a systematic review. *International Journal of Productivity and Performance Management*, *70*(4), 859-892. doi: https://doi.org/10.1108/IJPPM-06-2019-0293

Mattos, P. G. B., & Santos, D. R. (2022). Reverse logistics: an analysis of business communication on discarding electrical bicycle batteries. *Journal of Management and Sustainability*, *12*(1), 158-168.

Myers, M. D. (2019). *Qualitative research in business and management* (3rd ed.). Thousand Oaks: Sage Publications.

Nilsson, F. R. (2019). A complexity perspective on logistics management: rethinking assumptions for the sustainability era. *The International Journal of Logistics Management*, *30*(3), 681-698. doi: https://doi.org/10.1108/IJLM-06-2019-0168

Praskah, C., Barua, M. K. (2016). A combined MCDM approach for evaluations and selection on third-party reverse logistics partner for Indian electronics industry. *Sustainable Production Consumption*, *7*, 66-78. doi: https://doi.org/10.1016/j.spc.2016.04.001

Ribeiro, J. L. D., & Milan, G. S. (2004). Planejando e conduzindo entrevistas individuais. In J. L. D. Ribeiro, & G. S. Milan (Ed.). *Entrevistas individuais: teoria e aplicações* (9-22). Porto Alegre: FEEng/UFRGS.

Slomski, V., Slomski, V. G., Valim, G. G., & Vasconcelos, A. L. F. S. (2018). A disclousure of social and environmental results economy resulting from the implementation of reverse logistics and final disposal of the post-consumption product: the case of computer peripherals industry. *Environmental Quality Management*, 27(3), 73-87.

Soleimani, H., & Kannan, G. (2015). A hybrid particle swarm optimization and genetic algorithm for closed-loop supply chain network design in large-scale networks. *Applied Mathematical Modeling*, 39(14), 3.990-4.012. doi: https://doi.org/10.1002/tqem.21530

Valle, P. O., Menezes, J., Reis, E., & Rebelo, E. (2009). Reverse logistics for recycling: the customer service. *International Journal of Business Science and Applied Management*, 4(1), 1-17.

Vieira, B. O., Guarnieri, P., Silva, L. C., & Alfinito, S. (2020). Prioritizing barriers to be solved to the implementation of reverse logistics of e-waste in Brazil under a multicriteria decision aid approach. *Sustainability, 12*(10), 4337. doi: 10.3390/su12104337

Xin, C., Wang, J., Wang, Z., Wu, C. H., Nawaz, M., & Tsai, S. B. (2021). Reverse logistics research of municipal hazardous waste: a literature review. *Environmental Development and Sustainability*, *24*, 1495-1531. doi: https://doi.org/10.1007/s10668-021-01526-6

Yoshida, F., & Yoshida, H. (2019). *Waste Electrical and Electronic Equipment (WEEE) handbook* (2nd ed.). Thousand Oaks: Woodhead Publishing.

Authors

1 – Jandir dos Santos Alós

Institution: University of Vale do Rio dos Sinos
Porto Alegre, Rio Grande do Sul, Brazil
Master in Management and Business at UNISINOS. Graduated in Business Administration from Faculdade Porto-Alegrense. He is currently Logistics Coordinator for Midea Carr.
Orcid: https://orcid.org/0000-0003-0010-5569
E-mail: jandirsalos@gmail.com

2 – Gabriel Sperandio Milan

Institution: University of Vale do Rio dos Sinos
Porto Alegre, Rio Grande do Sul, Brazil
Professor and researcher at Unisinos linked to PPGs in Management and Business (Professional Master's and Doctorate) and Production and Systems Engineering (Academic Master's and Doctorate) at UNISINOS. Post-Doctorate in Business Administration (Marketing) from the Federal University of Rio Grande do Sul.
Orcid: https://orcid.org/0000-0003-3480-2653
E-mail: gsmilan@unisinos.br

3 – Luciene Eberle

Institution: University of Santa Cruz do Sul
Santa Cruz do Sul, Rio Grande do Sul, Brazil
Professor and researcher at UNISC linked to the Department of Business Management and Communication. Post-Doctorate in Production and Systems Engineering at the University of Vale do Rio dos Sinos - UNISINOS.
E-mail: luciene.eberle@gmail.com

Contribution of authors

Contribution	[Author 1]	[Author 2]	[Author 5]
1. Definition of research problem	√	√	
2. Development of hypotheses or research questions (empirical studies)	√	√	
3. Development of theoretical propositions (theoretical work)	√	√	
4. Theoretical foundation / Literature review	√	√	√
5. Definition of methodological procedures	√	√	
6. Data collection	√		
7. Statistical analysis			
8. Analysis and interpretation of data	√	√	
9. Critical revision of the manuscript		√	√
10. Manuscript writing		√	√
11. Structuring and review of the article		√	√

Conflict of Interest

The authors have stated that there is no conflict of interest.

Plagiarism Check

The ReA/UFSM maintains the practice of submitting all documents approved for publication to the plagiarism check, using specific tools, e.g.: Turnitin.

Edited by

Jordana Marques Kneipp