Brazil's Formal E-Waste Recycling System

Subjects: Engineering, Industrial | Engineering, Environmental | Environmental Sciences

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Disruptive innovation has led to the increased obsolescence and accelerated replacement of electrical and electronic equipment, resulting in the rapid growth of waste electrical and electronic equipment (e-waste) worldwide. However, amidst the challenges in e-waste management, the recovery of secondary raw materials from e-waste presents an attractive business opportunity.

reverse logistics | e-waste | circular economy | developing countries | waste management policy

1. Introduction

Brazil stands as the major e-waste generator in South America, generating approximately 2.1 million tons annually, with an average of 10.2 kg per capita in 2019 [1]. The estimated value of the raw materials in this e-waste stream reaches about USD 57 billion, yet only USD 10 billion are currently recovered in an environmentally sound manner [1]. Surprisingly, the increase in e-waste generation per inhabitant surged by 40% in Brazil between 2016 and 2019 [1][2], while the population growth remained less than 2% [3].

In this context, Brazil enacted Decree No. 10240/2020, establishing the formal reverse logistics system for e-waste [4], in alignment with the Brazilian Policy on Solid Waste (Law No. 12305/2010). This policy emphasizes shared responsibility for the life cycle of products, involving manufacturers, importers, distributors, traders, government, and consumers in waste management [5].

2. Waste Electrical and Electronic Equipment

There was an increase of 9.2 million tons of e-waste generated globally in 5 years, with 82.6% of the total generated having an unknown destination. While the global average per capita of e-waste generated is 7.3 kg, in Brazil, it is 10.2 kg, making the country the largest e-waste generator in South America [1].

Despite technological advancements having the potential for producing more durable and reverse-logistics-adapted equipment, products are intentionally designed for a short lifespan [6]. The life expectancy of electronic equipment is decreasing, especially small electronic devices such as laptops, tablets, and cellphones [7]. This characteristic also depends on the user's perception of the product and not necessarily on the end of its useful life. Reliable

information is lacking, and informality plays a huge role in Brazilian e-waste management [8]. Additionally, collecting primary data at a local, regional, or national scale for decision making in Brazil is challenging [9].

Echegaray [10] states that only 24% of Brazilian consumers attempted to repair their electrical and electronic equipment, with a higher tendency to seek repairs in the case of household appliances. However, most consumers ended up buying a new device due to the lack of a favorable cost–benefit ratio.

Rodrigues, Boscov, and Gunther [11] assert that there are 2.5 electronic and electrical equipment items per household that are stored out-of-use. The same study revealed an acquisition time (length of ownership) of less than 2 years for cellphones, while for most refrigeration equipment, it was over 5 years. In the case of information technology equipment, there is a trend of replacing the devices without them being damaged or faulty due to technological obsolescence (i.e., more fashionable equipment or with new functionalities) [11].

The chosen mode for electrical and electronic disposal depends on the type of equipment [10]. Storing small out-of-use equipment or even disposing of it with household waste was a remarkable behavior [11], while for household appliances, the preference is to sell or donate [10]. Consumers tend to store out-of-use equipment that could be discarded if there was a reverse logistics system operating [11], and 24% of them did not know where to dispose of e-waste. Ghisolfi et al. [12] highlighted that the retention of electrical and electronic equipment minimizes the benefits of the e-waste closed-loop supply chains.

3. Reverse Channel

A reverse distribution channel (or reverse marketing channel) for recycling is a bridge between physical and nonphysical gaps that exist between consumers and the recycling industry [13].

Since a reverse channel is established, there is a huge barrier to overcome in the case of altering it as it involves various issues, such as commercial agreements, members involved, documentation, and so forth [14]. Regarding the e-waste reverse channel, there is an even greater need for a systemic approach in defining the channels, as the first actor is the consumer, who is in control of the responsibility of disposing of e-waste at delivery points but is exceptionally monitored.

Marketing channel power is the ability of one channel member to influence the decision of another member [15]. The power that the "channel captain" (or channel manager) exerts over the other members can occur through coercive power or legitimate power. The former refers to a strict monitoring and punishment approach, while the latter refers to the power of position, expertise, and dissemination of information which results in voluntary cooperation [16].

Souza [8] presents the routes for returning e-waste, from its generation to disposal, demonstrating that the e-waste reverse channels are structured as multichannel systems, with different paths for the waste to move from the consumer to the recycler. The task of coordinating multiple channels forces managers to deal with a variety of

challenging issues, especially regarding synergies across channels and building strategic alliances [17]. Therefore, the channel strategy concerns the entire process undertaken by the waste, from the channel configuration, commercial operation, and contracts, and the responsibilities of the members [17].

The marketing channel is considered an interorganizational network consisting of interdependent firms with self-interest goals and a division of tasks and functions [18]. Therefore, it is assumed that negotiations among the involved parties are necessary to achieve the goals of the reverse channel. Governance constructed by local actors could be a thoughtful way to promote e-waste recycling [19].

4. E-Waste Flow in Brazil

There are more informal management practices for e-waste in Brazil than formal ones [20]. Informal waste management practices are observed in all regions of the country, with limited data available for analysis, especially for e-waste [8].

The way in which the consumer discards the residue defines the e-waste stream. In formal reverse channels, there is usually adequate treatment and value recovery of materials. On the other hand, in informal reverse channels, the activities of intermediaries are often not routine or lack structure to ensure proper implementation of the recycling activities, which can contribute to an increase in negative impacts on the environment and the health of workers handling such waste [8].

Collecting e-waste through periodic campaigns has been yielding significant results in the municipalities where they are carried out. ABDI [21] suggests this model for small towns that do not have fixed delivery points. Alves et al. [22] state that participation in collection campaigns tends to increase when they are well advertised (through radio, posters, and social media networks) and well structured. The authors observed that the public attending the campaigns was unsure of what materials they could deliver, despite the organizers considering that they had succeeded in awareness campaigns. Many consumers return to the collection site a second time with more waste after seeing the variety of products being delivered by other participants [22].

The fixed collection points model was established by Decree No. 10240/2020, which defines the municipalities with a population of over 80 thousand inhabitants that must implement the reverse logistics system for e-waste by installing at least one collection point for every 25 thousand inhabitants [4]. Although Ottoni et al. [6] suggest combining collection campaigns and fixed collection points in larger municipalities to ensure more visibility and reach the audience, the disposal of large household appliances (e.g., refrigerator, freezer, stove, etc.) is hindered by their size and weight. Collecting through collection campaigns and fixed collection points is more suitable, especially when the distances between the collection points are significant, thereby contributing to environmental education and increasing e-waste collection rates.

5. Environmental Regulations for E-Waste in Brazil

The Brazilian law establishes the principle of shared responsibility for waste management, which involves manufacturers, importers, distributors, retailers, consumers, and government entities working collaboratively, with individual responsibilities in each link of the reverse logistics process [5]. **Table 1** shows the stakeholder's responsibility, according to Decree No. 10240/2020.

Table 1. Reverse logistics players' responsibility. Source: Based on Brazil [4].

Reverse Channel Member	Responsibilities According to Regulation
Consumer	Dispose of e-waste at the delivery points
Manufacturer and importer	Provide appropriate disposal; collaborate with environmental education and the communication plan; finance the reverse logistics system
Distributor and retailer	Provide consolidation and collection points; inform consumers of their responsibilities (only retailers); collaborate with environmental education and the communication plan
Performance follow-up group	Monitor, support, and supervise the reverse logistics system
Manager entities (ABREE and Green Eletron)	Perform reverse logistics actions, being able to hire or subcontract third parties to provide services
Waste picker cooperatives, public cleaning services, big generators, and non-governmental and related organizations	They can join the reverse logistics system through a contract with companies or a manager entity

Differing from other countries, where producers are responsible for e-waste management (extended producer responsibility), the Brazilian model is complex and brings difficulties in defining the roles and operational responsibilities of each stakeholder, mainly because there are costs involved and attributed to them. While in the countries (mostly in Europe) where the policy is based on extended producer responsibility, the financial, physical, and legal responsibility falls on the producer [11].

After the implementation of Decree No. 10240/2020, the goal is to properly collect and dispose of 17% by weight of the household electronic products sold in the base year 2018, with the installation of approximately 5060 collection points by 2025, covering all Brazilian municipalities with more than 80 thousand inhabitants (400 cities). At the end of the five-year expansion, the reverse logistics system will serve 61% of the country's population [4].

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