WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT IN MACROMETRÓPOLE PAULISTA: LEGAL FRAMEWORK AND TECHNOLOGY AT THE SERVICE OF REVERSE LOGISTICS

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1. Introduction

Since the beginning of the 21st century, the increase in waste electrical and electronic equipment (WEEE) production has been the object of analysis in universities, research institutes, governmental and non-governmental organizations, and companies associated with the electrical and electronic equipment (EEE) global value chain. Recurrently, these institutions express their concerns about the various negative impacts that inadequate management of this type of waste can generate for both the environment and human health.

According to the surveys published in the report Global E-waste Monitor 2017 in the year 2016 were produced 44.7 million tonnes of WEEE worldwide, the equivalent of 4,500 Eiffel Towers (BUCKET et al. 2017). Furthermore, prognostics reveal that the production of this type of waste will exceed 52,2 million tons in 2021 and reach 120 million by 2050 if nothing changes in s current production dynamics, consumption, and disposal of EEE (BALDE et al., 2017; PACE, 2019).

In the composition of this scenario, the report indicates that only 20% of WEEE are appropriately processed so that 80% remaining are traded, disposed and handled under illegal and informal condition, especially in cities located in the Global South (UNEP, 2015; BALDE et al., 2017).

Generally, WEEE can be categorized in six groups: I) temperature change equipment such as refrigerators, freezers, air conditioning, and heat pliers; II) screens and monitors, such as television sets, monitors, computers (laptop and desktop) and tablets;

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III) lamps of all types; IV) large equipment, such as washing machines, clothes dryers, electric stoves, large printers, large copiers and photovoltaic panels; V) small equipment, such as vacuum cleaners, microwave ovens, fans, toasters, electric shavers, calculators, radio equipment, video cameras, electro-electronic toys, electro-electronic instruments, and medical equipment and; VI) small IT and telecommunications equipment, such as mobile phones, GPS devices, pocket calculators, routers, printers, among others (BALDE et al., 2015).

The improper management of that type of waste can be extremely harmful to both the environment and human health. The existing risks are because many EEE has a high concentration of toxic substances in its composition, such as arsenic, cadmium, lead, copper, mercury, zinc, among others (HUANG et al., 2014). Currently, approximately 65 % of the population worldwide is protected by appropriate WEEE regulations. However, on the outskirts of some African, Asian, and Latin American cities, the manual dismantling of electrical and electronic equipment is frequent. There, the open-air burning of plastic wires and the dissolution of waste by acid solutions take place (SANTOS, 2018) among other rudimentary and less capitalized technologies that intensify the air, water (surface and ground), soil and vegetation pollution. At the same time, the occurrence of various diseases in workers and residents of the areas in question is enhancing.

In parallel to the socioenvironmental harms it can generate, recycling of WEEE - commonly called urban mining - can also be understood as a manifestation of the so-called reverse logistics. As much as many normative and technical adjustments must be made, it is estimated that this waste can generate profitability of approximately $ 65 billion per year (PACE, 2019). The natural resources that have the highest recycling rates (above 50%) when obtained from WEEE are aluminum, titanium, chromium, manganese, iron, cobalt, nickel, copper, zinc, niobium, palladium, silver, tin, rhenium, platinum, gold and lead (PACE, 2019).

Together with the reverse logistics, it is clear the WEEE recycling potential for the development of circular economy, whose premise is to incorporate the reused and recycled waste - especially mineral resources - in the manufacturing process, thereby establishing a circular production chain instead of a linear one. As much as this notion has already appeared in the 1960s - in the essay The Economics of the Coming Spaceship Earth by Kenneth Boulding (BOULDING, 1966) - it was formalized as a concept at the book Economics of Natural Resources and Environment, written by David Pearce and Kerry Turner in the 1980s (PEARCE and TURNER, 1990).

Thus, from the review of these assumptions, this article aims to analyze the regulatory and technological conditions in which WEEE recycling occurs in one of the most dynamic regions of Brazil: the Macrometropolis Paulista (MMP). In this geographical area, live about 33 million people who have multiple ways to access the EEE and, consequently, generate waste from its consumption. On a broader scale, Brazil was the second-largest producer of WEEE in the Americas in 2016, producing 1.5 million tons, only behind the United States (whose production reached 6.3 million tonnes) (BALDE et al., op.cit.).

The methodological procedures developed to reach the objective of this study were, fundamentally, the collection and analysis of various secondary sources - such as articles, books, dissertations and theses produced in different areas of social and natural sciences about recycling of WEEE in Brazil and the world - and also in the analysis of laws such as the National Policy for Solid Waste (PNRS), the State Plan for Solid Waste of Sao Paulo State and the sector agreement for reverse logistics system (for household electronics and its components), that, until August 2019, was still in the stage of analysis and discussion.

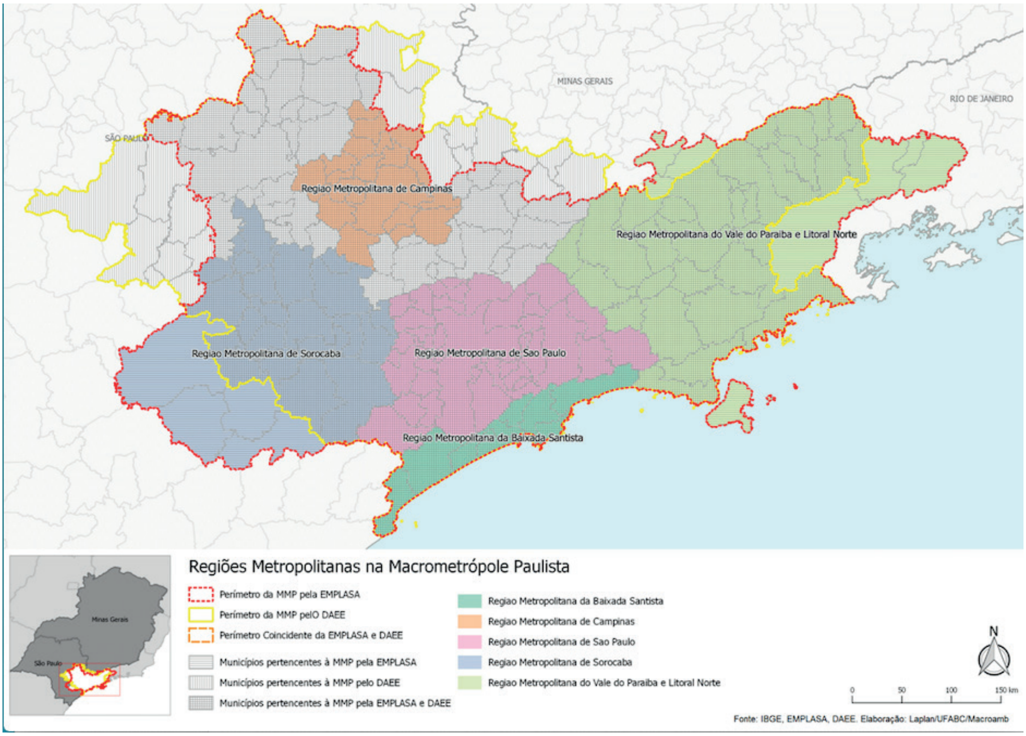
In the first half of 2019, there was a collection of institutional information from 28 companies that recycle WEEE in the MMP region, which were obtained from their websites. In this survey, it was possible to identify some essential aspects of enterprises, such as location, history, the origin of the capital used (national or foreign), technological aspects related to the processing of waste, and eventual partnerships with other economic activities. Thus, from the combination of these methodological procedures, it was possible to raise some crucial aspects of the regulatory and technological conditions that could guarantee the reverse logistics and the circular economy of WEEE in the Macrometropole Paulista.

2. The Macrometropole Paulista and the production of waste

Complex and multifaceted, the Macrometrópole Paulista (MMP) gathers in its extension of 53.4 km 2,174 municipalities - equivalent to 50% of the urbanized area of Sao Paulo - where 74.7% of the state's population lives, and it was responsible for the generation of 81.9% of Sao Paulo's Gross Domestic Product (GDP) in 2018 (EMPLASA, 2019). It is a geographical space that envisages a new territorial integration level marked by the intensification of flows of goods, people, ecosystem services, vulnerabilities, and information, having the state capital as the polarizing center. There is, therefore, markedly complex reality in both institutional and physical-territorial terms (JACOBI, 2013).

The area in question has become increasingly studied and debated in the scientific community, especially by geographers, sociologists, urban planners and environmentalists (JACOBI, CIBIM, and Leon, 2015; RICHTER and JACOBI, 2018; TAVARES, 2018, Pasternack and BOGUS, 2019) whom focus their analysis efforts on the multiple socio-environmental features of the region.

Map 1: Macrometropole Paulista



Source: IBGE, EMPLASA, DAEE. Developed by: Laplan / UFABC / Macroamb, 2019.

As the chief economic centrality of a country in the Global South that underwent a consistent industrialization process between the 1930s and 1980s (FURTADO, 1976; RANGEL, 1985; MAMIGONIAN, 1999), MMP is also the primary consumer market in Brazil, not only for its number of consumers but also for its diversity. Since the beginning of the 21st century, the consumption was boosted across the country due to income distribution policies - for example, the Bolsa Familia - and credit capillarity for the low-income population, which significantly increased the amount of consumption of EEE, especially in urban areas (SANTOS, 2017). Together with the expansion of family income and access to credit, consumption had its growth associated with the shortening of the EEE life cycle - a strategy called planned obsolescence (BULLOW, 1986) - and advertising, fundamental data of the so-called consumption society (BAUDRILLARD, 1995).

In this dynamic context of EEE consumption (SANTOS, 2017), it was enabled the increase of WEEE production. Given the lack of a specific indicator to measure the production and recycling of WEEE in Brazil, it is necessary to use data about the production and recycling of solid waste.

In MMP, it is estimated that approximately 30 tons of urban solid waste is produced per day, i.e., approximately 78% of the State of Sao Paulo. Even more alarming is the fact that only a small portion of this amount (about 190 t./day) is intended for recycling

(ESTADO DE SAO PAULO, 2014). Because of this situation, it is crucial to focus on the regulatory and technological aspects concerning the management of WEEE in MMP and how willing they are to guarantee the reverse logistics.

3. The regulatory aspects of WEEE management in Macrometropole Paulista

In the last decades, the management of waste from electrical and electronic equipment has been the subject of regulation as they have integrated the groups of hazardous or solid waste.

On the international scale, WEEE won special attention from the Basel Convention, held in 1989 in Switzerland. Ratified in 1992, the Basel Convention Treaty became the international legal framework regarding the movement and disposal of hazardous waste between nations and, more specifically, between developed and developing ones (BASEL CONVENTION, 1989).

Other conventions also aimed at reducing and controlling the transboundary flow of hazardous waste, such as the Bamako Convention (Mali, 1991), the Rotterdam Convention (The Netherlands, 1998), and the Stockholm Convention (Sweden, 2001) (UNITED NATIONS ENVIRONMENT PROGRAMME, 2015). Brazil was one of the signatories to the Basel Convention Treaty, making its international coherence explicit in the light of the 1988 Constitution, in which the need to protect the environment, fight against pollution and to guarantee the right of all Brazilians to a balanced environment was manifested:

> to an ecologically balanced environment, a common use of the people and essential to a good quality of life, imposing on the public power and the community the duty to defend and preserve it for present and future generations (BRASIL, 1988, s / p).

However, it was from 1999, with the approval of CONAMA Proposition 259 - entitled Technical Guidelines for Solid Waste Management - that more solid steps were taken regarding the regulation of WEEE management. As much as the proposal has not been published at that time, it raised a series of debates that culminated in the development of the National Policy of Solid Waste (PNRS), established by Law No. 12,305 of August 2, 2010.

More than prohibiting the import of hazardous waste, the PNRS offers of principles, goals, and instruments as well as guidelines for the integrated management of solid waste, including hazardous, the responsibilities of generators and the public authorities and applicable economic instruments (BRASIL, 2010).

Within the scope of the instruments, one can observe that:

> The instruments presented in the PNRS for its implementation include solid waste plans, inventories and an annual waste reporting system (SINIR), selective collection, reverse logistics of consumer

> goods and their packaging, and shared responsibility for the life cycle of consumers products, as well as tax, financial, and credit incentives (FREITAS, BESEN and JACOBI, 2017: 25).

In theory, the Solid Waste Plans should contain:

> [...] diagnosis, the proposal of scenarios, goals for reduction, reuse, and recycling, energy recovery, disposal and recovery of dumps, associated with the social inclusion of recyclable material collectors in the selective collection, programs, projects and actions for the care of targets, among other aspects. These apply to the national, state, municipal and large waste generators, that is, undertakings that, even if characterized as non-hazardous, due to their nature, volume or composition, are not equivalent to household waste generators by the government, with minimum chargeable content. (FREITAS, BESEN, and JACOBI, 2017: 26).

Based on the report of the Federal Court of Accounts (TCU), Freitas, Besen, and Jacobi (2017) reveal that the non-publication of the National Solid Waste Plan makes the PNRS empty of priorities, targets or indicators, discouraging production plans at state and municipal scales. However, this is not the case of São Paulo state, the federative unit of MMP. As a result of the PNRS - and sharing the same principles, goals, and instruments - the Solid Waste Plan of Sao Paulo state was conceived through the articulation between the Environmental Company of the State of Sao Paulo (CETESB), the Secretariat of State for the Environment (SMA) and other public agencies under the coordination of the Environmental Planning Coordination (CPLA) (ESTADO DE SAO PAULO, 2014).

From an overview of the solid waste management in the state, the plan prepared a regionalized study - making inferences to the MMP, despite considering mainly the metropolitan regions - and a proposal of inter-municipal arrangements. The goal was to provide a "decentralization of public policies on solid waste management and the sharing of services and activities of common interest to the municipalities" (ESTADO DE SÃO PAULO, 2014, p.5), thereby ensuring the optimization of resources and the generation of scale economies. Besides, the plan establishes a proposition of scenarios. It raises guidelines, goals, and actions, which "[...] deal with strategies to be adopted over ten years to ensure the implementation of the State Plan, guided by the mandatory adoption of the hierarchy in the management of solid waste - no generation, reduction, reuse, recycling, treatment and adequate final disposal of waste" (ESTADO DE SÃO PAULO, 2014, p.5).

In addition to solid waste plans, another instrument closely related to WEEE management is the reverse logistics, which, according to PNRS, is one of:

> Economic and social development instrument characterized by a set of actions, procedures, and means designed to enable the collection and return of solid waste to the business sector, for reuse, in its cycle or other productive cycles, or other environmentally appropriate final destination (BRASIL, 2010, art. 3).

Together with the shared responsibility, this instrument aims at developing the circular economy and implies the formulation of actions and procedures intended not only to the recycling of solid waste but also in its reintegration in the industry. That applies directly to WEEE that have, as already mentioned, numerous resources that can be recycled and reinserted in global value chains.

In the case of WEEE, it is up to manufacturers, importers, distributors, and traders to implement reverse logistics systems, regardless of the public service, so that "these systems can operate in the form of purchasing used products or packaging, providing voluntary delivery points, working in partnership with waste collectors' cooperatives" (FREITAS, BESEN, and JACOBI, 2017, p.27-28). The policy also provides tax, financial, and credit incentives as an instrument that, in theory, would stimulate the global value chain for recycling solid waste, in general.

In general, the regulatory aspects that have hindered the WEEE management in Brazil, and passed on MMP, are the different ways of framing materials (in the form of products, waste or tailings, and if deemed hazardous or inert). That fact leads to different environmental and labor safety obligations - including the requirement for the licensing of receiving points, the inspection of their transport, the use of protective equipment, the eventual remuneration for unhealthy work, and others (ABDI, 2013, p. 48). Besides, shared responsibility generates delays in closing inter-sectoral agreements, even though the instrument is essential for bringing different socioeconomic and political spheres into contact. Added to these factors is the failure to implement tax exemptions or subsidies to recycling companies.

Until the end of August 2019, the sectorial agreement for domestic WEEE and its components for reverse logistics was under public consultation. The drafting of the agreement was attended by not only the National State (through the Ministry of the Environment) but also companies that manufacture and distribute EEE, in addition to information technology software companies. Generally speaking, the object of the agreement is the structuring, implementation, and operationalization of the Reverse Logistics System for domestic electronic products placed on the national market. It provides for articulation between the state, companies that produce and distribute EEE, and companies that manage (recycle) WEEE. It is necessary to wait for the developments related to the approval and implementation of this agreement.

Given this legal framework, which presents advances and points to be improved, the technological aspects of the WEEE global value chain at MMP will be characterized based on the fact that there is where most of WEEE recycling companies in the Brazilian territory are concentrated.

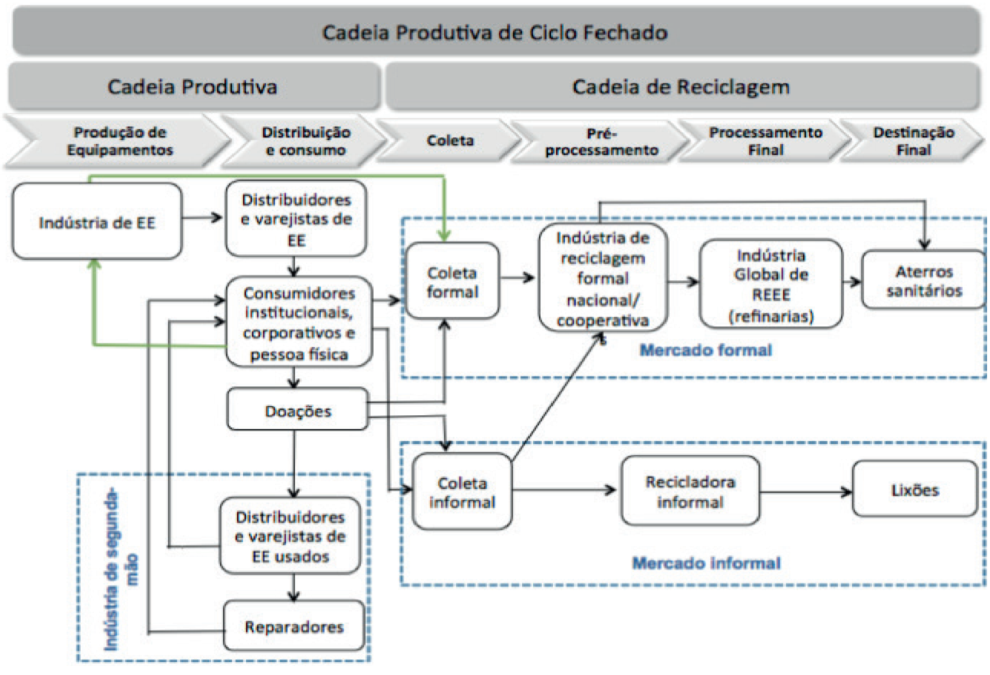
4. The technological aspects of WEEE management in the Macrometropole Paulista

The regulatory aspects on WEEE management - related to laws and plans on solid waste - reveals principles, goals, and some of the instruments by which one can establish reverse a reverse logistics system in the EEE sector in Brazil, in Sao Paulo state and, therefore, in the Macrometropole Paulista. However, it is essential to analyze the technical aspects related to the management of this type of waste, as this is what allows one to understand how the actors - especially recycling companies - involved in the WEEE global value chain operate.

In a synthetic effort, Mazon (2014) developed a flowchart of the WEEE recycling chain (Flowchart 1), linking it to the EEE production chain. This association is necessary given the opportunity to develop the circular economy in the sector since the recycled raw materials from WEEE - or recommodities (SANTOS, 2018) - are useful in the manufacture of new EEE.

This flowchart makes it possible to identify the existence of three relatively articulated universes in the post-consumption stages of EEE. The first of these is the second-hand industry, composed of several repair activities that expand the lifetime of electronic equipment after its disposal and reinsert them into the market. In Brazil, these activities can be translated into workshops, repair shops, and technical assistance that operate at different levels of organization and capitalization.

Flowchart 1: EEE and WEEE closed-loop production chain



* Cumprem etapas anteriores à produção de equipamentos eletroeletrônicos o setor primário e os fornecedores intermediários.

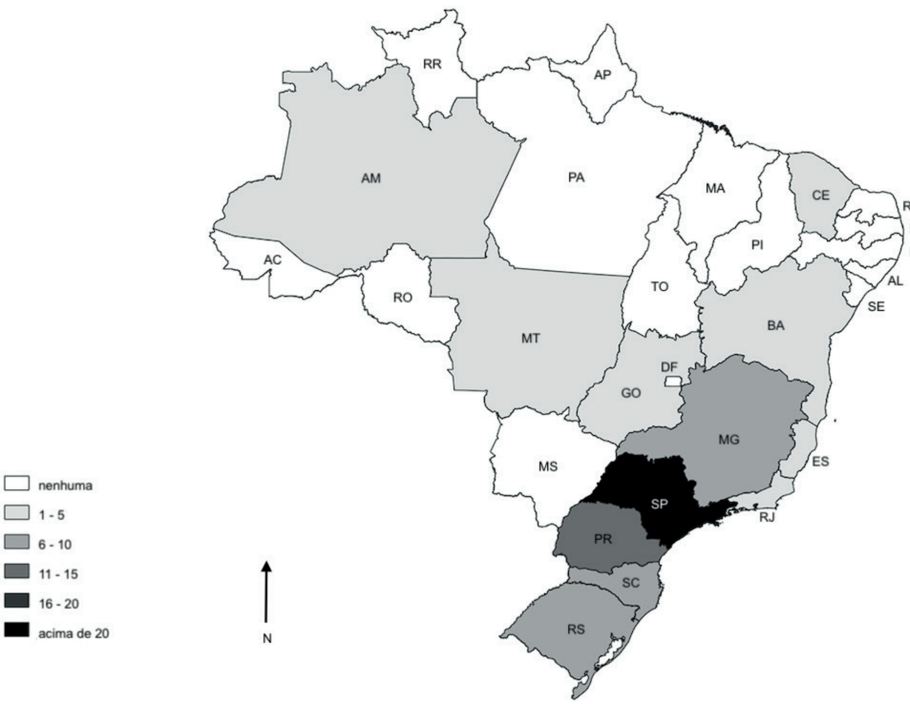
Source: Mazon, 2014.

Within the scope of the recycling chain, Mazon establishes the fundamental distinction between the formal and informal universes. The first comprises collection (both formal and informal) that destines waste to recycling companies in the country and that subsequently exports partially recycled waste for other industrial plants and waste for landfills. The second comprises the collection and informal recycling of WEEE, with the disposal of eventual waste in landfills. The analysis of the technological conditions of WEEE recycling contained in this article is specifically directed to the formal universe, more specifically, of recycling companies.

In Brazil - the largest producer of WEEE in Latin America - there are more than 90 WEEE formal recycling companies (ABDI, 2013). Such companies have different levels of capitalization, which are perceptible by the type of machinery used (and their renewal) and by the quantity and quality of the employed labor.

The distribution of WEEE recycling companies occurs in a markedly different manner in the national territory: most of them (37) operate in Sao Paulo state, as shown in Map 2. The second Federative Unit with the highest concentration of recyclers of this type of waste residue is Parana (15), followed by Rio Grande do Sul (10), Minas Gerais (9) and Santa Catarina (9).

Map 2: Distribution of WEEE recyclers in Brazil



Source: Prepared by the author based on ABDI, 2013.

From the collection of institutional data obtained from 28 WEEE recycling companies' websites[2] that operate in the MMP, it was possible to measure different economic aspects regarding the performance of these enterprises in the region. In this scenario, it predominates the national capital (Essencis, Reversis, Active, Silcon, Tecori, Lorene, Copermiti, Suzaquim, Ecobraz, Digital Scrap Recycling One, among others). Subsidiaries of foreign industry multinationals are the Belgian Umicore, which has facilities in Guarulhos (Metropolitan Region of São Paulo), Americana (Metropolitan Region of Campinas) and Manaus (due to its proximity to the Free Trade Zone, a pole for the production of electronic equipment in Brazil), the American Cintitec located in Osasco and the Chinese Cimelia located in Campinas.

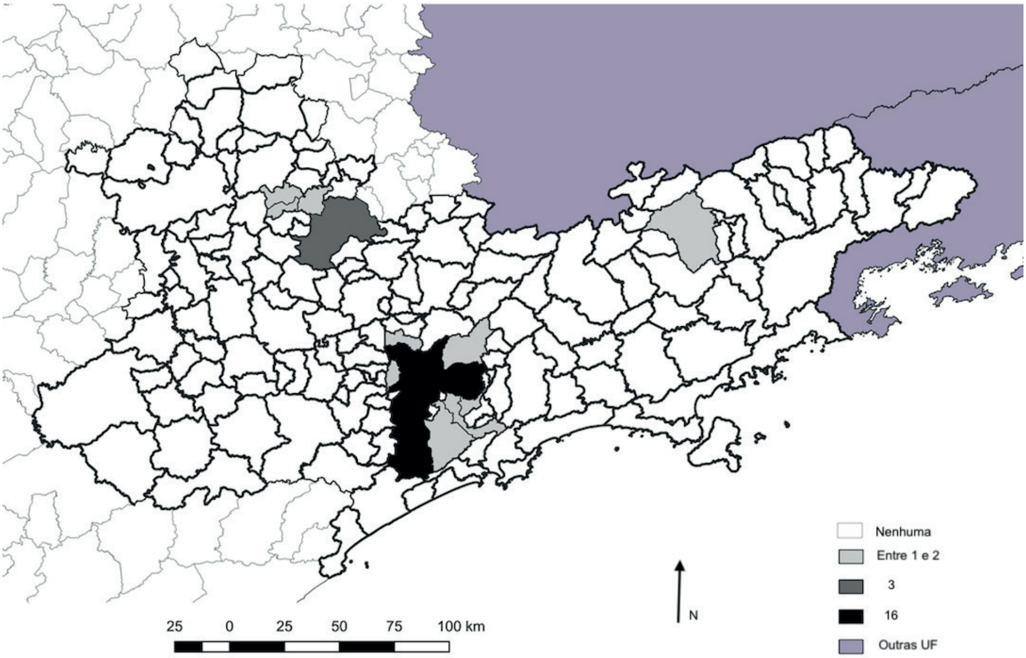
Most WEEE recycling companies are located in the peripheral neighborhoods (in the eastern and southern regions) of Sao Paulo City or the municipalities of its Metropolitan Region (Guarulhos, Mauá, Osasco, Santo Andre, and Sao Bernardo). There is also a concentration in the Metropolitan Region of Campinas (Campinas, Americana, Nova Odessa), but notoriously less expressive, as shown in Map 3, below.

The location of these companies can be explained by the proximity of the raw material, which, in this case, is the waste produced in the broad and heterogeneous consumer market and by companies from the secondary (industrial activities) and tertiary (commercial and service activities) sectors located in this urban agglomeration.

It should be noticed that, since the beginning of the 21st century, even the lower--income classes, composed of those who live in the urban peripheries, started to buy more EEE. When analyzing contemporary urban poverty in the city of Sao Paulo, Santos explains that this process of transforming the pattern of consumption in its periphery results from a capillarization of the financial system, so that the emergence of different types of credit and credit - associated with the planned obsolescence and advertising - stimulated an increase in the practice of consumption of material goods (SANTOS, 2017).

2. The 28 companies analyzed are: Umicore (with two plants), Essencis , Cimela , EcoVallore , Reversis , Ativa, Silicon (with two plants), Vertas, Descarte Certo, Cintitec , Tecori, Coopermiti , Lorene, RecicloAmbiental , San Lien , CRS Company, Digital scrap, Eco Computer Global, EcoBraz Recycling One, Hequiple , Recycare , Interamerican , Suzaquim , Ecotronics .

Map 3: Distribution of WEEE recyclers in Macrometropole Paulista



Source: Prepared by the author, 2019.

This understanding of the reality in Sao Paulo can be transferred to the MMP, given the access that the urban population in the region has to financial institutions and retail trade. Thus, it is possible to identify the importance of the region as a producer of WEEE.

The fact that MMP thickens numerous industrial, commercial, and service, as it can be translated by the fact that the region GDP reached 1.6 trillion BRL in 2016 (EMPLASA, 2019). Such activities make use of various electrical and electronic equipment, which are discarded as the projects renew their instruments and machinery.

Once EEE is discarded, its collection corresponds to the first stage of the WEEE global value chain. This activity is usually made by private companies (which are often their own recycling companies), associations, collectors cooperatives and, also by independent collectors. It is essential to mention that, as part of the logic of shared responsibility, the implementation of collection posts under the responsibility of industry and associations in the EEE sector has recently been expanded.

Once the collection is made,

> The separated materials are traded to intermediaries (popularly known in Brazil as scrap dealers and middlemen), who link the cooperatives (or even individual collectors), small and medium companies, and recycling industries. Thus, it is up to large [recycling] companies to determine the prices of scrap materials (GIGANTE, 2016: 52).

However, the unstable supply of raw materials has been a significant problem for WEEE recycling companies operating in Brazil. This instability is caused by high informality and inefficient logistics in the WEEE collecting stage. According to ABDI:

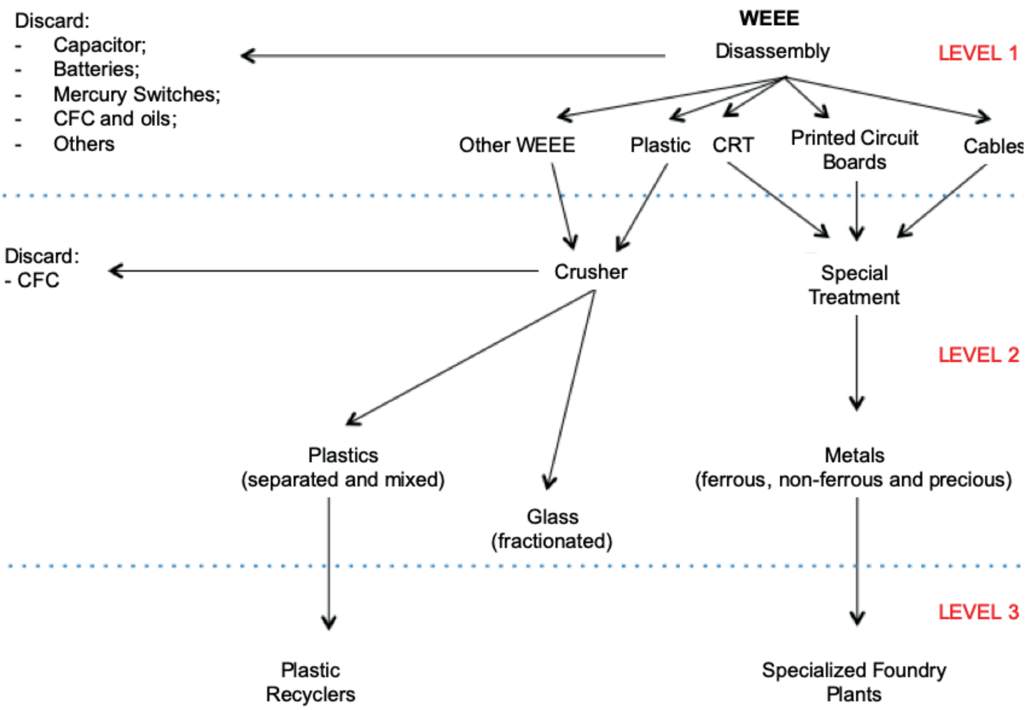
> Due to the still relatively small scale, the sector also lacks the conditions to invest in cutting edge technology. For this reason, what exists in the country in terms of separation and treatment of noble WEEE inputs has low efficiency when compared to existing technologies in other countries. A considerable part of the WEEE generated in Brazil needs to be exported for proper treatment. There are companies whose operation in the country is limited to the separation and handling of the material, which will later be processed at plants in Asia. A survey carried out by Aliceweb system pointed out that in 2011, a volume exceeding 20 thousand tons of waste originating from electronic equipment, were exported from Brazil (ABDI, 2013: 37).

One of the strategies founded by some recyclers to enables the entry of raw materials in their waste processing plants is to establish partnerships with companies in the industry manufacturers, retailers, services, or even workshops technical assistance. Tecori, for example, is located in Vale do Paraiba (in Pindamonhangaba) and receives waste from companies such as Siemens, Petrobrás, Alstom, GM, AES Brasil, Volkswagen, Pirelli, Bunge, Votorantim, CSN, Embraer, Vale, Unilever, Alcoa among others. Descarte Certo, in turn, is located in Nova Odessa (Campinas Metropolitan Region) receives waste from companies such as Carrefour and Ricardo Eletro.

Even with the adoption of this strategy, the input still does not fill the entire productive capacity of many companies. Therefore, they diversify their activities as a way to increase revenues. Other complementary activities are to recycle other types of waste - such as hospitals, municipal solid waste - and to provide environmental consultancy for companies (MAZON, 2014).

After the collection of WEEE, recycling activities are initiated by these companies. According to the WEEE Management Manual, there would be three stages of processing this type of waste, which could be summarized in the flowchart that follows (Flowchart 2).

Flowchart 2: Scheme of WEEE treatment levels



Source: Author's elaboration based on UNEP, 2007: 48.

The first level consists of the entry of collected WEEE. After sorting that classifies the waste according to the presence of components for reuse/recycling or the presence of components with hazardous substances (which will require specific safety processes), disassembly begins, which can occur manually or mechanically. From this stage, oils, CFCs, mercury switches, batteries, and capacitors are discarded. At the same time, plastics, cables, printed circuit boards and CRT (cube television sets) and other disassembled WEEE are taken to the second level.

In the second level, there is machinery responsible for crushing WEEE that has already been dismantled (mainly plastic). Other machinery covers the special treatment for crushing ferrous, nonferrous, and precious metals. According to Mazon:

> The operations present in this second stage are I) hammer mill; II). shredding; III). and individual treatment processes, such as CRT treatment, electromagnetic separation, centrifugal separation, and density separation (UNEP, 2007). The hammer mill and shredding reduce the size of the WEEE fractions so that the crushed material is then separated according to its density, size, and magnetic properties. The efficiency of the operations determines the metal recovery rate that will be obtained at the next technological level (MAZON, 2014: 46)

This level leaves fractions of plastics, ferrous metals, nonferrous (such as copper and aluminum) and precious (such as gold, silver, and palladium), which will be allocated to the next level (UNEP 2007; MAZON, 2014).

Finally, at the third level, these fractions undergo specific processes related to the physical-chemical conditions of the material itself, so that the use of pyrometallurgical techniques (with high temperatures in smelting furnaces), hydrometallurgical techniques (which use acids and aqueous and, caustic soda solutions) and electro-metallurgical (using electric current) (MAZON, 2014).

However, the studies by Mazon (2014), Gigante (2016), and Demajorovic, Augusto, and Souza (2016) point to the sector's limitations, given that companies located in Brazil do not carry out the entire recycling process in the national territory. According to Mazon:

[...] WEEE treatment facilities in Brazil consist of only the first treatment level (separation and manual dismantling) and, in a restricted way, the second treatment level (some automated pre-processing steps), while the third level (metal treatment) is geographically located in other countries, in most cases, developed ones (MAZON, 2014: 89).

None of these businesses operate across all the levels of recycling due to its technological conditions (absence of suitable machines), which stem from their level of capitalization since the machines - especially for the treatment of metals - are costly (imported mainly from Germany, Belgium, Italy, Sweden, and Japan) (GIANT, 2016).

Multinational companies operating in Brazil - which are sufficiently capitalized to establish the complete WEEE recycling process in the national territory - choose not to carry out the last stages of recycling in the country, exporting the waste already partially processed to their factories located in other parts of the world, especially in developed countries.

There is an idle capacity in the WEEE global value chain in MMP: when foreign companies choose to operate the third WEEE processing level outside of Brazil, they liberate a niche market to the national capital. It would be necessary, therefore, investments in costly technology capable of performing the processing of the third stage of recycling. This possibility of implementing a complete reverse logistics system would be fundamental to guarantee the development of the circular economy in MMP, thus guaranteeing greater sustainability in the extraction of natural resources from the environment and, at the same time, reducing the emission of waste to landfills, going in confluence to the premises of the National Policy of Solid Waste.

5. Final Remarks: challenges and possibilities towards reverse logistics

The growth in the production of waste of electrical and electronic equipment in the first decades of the twenty-first century represents a concrete manifestation of the consumer society. In Brazil, the Macrometropole Paulista is the more significant economic centrality of the country. It is also the region where the largest and most diversified consumer market is concentrated, in addition to the biggest solid waste production and where most WEEE recycling companies are located.

However, there are numerous challenges to make WEEE reverse logistics viable in MMP and Brazil. Although this is an instrument mentioned in the National Policy of Solid Waste and the Solid State Plan of Sao Paulo, the most significant impediments to its implementation are: I) the inconsistency in the classification of WEEE, which causes problems in scope of the definition of environmental and labor safety obligations concerning their recycling; II) the shared responsibility in the management, which generates delayed in closing sectoral agreement, essential to the functioning of the chain; III) the non-implementation of tax exemptions or subsidies to recycling companies (as provided by law); IV) the inefficiency of the WEEE collection channels and for recycling companies; V) non-closure of the recycling cycle in the country since Brazilian companies do not own the technology of the third stage of the WEEE processing, while foreign decide to perform this stage overseas.

At the same time that these challenges are posed, attention should be drawn to the enormous potential that adequate and efficient WEEE management in the MMP can offer to the region's economy, as well as to the environment and human health. The possibilities for reverse logistics must be built by analyzing the current challenges. There is still room for different stakeholders in this recycling chain to build initiatives that allow to implement regulations and enable the creation of efficient WEEE collection channels. Besides, they can absorb technologies that allow - within proper environmental and labor conditions - to close the loop of WEEE recycling in the national territory. Then it will be possible to reintegrate its merchandise (the recycled mineral raw materials) in the initial stages of EEE global value chains, enabling the circular economy.

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WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT IN MACROMETRÓPOLE PAULISTA: LEGAL FRAMEWORK AND TECHNOLOGY AT THE SERVICE OF REVERSE LOGISTICS

KAUÊ LOPES DOS SANTOS

WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT IN MACROMETRÓPOLE PAULISTA: LEGAL FRAMEWORK AND TECHNOLOGY AT THE SERVICE OF REVERSE LOGISTICS

Abstract: The increase in the production of waste electrical and electronic equipment (WEEE) became a widely discussed issue around the world in the early 21st century. If, on the one hand, this type of waste draws attention due to the risks that its improper management can generate to the environment and human health, on the other hand, it represents a concrete possibility of implementing reverse logistics. The objective of this paper is to understand the WEEE recycling conditions in the dynamic Macrometrópole Paulista. Thus, through a methodology that involves the survey and analysis of diverse secondary sources, It can be considered that the recycling of WEEE in the studied region is still in the structuring phase, so that some normative and technical challenges need to be overcome to ensure the establishment of the circular economy.

Key words: Waste electrical and electronic equipment; Reverse Logistic; Circular Economy; Macrometrópole Paulista; Recycling.

RESÍDUOS DE EQUIPAMENTOS ELETROELETRÔNICOS NA MACROMETRÓPOLE PAULISTA: NORMAS E TÉCNICAS À SERVIÇO DA LOGÍSTICA REVERSA

Resumo: O aumento na produção de resíduos de equipamentos eletroeletrônicos (REEE) tornou-se uma questão amplamente discutida em todo o mundo no início do século XXI. Se por um lado, esse tipo de resíduo chama a atenção devido os riscos que a sua gestão inadequada pode gerar ao meio ambiente e à saúde humana, por outro, ele representa uma possibilidade concreta de implementação da logística reversa. O objetivo deste artigo e compreender as condições de reciclagem de REEE na dinâmica Macrometrópole Paulista. Assim, por meio de uma metodologia que envolve o levantamento e análise de fontes secundárias diversas, pode-se considerar que a reciclagem de REEE na região estudada encontra-se ainda em fase de estruturação, de modo que alguns desafios de ordem normativa e técnica precisam ser transpostos para que possa se garantir o estabelecimento da economia circular.

***Palavras-Chave*:** Resíduos de equipamentos eletroeletrônicos; Logística Reversa; Economia Circular; Macrometrópole Paulista; Reciclagem.

RESIDUOS DE EQUIPAJES ELÉCTRICOS Y ELECTRÓNICOS EN LA MACROMETRÓPOLE PAULISTA: MARCO LEGAL Y TECNOLOGÍA AL SERVICIO DE LA LOGÍSTICA INVERSA

***Resumen*:** El aumento en la producción de residuos de equipos eléctricos y electrónicos (REEE) se convirtió en un tema ampliamente discutido en todo el mundo a principios del siglo XXI. Si, por un lado, este tipo de residuos llama la atención debido a los riesgos que su gestión inadecuada puede generar para el medio ambiente y la salud humana, por otro, representa una posibilidad concreta de implementación de la logística inversa. El objetivo de este articulo es comprender las condiciones del reciclaje de REEE en la dinámica Macrometrópolis Paulista. Así, a través de una metodología que involucra la encuesta y el análisis de diversas fuentes secundarias, se puede considerar que el reciclaje de REEE en la región estudiada aún se encuentra en la fase de estructuración, por lo que deben superarse algunos desafíos normativos y técnicos para garantizar el establecimiento de la economía circular.

***Palabras-clave*:** Residuos de equipos eléctricos y electrónicos; Logística Reversa; Economía Circular; Macrometrópolis Paulista; Reciclaje.