DOI: 10.5902/19834659 23803

WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT: RISKS AND OPPORTUNITIES UNDER A SUSTAINABLE PERSPECTIVE

Submission: 03/09/2016
Accept: 18/07/2018

Jaqueline Terezinha Martins Corrêa Rodrigues[1]
Liane Werner[2]
Marcia Dutra de Barcellos[3]

ABSTRACT

It is estimated that the amount of waste electrical and electronic equipment (WEEE) increases annually due to planned obsolescence, technological changes and changes in people's lifestyles. The aim of the present study is to identify risks and opportunities related to WEEE from an environmental, social and economic point of view, considering the intensified use of technology, the generation and the need to treat this waste. The study consisted of a bibliographic research followed by three case studies with waste disposal companies. Therefore, a table was drawn up outlining the risks and opportunities of WEEE, considering different points of view. From the environmental point of view, there is a risk of increasing the consumption of this equipment to increase the illegal and incorrect disposal, but the extraction of non-renewable raw materials can be reduced by implementing reverse logistics. From the economic perspective, the costs involved in the reverse logistics of WEEE are not clearly known; however, there is an expanding market for WEEE management. From the social point of view, the risk is the increase of informal and insecure work, which can be minimized through investments from public and private powers, thus generating formal jobs.

Keywords: Waste electrical and electronic equipment; WEEE; risks; opportunities.

1 Affiliation Instituto Federal de Educação, Ciência e Tecnologia do Rio Grande do Sul, Country Brazil, Doctor of Production Engineering from the Universidade Federal do Rio Grande do Sul (2016), Master of Production Engineering from the Universidade Federal do Rio Grande do Sul (2009) and graduated of Electric Engineering from the Universidade Federal do Rio Grande do Sul (1998). She is a Professor of Logistics, Project Management and Quality. It operates mainly in the following areas: Waste Electrical and Electronic Equipment, Quality, Logistics, Reverse Logistics and Production Management. E-mail: jaquecorrea@yahoo.com.br. ORCID: 0000-0002-2786-367X

2 Affiliation Universidade Federal do Rio Grande do Sul, Country Brazil, Doctor of Production Engineering from the Universidade Federal do Rio Grande do Sul (2005) and Master of Production Engineering from the Universidade Federal do Rio Grande do Sul (1996), graduated of Statistics from the Universidade Federal do Rio Grande do Sul (1988). She is a associate professor at the Universidade Federal do Rio Grande do Sul. She works with the undergraduate statistics course and engineering courses. She has worked in the postgraduate degree in Production Engineering as a teacher and advisor for master and doctorate. She is an evaluator of national and international journals and congresses. Areas of interest are: Statistical Quality Control, Statistics applied to industry; Forecasting Techniques, Market Research and Analysis. E-mail: werner.liane@gmail.com. ORCID: 0000-0001-5394-8063

3 Affiliation Post-Graduate Programme in Management - Federal University of Rio Grande do Sul (PPGA/UFRGS), Doctor of Agribusiness from the Center for Study and Research in Agribusiness (CEPAN), Federal University of Rio Grande do Sul (UFRGS), with Doctoral Stays/PhD Sandwich at Wageningen University, The Netherlands and at the University of New England, Armidale, Australia. Currently she is Director for the Center of Study and Research in Management (CEPA) and Associate Professor and Researcher at the Post-Graduate Programme in Management (PPGA) from UFRGS. She is also Affiliated Staff from Aarhus University, Denmark and Productivity Researcher level 1 – D from The National Council for Scientific and Technological Development (CNPq). Her main research interests are in Sustainability, Marketing and Innovation. ORCID: 0000-0002-4311-2921. Email: marcia.barcellos@ufrgs.br / mdutrab@gmail.com

RESUMO

Estima-se que a quantidade de resíduos de equipamentos eletroeletrônicos (REEE) aumente ano a ano, devido à obsolescência planejada, às alterações tecnológicas e às mudanças no estilo de vida das pessoas. O objetivo deste artigo é analisar o impacto da geração de REEE para trabalhadores, empresas e população em geral. A realização do trabalho consistiu em uma pesquisa bibliográfica seguida por três estudos de caso com empresas gerenciadoras de resíduos. Como resultado deste trabalho foi elaborado um quadro apresentando os riscos e as oportunidades dos REEE, considerando os pontos de vista ambiental, social e econômico. Do ponto de vista ambiental, há riscos do aumento do consumo destes equipamentos ampliar os descartes incorretos e ilegais, porém, com a implantação da logística reversa pode-se reduzir a extração de matérias primas não renováveis. Do ponto de vista econômico, os custos envolvidos na logística reversa dos REEE não são claramente conhecidos, entretanto, há um mercado em expansão para gerenciadores deste tipo de resíduos. Já do ponto de vista social, o risco é o aumento do trabalho informal e inseguro, que pode ser minimizado com investimentos na área pelo poder público e privado e gerar empregos formais.

Palavras-chave: *Resíduos de equipamentos eletroeletrônicos; REEE; riscos; oportunidades.*

1 INTRODUCTION

Electronic devices are increasingly present in people's lives. In the survey conducted by the IBGE in 2015, it is noted that most Brazilian households have TVs (97.1%), refrigerators (97.8%) and washing machines (61.1%) (IBGE, 2019). When analyzing data from Anatel (2019) for mobile telephony, an even greater growth is noted, going from 67.4 million accesses in 2005 to 228.2 million accesses in 2019. If, on one hand, these devices bring benefits such as connectivity and improvements in communication, on the other hand, when they no longer serve the users, either at the end of their useful life or by replacing with a more modern one, they will become waste electrical and electronic equipment (WEEE).

Studies performed by the United Nations University estimate that by 2020 about 12 million tons per year of this waste would be generated in the European Union (HUISMAN *et al.*, 2007). According to estimates by Araújo *et al.* (2012), 3.77 kg of WEEE per inhabitant is generated per year in Brazil, considering only seven most common types of electronic equipment in households. Considering the Brazilian population informed by the IBGE (2016) in the 2010 Census (190,732,694 people) and the waste rate by Araújo *et al*. (2012), it is estimated that more than 719 million kg of WEEE are generated per year in the country.

In Brazil, some studies have already been performed on WEEE. Miguez (2007) evaluated the environmental and economic benefits of reverse logistics applied to this waste. Virgens (2009) conducted an extensive research on the responsibilities, interests and barriers of the WEEE management process. Franco and Lange (2001) estimated the flow of WEEE in Belo Horizonte, MG, Brazil. Santos (2012) analyzed the environmental, social and economic outcomes of the WEEE management.

Thereby, the aim of the present study is to identify risks and opportunities related to WEEE from an environmental, social and economic point of view, considering the intensified use of technology, the generation and the need to treat this waste. Consequently, it will be possible to understand the current scenario of the issue involving WEEE in Brazil, specifically in the state of Rio Grande do Sul.

2 WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT (WEEE)

During the manufacturing of electrical and electronic equipment (EEE), various chemical components present in raw materials are used, besides energy and water. Oliveira, Chiesi and Barbieri (2012) cite the case of chip manufacturing, which requires a large amount of filtered and distilled water and that, at the end of the production process, is contaminated with heavy metals and other harmful chemical substances. Heavy metals are reactive and bioaccumulative chemicals, i.e., the body cannot eliminate them if ingested.

After being used by consumers, EEE can be reused, donated, recycled or discarded. Popularly, equipment no longer in use is called e-waste. Waste from such equipment may be undesirable, but not useless, since it may return to the production process after recycling or being reused in a variety of applications. According to Leite (2009), the reduced product life cycle is due to the introduction of new models, the use of less durable raw materials and the technical and economic difficulty of repair, for example. Therefore, WEEE are those waste derived from electrical or electronic equipment, its components and its peripherals.

According to Oliveira, Chiesi and Barbieri (2012), the substances most commonly found in this waste is epoxy resin, glass fiber, PCB (polychlorinated biphenyl), PVC (polyvinyl chloride), lead, tin, copper, silicon, beryllium, carbon, iron and aluminum. Other components are found in reduced amounts such as gold, silver, titanium, arsenic, boron, cobalt, indium, lithium, manganese, selenium and platinum.

Considering the harmfulness of some of these chemicals, the European Parliament created the RoHS (Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment) directive aiming to eliminate and/or reduce certain substances present in EEE, such as lead, cadmium, mercury, chromium and flame retardants (polybrominated biphenyls [PBB] and polybrominated diphenyl ethers [PBDE]). These restrictions are mandatory for the marketing and production of equipment in the European Union, being necessary to present certifications proving compliance with RoHS, influencing the design and production of equipment in several countries of the world which export their products to the region, including Brazil (EUROPEAN COMISSION, 2012).

The National Policy on Solid Waste (PNRS) was established in Brazil by the Law 12,305 of August 2, 2010. Its principles are the systemic vision of solid waste management, sustainable development, shared responsibility for the product life cycle, and the recognition of reusable and recyclable solid waste as an economic, income-generating and socially-valuable asset, able to generate jobs and promote citizenship (BRASIL, 2010).

Article 33 of the PNRS establishes the enforcement of establishing reverse logistics for electronic products and their components, being that manufacturers, importers, distributors and dealers of these equipment are responsible for ensuring the implementation and operation of this system. Reverse logistics is understood as a system (actions, procedures and means) aimed to enable the return of goods or their constituent materials to the production cycle for reuse or adequate disposal (BRASIL, 2010; LEITE, 2009). In Article 33 of the PNRS is also suggested the performance of these agents in partnerships with cooperatives, association of scavengers and with the public power. In article 42, it is informed that the public power may institute incentive and financing measures for the sector in order to prevent and reduce the volume of solid waste generated in the production process, develop products less aggressive to the environment and human health, acquire equipment for cooperatives, structure reverse logistics systems, among others (BRASIL, 2010).

The Ministry of the Environment (MMA, 2015) created in 2011 a Technical Working Group to elaborate proposals for implementation of reverse logistics in the chain of Electrical and Electronic Products aiming at the Elaboration of the sector understanding. The technical-economic feasibility study and analysis of the waste situation were concluded in November 2012 (ABDI, 2015). This study presented recommendations for the implementation of reverse WEEE logistics, identifying the necessary conditions for this implementation, such as the risk analysis of waste, the review of levying taxes in the recycling chain, the provision of credit lines for investments in recycling companies and incentives to research in the area. This feasibility study was approved in January 2013 by the steering committee for the implementation of reverse logistics (SINIR, 2015).

Continuing the process, the public notice to receive proposals for sector understanding was published in February 2013. Ten proposals were received by June 2013, four of which were considered as valid and have already been negotiated between the parties to present a unified proposal in January 2014 (SINIR, 2017). In November 2019 the Sectorial Acording of WEEE was finaly published (SINIR, 2019).

3 RISKS AND OPPORTUNITIES OF WEEE

The EEE consumer behavior is one of the determining factors for the success of the proper disposal process. The study performed by Arenhardt *et al*. (2016) analyzed the behavior of cellular handsets' consumers in the city of Santa Maria, RS, Brazil, through quantitative research, presenting results such as lack of knowledge of the legislation, lack of willingness to contribute financially to the correct disposal of devices and preference in storing the equipment at home, not forwarding them to reverse logistics systems, since these consumers did not know where to discard them or donated the devices to family or friends.

The lack of adequate disposal sites for WEEE led Sigrist *et al*. (2015) to develop a prototype of a collection point for this waste, considering requirements such as sizing, design, location, disclosure and cost. This prototype was installed in a university in the countryside of São Paulo, and publicity campaigns were performed for the institution's internal public. Before this collector, there was a specific WEEE container similar to a garbage can, and people discarded other types of waste, including organic waste. There was an increase in the amount collected after installing the prototype and no other types of waste mixed with WEEE were found, showing the importance of offering suitable disposal sites.

According to Oliveira, Chiesi and Barbieri (2012), WEEE can bring problems related to the environment and society. In relation to the environment, this waste can cause damage to the soil, water and air. When EEE is inappropriately disposed, the toxic chemical substances which constitute this equipment can affect the soil and contaminate the groundwater. There are risks involving air contamination whether this waste is incinerated. From the environmental point of view, WEEE can also represent a waste of nonrenewable natural resources, since if this waste were recycled, there would be no need to extract some metals, saving the natural reserves and energy required for the extraction.

Ferreira and Ferreira (2008) point out that WEEE can cause skin infections, respiratory problems, impair the nervous and reproductive system and even cause diseases more serious, such as cancer. Most people are unaware of the negative potential of this waste, and there is an informal recycling market that handles this waste without concern with the people's safety or the proper collection and storage. The protective equipment required to work with WEEE containing heavy metals, according to Silva, Martins and Oliveira (2008), are: face respirator, goggles, gloves, suitable clothing, steel-toe boots and helmet.

Another problem is the marginalization of waste scavengers. Dejours (2006) states that work is a source of paradox: it can be alienating and emancipatory, bringing pleasure and suffering. Work is alienating when people become to tolerate, allow and participate in social injustices, violations of labor laws, and work under poor security conditions, for example, even unconsciously. In this way, the worker suffers by living with these injustices and with the idea of not meeting the organizational demands, not achieving the expected performance. However, the work is emancipatory because those who have work can generally sustain themselves, have a decent life and be recognized as a citizen, with an identity, bringing them pleasure and social fulfillment.

According to the United Nations Environment Programme (UNEP), about 90% WEEE is traded or dumped in landfills illegally. Europe and North America are the major producers of this waste in the world, but Asia has grown significantly in recent years. Ghana, Nigeria, Côte d'Ivoire, Republic of Congo, China, Hong Kong, Pakistan, India, Bangladesh and Vietnam (UNEP, 2015) are frequent destinations for this waste.

Some countries with more restrictive or higher purchasing power export their WEEE as "donation" or "secondhand" equipment to African and Asian countries, although the Basel Convention has banned the export of hazardous waste since 1992. Bhutta, Omar and Yang (2011) state that in New Delhi, India, 70% WEEE were imported from developed countries. Another example is Nigeria, where there is a local decree of 1988 prohibiting the import of hazardous substances, but the equipment that arrives at the port in good conditions of use are sent to street markets and the others are sent to the dumps, which do not have control of toxic substances that can contaminate the groundwater and the air. In addition, the workers of these markets and the port are exposed without any kind of protection (MIGUEZ, 2007).

Carvalho and Xavier (2014) argue that developing countries, such as Brazil, consider waste management as an opportunity for social inclusion, with workers organized or not in associations or cooperatives. However, the remuneration is generally low and there are no minimum safety conditions. Oliveira, Bernardes and Gerbase (2012) classify WEEE recycling organizations into three types: (i) companies that collect, select and sell the material for recycling in other specialized companies; (ii) companies that collect, select and sell part of materials to other recycling companies and export the printed circuit boards; (iii) international recycling companies with offices in Brazil which manage the entire process, from collection to recycling outside the country. Dias et al. (2018) state also that approximately 90% of the Brazilian WEEE recycling organizations only perform the dismantling and separation of waste and that there is no precise government information on the number of such organizations in the country.

The gathering on the situation of scavengers of recyclable materials in Brazil, conducted by IPEA (2015) with 2010 data, shows that illiteracy reached 20.5% of scavengers, being the Brazilian index of 9.4% for the general population. Illiteracy or short study time limits the professional opportunities and social progress of these workers. It is also noticed that quality of life is precarious for many scavengers, since only 49.8% of their residences have adequate sanitary sewer (index for the general population is 66.7%). The average income of these workers was R$ 571.56, slightly above the minimum wage of R$ 510.00 in 2010, and only approximately 57% of the scavengers claimed for social security contribution, which ensures benefits such as retirement, sick leave, parental leave and others. The new National Policy on Solid Waste (PNRS) aims to promote social inclusion and value the work of waste scavengers and recyclers' cooperatives, but there is still not sufficient practical results of the necessary cooperation between government and companies to change this reality (OLIVEIRA; CHIESI; BARBIERI, 2012).

On the other hand, WEEE can also mean business and employment opportunities, either through recycling, reuse, reverse logistics, among others. Recycling is aimed to take advan-

tage of waste and reuse it again in the production of similar products or in other applications, and can allow reducing production costs. De Brito and Dekker (2002) believe that implementing a reverse logistics system can generate profits for companies directly or indirectly, either through reuse of components or through the image of a sustainable/green company.

However, an efficient reverse logistics process is required in order to enable recycling or reuse for WEEE to be collected, transported and stored. Lavez, Souza and Leite (2011) emphasized the cost of transport due to the low added value of waste, the pulverization of collection points and the low volumes collected. Demajorovic and Migliano (2013) pointed out that the continental dimension of Brazil, associated with the lack of tax incentives and the large supply of orphan products (without identified producer or imported illegally) make reverse logistics even more complex.

Similarly, Leite (2009) presents the environmental and economic benefits for the implementation of reverse logistics. Based on the environmental point of view, the reduction of unsafe and illegal disposals, the reduction of pollution, the saving of raw materials and energy are expected. From the economic point of view, new businesses and new revenue sources can be created through the marketing of by-products and waste, besides improving the company's image and making possible to obtain financing due to their ecologically correct procedures.

The City Hall of Porto Alegre (RS, Brazil), in an agreement with waste management company, held three fairs for the disposal of technological waste in the city until 2013. In the first two editions, more than 40 tons of WEEE were collected; and in the third, there was a big increase in the collection, reaching 35 tons of waste. This waste is sent to the company responsible for the correct destination of WEEE (PORTO ALEGRE, 2013). Moreover, the City Hall provides six fixed points for the collection of WEEE and performs the Itinerant Collection of Electronic Waste, organized by the Municipal Department of Urban Cleaning (DMLU) in partnership with the waste management company and the Trade Union of Shopkeepers of Porto Alegre (Sindilojas). Since August 2014, every Saturday, a truck is parked in one of the three previously defined sites for waste collection, such as computers, CPUs, displays, keyboards, cables, stabilizers, and other obsolete appliances (PORTO ALEGRE, 2015). The idea is that the waste be separated by a cooperative of homeless people, the Paulo Freire socio-environmental cooperative. After these steps, the waste can be commercialized, generating income and social inclusion for the cooperative members (ECOPROFETAS, 2015).

In the city of Porto Alegre (RS, Brazil), Santos (2012) interviewed stakeholders of the WEEE reverse chain and cited the project of the network Maristas high schools in partnership with the Federal Government, Conceição Hospital and City Hall of Porto Alegre, which created the Center for Computer Reconditioning (CRC Cesmar) in 2006, as another path to social inclusion and education. The center receives donations of computer equipment, mainly from public agencies, which are disassembled and the parts are tested and stored. The parts not used are sent to an electronic waste management company for proper disposal. The others will be used for computer reconditioning. The reconditioning is performed by low income students of the Youth Apprenticeship program, guaranteeing them scholarship and food. At the end of the course, the students receive the certificate of the technical course, making possible their better insertion in the labor market. Additionally, reconditioned equipment will be used by public schools, social entities and telecenters (equipment available to the community), allowing the digital inclusion of the population served.

In general, Brazil has potential for studies involving greater knowledge about WEEE. For instance, Peréz-Belis et al. (2015) conducted an extensive search in the literature investigating the trends and evolution of the global context of WEEE. Of the 307 articles analyzed, only three referred to studies performed in the country. Echegaray and Hansstein (2017) identified a positive attitude towards the recycling of WEEE by consumers, but in practice there is still a gap

between such attitude and the behavior, indicating the need to raise awareness on this issue combined with a greater infrastructure and convenience that allows the use of WEEE.

Thus, the present study aims to contribute in the identification of risks and opportunities for WEEE based on the business view, taking into account the economic, social and environmental perspectives.

4 RESEARCH METHOD

The present research is characterized as qualitative and exploratory (Gil, 2008), since it deals with a subject still little known and studied in Brazil. The research protocol indicates that it was developed in five steps, as shown in Figure 1. The first research stage was the planning. In this phase, it was defined the research objective, the form of data collection, the instrument type that would be used in the data collection, besides the target audience of the research, namely waste management companies, cooperatives and associations of waste scavengers working with WEEE.

Figure 1 - Research protocol

According to Cervo, Bervian and da Silva (2007), in the second phase (literature review), necessary in any survey, national and international books and articles dealing with WEEE were consulted, more specifically environmental risks and opportunities, economic and social impacts of this waste. Some websites of associations, agencies and government bodies were also verified.

The questionnaire for interviews was prepared in the Data Collection stage. The questionnaire should begin with general questions, it cannot be too long to tire the respondent, nor very short, precluding the proper analysis of answers (MARCONI; LAKATOS, 2009). The questionnaire of the present research, based on study objectives and literature, began with general information about the company, such as location and number of employees. Thereafter, open questions were presented asking for information about stages of the waste management process, the employees and the market view regarding business risks and opportunities. In Table 1 is presented the questions and references used to elaborate the questions:

Table 1 - Information on the questionnaire used in the survey

Group	Issue	Main references
Process	What are the main steps of the process involving waste electrical and electronic equipment in your organization? Describe this process.	Franco and Lange (2001) Rodrigues (2007) Santos (2012) Silva, Martins and Oliveira (2008) Virgens (2009)
	How is the equipment stored when arriving at the organization and after the process?	
Contributors:	How is the selection of these employees?	
	Is there any specific training performed by these employees?	
	Which individual and collective protective equipment are used throughout the process?	
Business	Legislation regarding waste electrical and electronic equipment is increasingly imposing conditions and obligations on manufacturers, sellers and distributors of this equipment. In Brazil, the National Policy on Solid Waste requires the implementation of reverse logistics for this type of waste. What business opportunities could arise with the regulation of this policy?	

The next step of this data collection stage was to contact cooperatives, associations and recycling companies by e-mail presenting the research, informing the theme and the objectives. The judgmental and non-probability sampling was used. According to Mattar (1996), some criteria used to select the elements of a non-probability sample can be: its location, size, the existence or not of certain (quality, productivity) programs, the number of employees, the industry, among others.

In the present study, the used criteria were the company's location (Rio Grande do Sul, due to the convenience for data collection) and the type of recycling performed; in this case, the selected company should necessarily work with recycling of electrical and electronic equipment. Based on the list of CEMPRE (Business Commitment for Recycling, 2013) and on the Google website through the search words (RS electronic recycling), companies which had website, contact email and located in RS were selected. The questionnaire was sent to 10 organizations from Rio Grande do Sul (RS) in the period between December 2012 and June 2013, being that three WEEE management companies sent back their answers, which were identified in this article as A, B and C.

A multi-level analysis was performed, since according to Yin (2001), it is a strategy to evaluate contemporary events, although it does not allow for statistical generalizations, and aims to discover the points of convergence and divergence of the companies studied. In order to analyze and interpret the data (step 4 of the research protocol), a comparison between the collected information and the data from the literature was performed in similar studies, such as Santos (2012), Virgens (2009), Franco and Lange (2011), Miguez (2007), and Rodrigues (2007). At the end of the study, a table was constructed containing the main results of the research, which were divided into risks and opportunities based on the environmental, social and economic points of view.

5 REPORT OF THE RESPONSES OF WEEE MANAGEMENT COMPANIES

Company A is located in the metropolitan area of Porto Alegre, small-sized, with nine employees. The production process in this company begins in the contact with natural persons and legal entities to survey the materials provided for disposal and definition of the way of col-

lection and transportation to the company. The equipment is stored until disassembly, generating waste that will be sold in the local market or sent abroad (printed circuit boards). The storage of products is performed using bags or stacking them in an orderly way, in the case of monitors and CPUs. After disassembly, the materials are placed in bags or cardboard boxes.

Company A' employees are selected through interviews in order to assess whether the worker's profile is compatible with the role. The first trial period agreement lasts 30 days. The new workers undergo on-site training given by the production supervisor, which shows how to disassemble and sort the waste. In relation to protective equipment, workers wear gloves, goggles, ear protectors and steel-toe boots.

Company A considers that by implementing the PNRS, "there will be a more regulated market, reducing the informal one", since public or private organizations will require guarantees of correct disposal of their equipment. There will be likely an increase in the amount of disposed waste and concentration of waste in the WEEE management companies, which should lead to a growth in the sector.

The second waste management, company B, is also located in the metropolitan area of Porto Alegre. It works only with computers, telephones and batteries, differing from most of its competitors by serving only legal entities. It is a small-sized company with six employees.

The service provided begins with the waste collection in the contractor. When arriving at the management company, the waste is weighed, dismantled and separated into specific containers for each material: plastic, ferrous metal, non-ferrous metal, batteries and printed circuit boards. There is a step for grinding the plastic and damaging hard disk (HD) and mobile devices to avoid undue using of data. According to the company, its role is to "properly allocate each waste and follow the process until this waste becomes raw material for new products". Plastic and metals are shipped to partners in RS, batteries to a specialized company located in Suzano (SP, Brazil), and printed circuit boards to Singapore. The storage of materials is performed in bags and cardboard and plastic boxes. There are exclusive areas for each type of waste, since it is necessary to accumulate a minimum amount before sending to the recyclers.

Employees wear gloves and uniforms with closed shoes at all stages of the process. They also use goggles and ear protectors in part of the process. In relation to collective protection, all areas are marked with yellow stripe and signs indicating what should be placed at each storage location. There is an isolated area for batteries and other fenced and with restricted access. The company hires the employees through interviews and the trainings are performed internally, taught by skilled professional or supervisor. There is concern on how recyclers receiving their separated waste are operated (working conditions and processes), which leads to regular visits to their business partners in order to assess these points.

Company B believes that the regulated PNRS should provide growth in the electronics' recycling sector. Additionally, the informal market will be reduced since it would be necessary to prove that the environmentally correct destinations have been given for the equipment, and only regular companies can obtain the necessary environmental licenses and provide these certificates.

The third organization that participated in the research (company C) is located in the mountain region of Rio Grande do Sul and has seven employees. It performs the on-site collection informed by the client according to a previous schedule by e-mail or telephone, transporting the waste to its headquarters. The input material is sorted and weighed. Thereafter, the equipment is dismantled and the material is stored in pallets, boxes or big bags. Depending on the material type, a decontamination may be necessary. After this process, each type of material is sent to specific recycling companies.

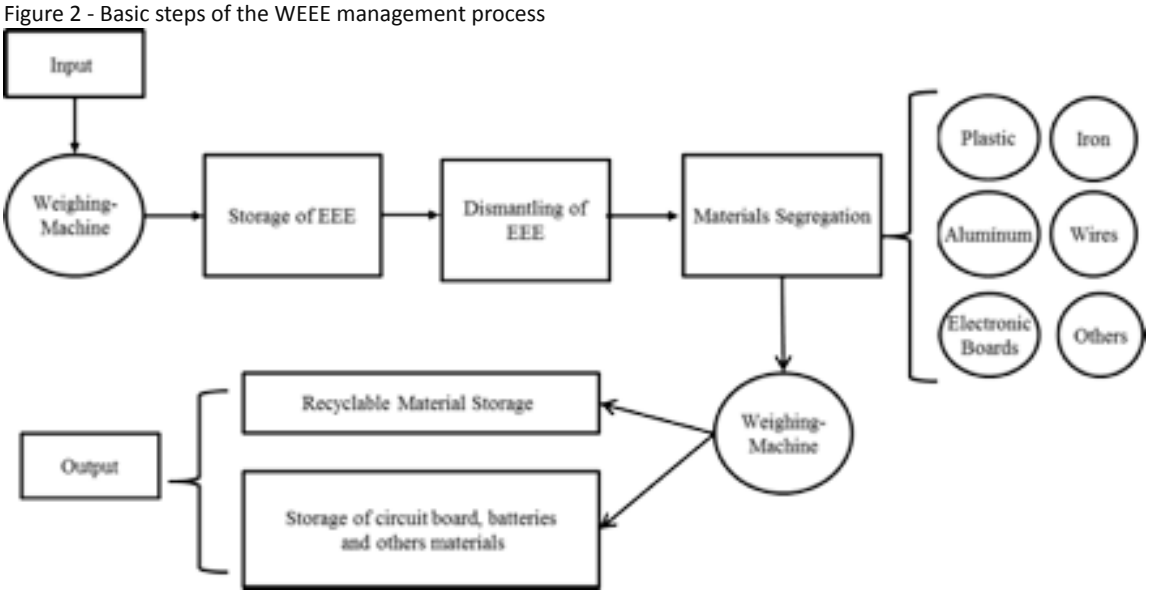
The background of company C' employees is complete high school and with knowledge in operating tools, environmental management systems and previous professional experience of at least one year. Employees are trained in terms of handling, storage and loading of industrial waste, using PPE's such as gloves, goggles, respirators, shoes, industrial coats and helmets. In relation to collective protection, the company has ventilation in the workplace, handrail and guardrails on stairs, signaling tapes, non-slip steps, non-slip flooring and fire extinguishers.

Company C believes that to implement reverse logistics in Brazil for the EEE, a consortium system will be created similar to carbon credit, where manufacturers and importers "will buy e-waste credit from companies that perform this reverse logistics" in accordance with the legislation.

6 DISCUSSION AND ANALYSIS OF RESULTS

In relation to the process of interviewed companies, by analyzing the responses, it is noted that these internal processes of the WEEE management companies are similar. The work flow presented by Dias et al. (2018) has four phases: (i) initial sorting and disassembly; (ii) separation; (iii) recycling; and (iv) refinement. The WEEE managers of the present study perform only the first two phases. In Figure 2 is shown a diagram of this process in the organizations under study, emphasizing the process organized as a production line and using scales in order to control the quantity of input materials and the resulting from the separations by type of material.

Figure 2 - Basic steps of the WEEE management process



In the study conducted by Rodrigues (2007), who interviewed scrap metal pick up and recycling companies in 2005 and 2006, it was commented that the WEEE market is unattractive and unprofitable. One of these organizations pointed out that this type of waste requires skilled labor for dismantling. The lack of environmental commitment by some companies was also evidenced, which reported that the waste was destined to the public cleaning service.

When observing the responses of companies participating in this research, the market view is different. The three companies believe that there will be growth in the WEEE management sector, reduction of the informal market and increase in business due to the promulgation

of the PNRS in 2010. This result is also presented by Santos (2012). It should be noted that when the research was performed by Rodrigues (2007), the policy was negotiated at the national congress for many years, with no real prospects for approval, thus justifying the lack of attractiveness of the sector at that time.

This new reality in the sector has made the CEMPRE, a non-profit organization dedicated to promoting recycling and maintained by private companies from several sectors, to create a committee for discussing the issue of WEEE. The organization highlights that recycling these equipment requires more complex and expensive technologies. It also states that there is too much informality in this market, commercializing products for reuse and disposing irresponsibly this waste. Another important factor is the relationship that consumers have with electronic products, valuing these equipment and storing them, wondering that they may be useful in the future (CEMPRE, 2013; ARENHARDT *et al*., 2016).

Regarding the risks for workers' health, Rodrigues (2007) states neither that all companies participating in their research use personal protective equipment (PPE) adequately or have a suitable work environment. In the research by Santos (2012), one of the waste management companies states that their employees use PPE, but shows a disorganized WEEE storage location. However, the three companies participating in the present study demonstrate concern about workers' PPE, mentioning safety items presented by Silva, Martins and Oliveira (2008). In relation to collective protection, companies operate in large and airy locations, segregating the most aggressive materials in isolated and properly signaled areas. In Table 2 is shown the comparison of survey respondents' responses in relation to employee selection, training, and PPE usage.

Table 2 - Comparison between WEEE management companies

Items	**Company A**	**Company B**	**Company C**
Selection of employees	Interviews	Interviews	Interviews Requires high school and previous experience
Training	In-company	In-company	In-company
Use of PPE	Gloves, goggles, ear protectors and steel-toe boots	Gloves, goggles, ear protectors, closed shoes and uniform	Gloves, goggles, closed shoes, industrial coats, masks and helmets

In companies legally formalized, there are no problems of the same severity as in the informal market. According to Silva, Martins and Oliveira (2008), the scavengers are usually excluded from the labor market, with no education and very low income. These people collect the waste interesting for them before the passage of trucks from the public collection or in the dumps. Such work is unhealthy because there is a risk of these people having illnesses or hurting themselves by flipping the trash, transporting some types of WEEE without safety, and especially by manipulating this waste to extract the most commercially valuable materials.

Franco and Lange (2011) performed a research to evaluate the flow of WEEE in Belo Horizonte (MG, Brazil), conducting interviews with consumers, in waste deposits, cooperatives and non-governmental organizations. The waste deposits visited by researchers showed that they were unprepared to work with WEEE, a feature highlighted in a photograph of a person dismantling an electric motor to remove copper sitting in an inadequate location and without the required PPE. In an interview with a worker from a cooperative, it was reported that, in order to remove the copper from a cathode ray tube, they put the tube inside a plastic bag, wrap it with a plastic canvas, break the glass, and wait for "the dust falls down because it is bad for health".

Then, they remove the desired material and send the (contaminated) glass for recycling. Cooperatives generally receive this waste from companies which transfer their environmental liabilities without any responsibility.

Among the PNRS principles presented in its article 6, there is the value recognition of solid waste from the economic and social point of view, which can generate work, income and promote citizenship (BRASIL, 2010). Therefore, the reduction of the informal market is an expected social benefit from the implementation of reverse logistics for the EEE. It can be noted that the three companies in the present study are formalized and hire workers according to Brazilian labor legislation, providing internal training to qualify them and offering adequate working conditions, unlike the presented by Franco and Lange (2011).

Based on the information from interviewed companies and in the literature review, a summary of Table 3 was prepared, presenting the risks and opportunities of WEEE from an environmental, economic and social point of view.

Table 3 - WEEE risks and opportunities

	Risks	Opportunities
Environmental	Increase of incorrect or illegal disposals resulting from: (a) shorter life cycle of products and hence higher volume of unused electronic equipment; (b) lack of information and environmental education for the population; (c) paucity of collection points.	Reduction of pollution and incorrect disposal of WEEE, besides reduction of landfill volume, as a result of: (a) Improvement of population awareness; (b) implementation of reverse logistics by the sector.
Economic	Cost is not fully known for the implementation of reverse logistics for WEEE, although considered as high by the sector and thus becoming one of the major obstacles to such implementation.	New business derived from the implementation of reverse logistics. Possible savings in the acquisition of recycled or reused raw materials. Possibility of encouraging innovation in order to develop new products less aggressive to the environment.
Social	Continuity of informal and unsafe work in the recycling sector; Unawareness of the risk involved in the handling, transportation and storage of WEEE.	Expansion of the recycling market, with the purpose of proving the correct destination of the waste in order to comply with the legislation. Expansion of formal jobs in the recycling sector, thus contributing to the improvement of workers' living conditions.

7 FINAL CONSIDERATIONS

The topic addressed in the present study is current and has generated discussions in the academic and business world. The repercussion due to approval of the National Policy on Solid Waste is visible in the sector, which seeks alternatives to meet it.

However, it is difficult to implement it, because there is no model defining how the reverse logistics will work in practice. Efforts have been made by the government and society. The Brazilian Association of Technical Standards (ABNT) drew up the NBR 16156: 2013 entitled “Waste Electrical and Electronic Equipment - Requirements for Reverse Manufacturing Activity” with the objective of protecting the environment and controlling occupational safety and health risks applicable to organizations which perform reverse manufacturing of electronic waste (ABNT, 2013). The sector understanding has been coordinated by the Ministry of the Environment and counts on the involvement of society and representative entities of those involved in reverse logistics (SINIR, 2015b). Some cities of Rio Grande do Sul can be mentioned, besides the capital

Porto Alegre, where the city halls participate in campaigns for WEEE collection: Alegrete (2016), Canoas (2016), Farroupilha (2016), Pelotas (2016) and Santo Ângelo (2016).

The population involvement with the correct destination of WEEE needs to be encouraged through activities related to environmental education and publicity campaigns. There is a long way to implement the PNRS and there are obligations for all involved: government, manufacturers, distributors, traders, waste management companies and population. There is a need to know the costs involved, the actual environmental and social impact of the increased generation of this waste, what actions can be taken to minimize these effects, how the collection will be operationalized, how to facilitate the correct disposal by the population, among others.

Based on the social point of view, there is still a great informality in the sector, with scavengers working in unhealthy and inhumane conditions. The positive aspect is the increase of legally installed companies managing waste in recent years. In general, these companies work with regularized and trained labor, using appropriate equipment to perform the work, such as the three companies that participated in the present research. It is also noted the increasing concern of the government and the population in relation to the theme, creating campaigns and expanding the collection of this waste. Another point to be observed is the issue of worker safety, which deals with hazardous materials and, especially in the informality, does not use the necessary PPE and does not know the risks of this work. There is also a need for greater support from governments and manufacturers to reduce informality in the sector, with inclusion policies, financing and partnerships with cooperatives or associations working with this type of waste, as suggested in Article 33 of the PNRS (2010).

The current scenario seems more optimistic from the environmental, social and economic points of view than the previous one to the promulgation of the PNRS. Although there are risks which need to be minimized, there are already actions being implemented and starting to work. The results of the present study also indicate that there are more opportunities than risks perceived by the interviewed companies, signaling a potential growth for the management of WEEE. Taking into account the evolution and technological enhancement, the need for systemic solutions in terms of sustainability for this problem is fundamental, both from public and private points of view.

Only three companies participated in the survey, representing 30% of all the organizations contacted. It becomes a limitation of the research; however, the results presented consider similar studies performed by other authors which are included in the theoretical framework of this article. A generalization of these results is not proposed, but presenting the reality of these small-sized companies located in the axis Caxias - Porto Alegre, in the state of Rio Grande do Sul, Brazil.

Hereafter, it would be interesting to continue the interviews, focusing on cooperatives of scavengers and other small-sized companies, which face budget restrictions for the acquisition of tools and equipment for disassembling, storing and transporting WEEE, in order to obtain more information and enable the comparison with the data already obtained. The follow-up of the sector after implementing the sector agreement, verifying the changes that will appear in the companies of the sector, in the public sphere and in the consumer's behavior is also a possibility of continuity of this research.

REFERENCES

ABDI - Agência Brasileira de Desenvolvimento Industrial. **Logística Reversa de Equipamentos Eletroeletrônicos - Análise de Viabilidade Técnica e Econômica**. Available at: <http://www.mdic.gov.br/arquivos/dwnl_1362058667.pdf>. Accessed: 28 mai 2015.

ABNT - Associação Brasileira de Normas Técnicas. **Resíduos de Equipamentos Eletroeletrônicos – Requisitos para atividade de manufatura reversa**. Available at: <http:www.abnt.org.br>. Accessed: 10 out 2013.

ALEGRETE. **Neste mês, inicia campanha de recolhimento de lixo eletrônico**. Available at: <http://alegretetudo.com.br/em-outubro-inicia-campanha-de-recolhimento-de-lixo-eletronico/>. Accessed: 07 fev 2016.

ANATEL - Agência Nacional de Telecomunicações. **Acessos de telefonia móvel no Brasil**. Available at: < https://www.anatel.gov.br/dados/destaque-1/283-acessos-smp>. Accessed: 26 dez 2019.

ARAÚJO, M.G.; MAGRINI, A.; MAHLER, C.F.; BILITIEWSKI, B. A model for estimation of potential generation of waste electrical and electronic equipment in Brazil. **Waste Management.** v. 32, p. 335–342, 2012.

ARENHARDT, D.L.; DAMKE, L.I.; RODRIGUES, L.A.; DILL, R.A.; TREVISAN, M. Comportamento, atitudes e consciência ambiental quanto ao descarte de telefones celulares: um estudo quantitativo na Cidade de Santa Maria, Rio Grande do Sul. **Rev. Adm. UFSM**, Santa Maria, v. 9, Ed. Especial, p. 43-60, AGO. 2016.

BHUTTA, M.K.S.; OMAR, A.; YANG X. Electronic Waste: a growing concern in today´s environment. **Economic Research International**. v. 2011. Id 474230. 8 pages.

BRASIL. **Lei nº 12.305. Política Nacional de Resíduos Sólidos**. 2 ago 2010.

CANOAS. **Canoas organiza Campanha de Recolhimento de Resíduos Eletrônicos**. Available at: <http://www.canoas.rs.gov.br/site/noticia/visualizar/idDep/16/id/2594>. Accessed: 07 fev 2016.

CARVALHO, T. C. M. B.; XAVIER, H. L. **Gestão de Resíduos Eletroeletrônicos: Uma abordagem prática para a sustentabilidade**. Rio de Janeiro: Elsevier, 2014.

CEMPRE. **Compromisso Empresarial para reciclagem**. Available at: <http://www.cempre.org.br/ComiteEletronicos.php>. Accessed: 7 jan 2013.

CERVO, A. L.; BERVIAN, P. A.; SILVA, R. **Metodologia Científica**. 6ª ed. São Paulo: Pearson Prentice Hall, 2007.

DE BRITO, M. P.; DEKKER, R. **A Framework for Reverse Logistics**. Eramus Research Institute of Management (ERIM). ERS-2003-045-LIS. 2003.

DEJOURS, C. **A banalização da injustiça social**. 7ª ed. Rio de Janeiro: Editora FGV, 2006.

DEMAJOROVIC, J.; MIGLIANO, J.E.B. Política Nacional De Resíduos Sólidos e suas implicações na

cadeia da logística reversa de microcomputadores no Brasil. **Gestão & Regionalidade**, v. 29, n. 87, p. 64-80, set-dez, 2013.

DIAS, P.; MACHADO, A.; HUDA, N.; BERNARDES, A.M. Waste electric and electronic equipment (WEEE) management: A study of the Brazilian recycling routes. **Journal of Cleaner Production,** v.174, p. 7-16, 2018.

ECHEGARAY, F.; HANSSTEIN, F.V. Assessing the intention-behavior gap in electronic waste recycling: the case of Brazil. **Journal of Cleaner Production,** v.142, p. 180-190, 2017.

ECOPROFETAS. **Moradores de rua de Porto Alegre reciclam seis toneladas de eletroeletrônicos por mês com apoio técnico do EcoProfetas.** Available at: <http://www.ecoprofetas.org.br/2015/01/moradores-de-rua-de-porto-alegre.html>. Accessed: 28 mai 2015.

EUROPEAN COMISSION. **Legislação**. Available at: <www.ec.europa.eu>. Accessed: 22 dez 2012.

FARROUPILHA. **Campanha de Coleta de Lixo Eletrônico**. Available at: <http://farroupilha.rs.gov.br/novo/meio-ambiente/campanha-de-coleta-de-lixo-eletronico/>. Accessed: 07 fev 2016.

FERREIRA, J.M.B.; FERREIRA, A.C. A sociedade da informação e o desafio da sucata eletrônica. **Revista de Ciências Exatas e Tecnologia**. v. III, nº 3, p. 157-170, 2008.

FRANCO, R.G.F.; LANGE, L.C. Estimativa do fluxo dos resíduos de equipamentos elétricos e eletrônicos no município de Belo Horizonte, Minas Gerais, Brasil. **Eng Sanit Ambient**. v.16. n. 1. p. 73-82. jan/mar 2011.

GIL, A. C. **Como elaborar projetos de pesquisa**. 5. ed. São Paulo: Atlas, 2008.

HUISMAN J.; *et al.* **Review of Directive 2002/96 on Waste Electrical and Electronic Equipment (WEEE).** Bonn: United Nations University, 2007.

IBGE. **Censo Demográfico 2010**. Available at: <http://www.ibge.gov.br/home/ estatistica/populacao/censo2010/default.shtm>. Acesso em 05 mar 2016.

IBGE. **Pesquisa Nacional por Amostra de Domicílios – PNAD**. Available at: < https://www.ibge.gov.br/estatisticas/sociais/trabalho/ 19897-sintese-de-indicadores-pnad2.html?edicao=9129&t=resultados>. Acesso em 27 dez 2019.

IPEA. **Situação social dos catadores e catadoras de material reciclável e reutilizável – Região Sul.** Available at: <http://www.ipea.gov.br/portal/ index.php?option =com_content&view=article&id=19733>. Acesso em 17 mai 2015.

LAVEZ, N.; SOUZA, V.M.; LEITE, P.R. O papel da logística reversa no reaproveitamento do "lixo eletrônico" – um estudo no setor de computadores. **Revista de Gestão Social e Ambiental - RGSA**, São Paulo, v.5, n.1, p. 15-32, jan./abr., 2011.

LEITE, P.R. **Logística Reversa:** meio ambiente e competitividade. São Paulo: Pearson Prentice Hall, 2009.

MARCONI, M.A.; LAKATOS, E.M. **Técnicas de pesquisa**. 7ª ed. São Paulo: Atlas, 2009.

MATTAR, F. N. **Pesquisa de Marketing**. Edição Compacta. São Paulo: Atlas, 1996

MIGUEZ, E.C. **Logística Reversa de Produtos Eletrônicos: benefícios ambientais e financeiros.** Dissertação de Mestrado em Engenharia de Produção. Universidade Federal do Rio de Janeiro. 2007.

OLIVEIRA, C.R.; BERNARDES, A.M.; GERBASE, A. E. Collection and recycling of electronic scrap: A worldwide overview and comparison with the Brazilian situation. **Waste Management**. V. 32. N. 8. P. 1592-1610. 2012.

OLIVEIRA, L.H.; CHIESI, F.K.;BARBIERI, J.C. Manufatura reversa e gerenciamento de resíduos eletroeletrônicos: o Caso da Oxil. In: XXIII ENANGRAD – Encontro Nacional dos Cursos de Graduação em Administração. **Anais***.* Bento Gonçalves, 2012.

PELOTAS. **Lixo eletrônico pode ser entregue no Mercado Central**. Available at: <http://www.pelotas.rs.gov.br/noticias/detalhe.php?controle=MjAxNS0wNi0xNg==&codnoticia=39235>. Accessed: 07 fev 2016.

PÉREZ-BELIS, V.; BOVEA, M.D.;IBÁÑEZ-FORÉS, V. An in-depth literature review of the waste electrical and electronic equipment context: Trends and evolution. **Waste Management & Research** 2015, Vol. 33(1) 3–29.

PNUMA. **Illegally Traded and Dumped E-Waste Worth up to $19 Billion Annually Poses Risks to Health, Deprives Countries of Resources, Says UNEP Report.** Available at: <http://www.unep.org/chemicalsandwaste/hazardoussubstances/News/PressRelease/ tabid/425/language/en-US/Default.aspx?DocumentID=26816&ArticleID=35021&Lang=en>. Accessed: 29 mai 2015.

PORTO ALEGRE. **Coleta itinerante de resíduos eletrônicos**. Available at: <http://www2.portoalegre.rs.gov.br/dmlu/default.php?p_secao=192>. Accessed: 28 mai 2015.

_____ **Arrecadação recorde na feira de descarte contabiliza 35 toneladas**. Available at: <http://www2.portoalegre.rs.gov.br/dmlu/default.php?p_noticia=153155&ARRECADACAO+RECORDE+NA+FEIRA+DE+DESCARTE+CONTABILIZA+35+TONELADAS>. Accessed: 27 mai 2013.

RODRIGUES, A.C. **Impactos socioambientais dos resíduos de equipamentos elétricos e eletrônicos: estudo da cadeia pós-consumo no Brasil.** Dissertação de Mestrado. Programa de Pós-graduação em Engenharia de Produção. Universidade Metodista de Piracicaba/SP. 2007.

SANTO ÂNGELO. **Sema e Sindilojas realizam Campanha de Recolhimento de Lixo Eletrônico.** Available at: <http://demo.abase.com.br/pcm_pmsantoangelo/Visualiza Noticia.aspx?ID=9423>. Accessed: 07 fev 2016.

SANTOS, C.A.F. dos. **A gestão de resíduos eletroeletrônicos e suas consequências para a sustentabilidade: um estudo de múltiplos casos na região metropolitana de Porto Alegre.** Dissertação de Mestrado. Programa de Pós-graduação em Administração. Federal University of Rio Grande do Sul. Porto Alegre, 2012.

SIGRIST, C.S.L.; FONSECA, L.F.B.; VEIGA, J.M.; PAIVA, J.M.F.; MORIS, V.A.S. Desenvolvimento de ponto de coleta de Resíduos Eletroeletrônicos. **Revista Eletrônica em Gestão, Educação e Tecnologia Ambiental**. v. 19, n.2, p. 1423-1438, mai – ago.. 2015.

SILVA, B.D.; MARTINS, D.L.; OLIVEIRA, F.C. **Resíduos Eletroeletrônicos no Brasil**. Available at: < http://lixoeletronico.org/system/files/lixoeletronico_02.pdf>. Accessed: 10 jan 2013.

SINIR. **Deliberações do Comitê Orientador**. Available at: <http://sinir.gov.br/ web/guest/ deliberacoes-comite-orientador>. Accessed: 28 mai 2015.

_____ **Logística Reversa**. Available at: <http://sinir.gov.br/ web/guest/logistica-reversa>. Accessed: 28 ago 2017.

_____ **Acordo setorial para implantação de sistema de logística reversa de produtos eletroeletrônicos de uso doméstico e seus componentes**. Available at: < https://sinir.gov.br/ component/content/article/2-sem-categoria/474-acordo-setorial-de-eletroeletronicos>. Accessed: 26 dez 2019.

VIRGENS, T.A.N. **Contribuições para a Gestão de Resíduos de Equipamentos Elétricos e Eletrônicos: Ênfase nos Resíduos Pós-consumo de Computadores**. Dissertação de Mestrado em Engenharia Ambiental Urbana. Universidade Federal da Bahia. Escola Politécnica. 2009.

YIN, R. K. **Estudo de caso:** planejamento e métodos. Porto Alegre: Bookman, 2001.

Contribution of authors

Contribution	[Author 1]	[Author 2]	[Author 3]
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. Other (please specify)			