An Action Research Study for Elaborating and Implementing an Electronic Waste Collection Program in Brazil

Roberta Alves, Karen Lana Alves Ferreira, Renato da Silva Lima & Flavia Tuane Ferreira Moraes

Systemic Practice and Action Research

ISSN 1094-429X

Syst Pract Action Res
DOI 10.1007/s11213-019-09509-5

Springer

Systemic Practice and Action Research
https://doi.org/10.1007/s11213-019-09509-5

ORIGINAL PAPER

An Action Research Study for Elaborating and Implementing an Electronic Waste Collection Program in Brazil

Roberta Alves[1] · Karen Lana Alves Ferreira[1] · Renato da Silva Lima[2] · Flavia Tuane Ferreira Moraes[2]

Published online: 17 December 2019

Abstract
The objective of this study was to conduct Action Research (AR) to create and implement a WEEE management program that was in line with the BNPSW regulations. The city chosen for this study was São João del Rei (SJDR) located in the state of Minas Gerais, Brazil. Using AR it was possible to structure a WEEE management program that involved stakeholders from the city administration, the Federal University of São João del Rei, and representatives from the private sector. The program ultimately collected 1710 kg of WEEE that received an environmentally appropriate destination. Although no major difficulties were observed with respect to the AR process itself, some challenges were encountered. Lack of infrastructure and hesitance on behalf of the public with respect to implementing WEEE Reverse Logistics were complicating factors. The action research as methodology proved to be highly efficient in dealing with e-waste reverse logistics. It resulted in faster decision making, in turn generating better results. Good decisions were repeated and errors were corrected. The Action Research project highlighted the need for raising public awareness about WEEE disposal. It also showed that the public was ultimately interested in participating and contributing to the proposed WEEE management program. The awareness of the population has led to a significant increase in the amount of collected waste. The model resulting from this research serve as a reference for decision makers in implementing similar programs around the world and to contribute to the existing body of knowledge on the subject.

Keywords Waste electrical and electronic equipment (WEEE) · Managing e-waste · Reverse logistics · Action research

✉ Roberta Alves
robertaalves@ufsj.edu.br

Extended author information available on the last page of the article

Introduction

Waste Electrical and Electronic Equipment (WEEE), also called electronic waste or e-waste, is the name given to all electrical and electronic equipment that reaches the end of its useful life cycle (Oteng-Ababio 2012; Paes et al. 2017). This waste may consist of materials that have economic value such as metals and plastics. By contrast, this waste also contains toxic substances like heavy metals and brominated flame retardants that can harm the environment and pose public health risks (Garlapati 2016). Proper WEEE disposal techniques should, therefore, be a constant societal concern and priority. According to Orlins and Guan (2016), efficient WEEE management systems must be developed to promote recycling and reduce negative impacts caused by this waste.

New technologies, the growth of the electronics industry, and increasing product versatility along with obsolescence of certain electronic products have all contributed to rises in Waste Electrical and Electronic Equipment (WEEE) worldwide (Babu et al. 2007; Migliano et al. 2014). According to Garlapati (2016), developing countries will produce twice as much WEEE as developed countries in 6 to 8 years. It is estimated that by 2030 developing countries will discard between 400 and 700 million obsolete computers, while developed countries will cut their WEEE by around 200 or 300 million units (Sthiannopkao and Wong 2013; Garlapati 2016).

Developed countries have had to deal with WEEE for quite some time now. The European Union, for example, has instituted the European Union Directive on WEEE. This holds manufacturers, governments, and consumers accountable for waste management (Qu et al. 2013). Developing countries, by contrast, have more problems with managing WEEE. These troubles arise principally from the reluctance to pay for recycling and disposing waste, an over dependence on outdated electronic equipment, a lack of investment in recycling, the lack of recycling and waste management infrastructures, inefficiencies in collecting or recycling programs, a lack of interest in WEEE management on behalf of multinational companies in developing countries, importing WEEE, and finally the absence of laws specifically addressing WEEE (Nnorom and Osibanjo 2008).

In Brazil, recovering and recycling WEEE is hampered by the absence of efficient management systems (Govindan et al. 2013; Silveira 2013; Pereira and Silveira 2014; Cardoso et al. 2017; Furtado and Rodrigues 2017). According to Souza et al. (2016), Brazil has one of the highest WEEE generation rates, around 7 kg per capita. The country has very few waste management programs in place, leading to large amounts of WEEE ending up in landfills (Araújo et al. 2012; Souza et al. 2016). It is therefore very important to adopt Reverse Logistics (RL) principles for recycling and reusing WEEE (Ayvaz et al. 2015; Cardoso et al. 2017), applied to a collection system that includes private citizens, private industries, distributors, and governments (de Oliveira et al. 2012) as required by the Brazilian National Policy on Solid Waste (BNPSW).

The BNPSW stipulates that Brazilian cities must act directly in managing any waste generated within their territories (Brazil 2010). Paes et al. (2017) state however that laws do not guarantee that waste will be disposed of properly. Even since the BNPSW, recycling efforts are often hampered by incompatibilities between guidelines and disposal procedures. Despite the legal framework for implementing WEEE RL systems, Brazil still has trouble properly allocating this waste (Kiddee et al. 2013; Paes et al. 2017). Information gaps and a lack of WEEE management programs have had detrimental results for collecting and disposing of this waste. These facts serve to justify studies that evaluate and present solutions to the WEEE problems in Brazil, especially since information gaps have led to very unfavorable scenarios

with respect to promoting recycling programs within the country (Silveira 2013; Furtado and Rodrigues 2017; Dias et al. 2018).

The main studies on the management of WEEE in developing countries involve mainly data collection. Qu et al. (2013), for example, studied the management of WEEE in China by means of interviews and secondary sources (government sites and technical publications). It has also been found review papers and overviews about the state of knowledge of e-waste and estimation of WEEE generation. (Nnorom and Osibanjo 2008; Babu et al. 2007; Garlapati 2016; Araújo et al. 2012). Other research proposed a generic model of Reverse Logistics Network Design (Ayvaz et al. 2015). Although these studies showed the problem and needs of RL of WEEE, they did not show practical solutions for the management. Paes et al. (2017) obtained significant results in Action Research for the management of WEEE in a Brazilian public university. However, it is possible to observe the need for studies that show practical results and guide the development of future management systems of WEEE. In this way, it is interesting to use the research for the management of municipal WEEE.

Action Research (AR) has been very useful in the past for structuring and implementing waste collection and management programs (Bernardo and da Silva 2017; Fagundes et al. 2017; Paes et al. 2017). Additionally, AR can help adapt these programs to the BNPSW norms since AR promotes faster decision making. Positive actions can be repeated and errors can be corrected, both during and between cycles (Bernardo and da Silva 2017). Decision markers can improve processes and direct future actions by promoting integration among those involved in management, AR and organizational learning processes (Paes et al. 2017).

The objective of this study was to conduct Action Research (AR) to create and implement a WEEE management program that was in line with the BNPSW regulations. This was done in the city of São João del Rei (SJDR), located in the Southeastern region of Brazil. AR is used to acquire knowledge for constructing management models. Our proposed model encompassed a wide array of participants in SJDR who were responsible for managing WEEE. These participants included the city government, the Federal University of São João Del Rei, and representatives from the private sector. Our model also took public awareness into account, and determined that it was one of the key factors for efficiently implementing WEEE management programs in the city of SJDR.

The Brazilian National Policy on Solid Waste (BNPSW) and Managing Waste Electrical and Electronic Equipment (WEEE)

The Brazilian National Policy on Solid Waste (BNPSW) regulates waste management in Brazil. It has been in effect since 2010. The BNPSW brings together a set of principles, objectives, instruments, guidelines, goals, and actions that seek to manage solid waste in Brazil. The policy introduces the concept of Shared Responsibility in waste management. In other words, consumers, producers, distributors, and retailers all have responsibilities with respect to waste management. Reverse Logistics can be used as an economic and social tool. It can be defined as a set of actions designed to collect and return waste for reuse, or to make recycling feasible, resulting in the proper disposal of products. Brazilian cities are also responsible for drafting and implementing Integrated Solid Waste Management Plans (ISWMPs), which should contain guidelines for RL systems at the local level. Cities are not only responsible for collecting, transporting, and disposing of waste, but also for creating citywide programs that involve entire communities, companies, and cooperatives in order to promote recycling and proper waste disposal (Brazil 2010).

The BNPSW makes manufacturers, importers, distributors and merchants responsible for creating RL systems for WEEE. It also makes it mandatory for them to implement these RL systems. It does not, however, outline specific guidelines for disposing WEEE (Souza et al. 2015). As a result, consumers (institutions and the public alike) are responsible separating and delivering WEEE to appropriate predetermined drop-off points that are to be set forth in the ISWMPs. Retailers and distributors operating in the electronics sector are also responsible for returning products to producers or importers who should then properly allocate this WEEE (Souza et al. 2016).

Fully aware of the difficulties highlighted in several studies (Townsend 2011; de Oliveira et al. 2012; Kiddee et al. 2013; Migliano et al. 2014; Garlapati 2016; Cardoso et al. 2017; Furtado and Rodrigues 2017) we conducted Action Research (AR) to demonstrate how this type of research can aid in implementing WEEE collection programs. AR aids in better understanding city and state demographics. Additionally, it aids in making people more aware of these programs and identifies the key players who might help in making waste management more efficient.

Action Research

Action Research (AR) was used in this study as the basis for developing a collections and waste management program for WEEE located in the city of São João Del Rei, Brazil. According to Fagundes et al. (2017) positive results have been obtained before when using AR in RL waste management programs since AR helps solve existing problems by implementing improvements with the added benefit of acquiring scientific knowledge. Studies by Paes et al. (2017), Cullen et al. (2013) and Hameri and Paatela (2005), confirm the efficiency of AR applied to RL.

Westbrook (1995) points out that there is no global standard to follow when developing AR; rather there are some basic steps that should be followed when using this methodology. The AR conducted in this study followed steps proposed by Fagundes et al. (2017) which are as follows: Step (1) Action Research Planning; Step (2) Data Collection Planning; Step (3) Data Analysis and Action Planning; Step (4) Implementing the Action Plan; Step (5) Assessment of the Results. Figure 1 shows the steps followed in this study.

In the next sections, the study will follow the steps showed below:

- Action Research Planning: the step in which we understand the problem (Sect. 3.1).
- Data Collection Planning: the step where we planned the Action Collect (Sect. 3.2)
- Data Analysis and Action Planning (Sect. 3.3)
- Implementing the Action Plan: in this step, we compile the main information and start the Action Planning (Sect. 3.4)
- Assessment of the Results: in this step, we analyze the results and evaluate what we have learned from the Action research (Sect. 4)

Action Research Planning

The first step in AR planning revolves around understanding the context of the problem and the goal, as well as establishing the Action Research team (AR team). Our AR study initiated with the university administration and the IT sector of the university. The latter had already

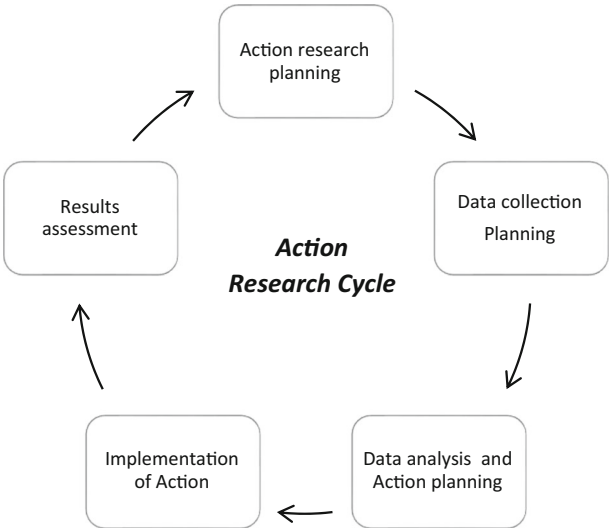

Fig. 1 Stages used in developing AR. Source: Adapted from Mello et al. (2012) and Fagundes et al. (2017)

realized that WEEE was a problem at UFSJ, and that it extended beyond the campus limits into the city of São João del Rei. The administration gathered a team of four researchers from the Institute of Industrial Engineering and Management, who were specialists in Reverse Logistics (RL) and Waste Management, to look for a solution to the problem.

University-generated WEEE had long been stored in a warehouse. The waste had been in storage for so long because there was a minimum weight requirement (1500 kg) for picking up and transporting it, due to high transportation costs. After such a long time in storage and given the lack of a suitable storage place, much of the equipment was destroyed due to weather exposure, ultimately resulting in economic losses and risks to public servants, students, and/or anyone who frequented the campus.

The problem was presented to the researchers and the team visited the warehouse where the WEEE was stored. After the initial inspection of the waste the following question was elaborated:

- How might we more adequately dispose of the WEEE generated at the University and in the city of São João del Rei?

After the first inspection the team identified that any immediate solution would imply regularly meeting the minimum weight requirement of 1500 kg so that waste could be collected more frequently. One way to collect more WEEE would be to create collection programs in São João del Rei, especially given the fact that the city did not have any structured programs for managing WEEE in place, despite the BNPSW guidelines. Four researchers formed the AR team and were given full responsibility for carrying out AR to assess the viability of any collection program that was to be implemented.

The team plans to develop a WEEE management program that ensures an efficient reverse logistics system. In this way, it enables the proper disposal of waste, the active participation of the population, private sector and public administration.

The researchers began with the WEEE problem in the city São João del Rei. SJDR is a medium-sized city in the state of Minas Gerais, Brazil. It is located 473 km from the city of São Paulo, and 335 km from Rio de Janeiro, the two largest cities in Brazil. The city currently has a population of 89,832 inhabitants, a total land area of 1,452,002 km^2, most of which is historical (IBGE 2015).

Data Collection Planning

During the data collection phase, the AR team sought out information on opportunities for improving RL processes for WEEE. Data was collected by observing processes, conducting individual interviews, and distributing questionnaires.

The team contacted a recycler who was interested in increasing WEEE collection. The recycler participated in the SJDR collection program and provided information on collection processes. The partnership between recycler and AR team was important because it made possible disposal and recycling.

In addition the partnership with the recycler, public participation was a determining factor in satisfactorily implementing the collection program. The AR team decided that it would be important to survey public interest in WEEE management programs. A questionnaire led to the team creating a management program that took city-specific characteristics into account. The questionnaire sought information on the following items: (i). the profile of the interviewees; (ii) their knowledge about WEEE; (iii) the problems caused by WEEE; (iv) the current WEEE disposal facilities in São João del Rei and (v) interest in participating WEEE management programs. The questionnaire was prepared and applied by the AR team. The sample size that statistically validates the study was defined based on Gil (2008). We used formula (1):

$$n = \left(\frac{Z_{\alpha/2}.\sigma}{E}\right)^2 \tag{1}$$

Where:

- n = is the sample size
- Z = Normal distribution of probability that establishes a 100 (1-α) confidence level;
- E = the desired margin of error
- σ = the Standard Deviation of the Population for the variable under studied

A confidence level of 95% (Z = 1.96) was established, as well as a sample E (error) of 10% for this calculation. The population size was obtained from the Brazilian Institute of Geography and Statistics (IBGE) database. Given that the selection process for the population was based on a method of simple random sampling, the sample size was 384 people from different neighborhoods throughout the city.

Having all the necessary data in hand, the team set up a meeting with the city's environmental Secretary to present their findings and to establish a partnership with city management.

Data Analysis and Action Planning

In this phase (Data Analysis) of the AR project the main objective of the team was to compile the most relevant information obtained from meetings with the city's environmental Secretary,

the recycler, and from the questionnaires distributed to the public. The profile of the interviewees is presented in Fig. 2.

With respect to public awareness surrounding WEEE (Fig. 3), it was clear that the public needed to be better informed about WEEE practices. Although 85.7% of those interviewed claimed that they knew what WEEE is, only 4.7% truly accurately identified WEEE (all items presented to the public were WEEE items excluding incandescent light bulbs). Most respondents recognized that WEEE could potentially cause various problems (Fig. 3). However, there were few who could specifically identify these problems since only 19.5% of those surveyed marked all of the options.

On the questionnaire respondents could select more than one option when asked about where they thought WEEE should be delivered (Fig. 4a). The results showed that most respondents incorrectly dispose of their WEEE. With respect to the difficulty of disposing other types of waste (Fig. 4b), the interviewees were presented with other waste types included on the BNPSW list, items which need special treatment and must undergo RL processes. It was clear that, like WEEE, respondents found it difficult to properly dispose of such materials.

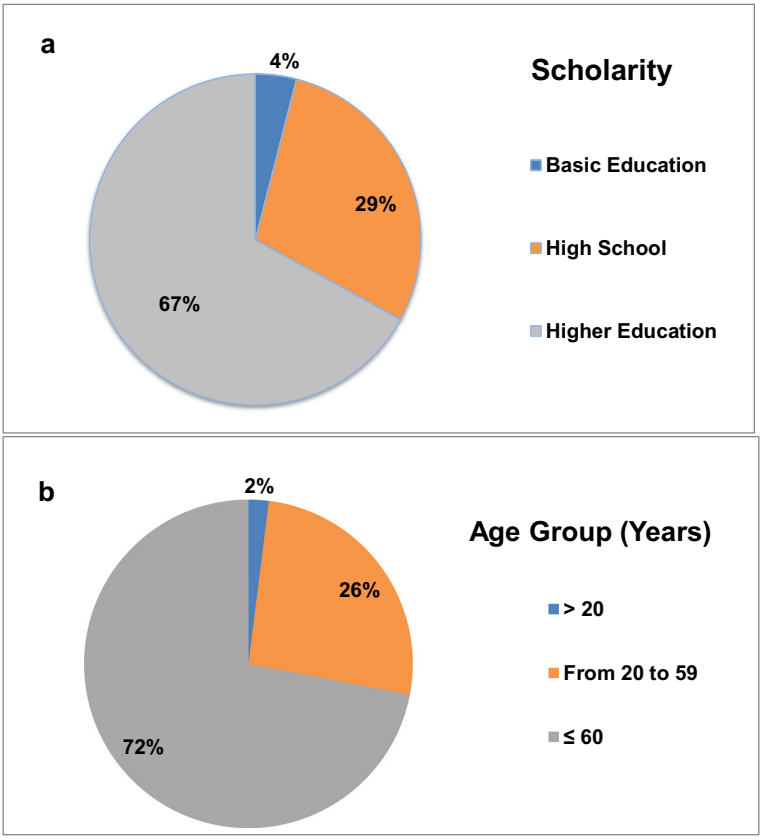

Fig. 2 Profile of respondents

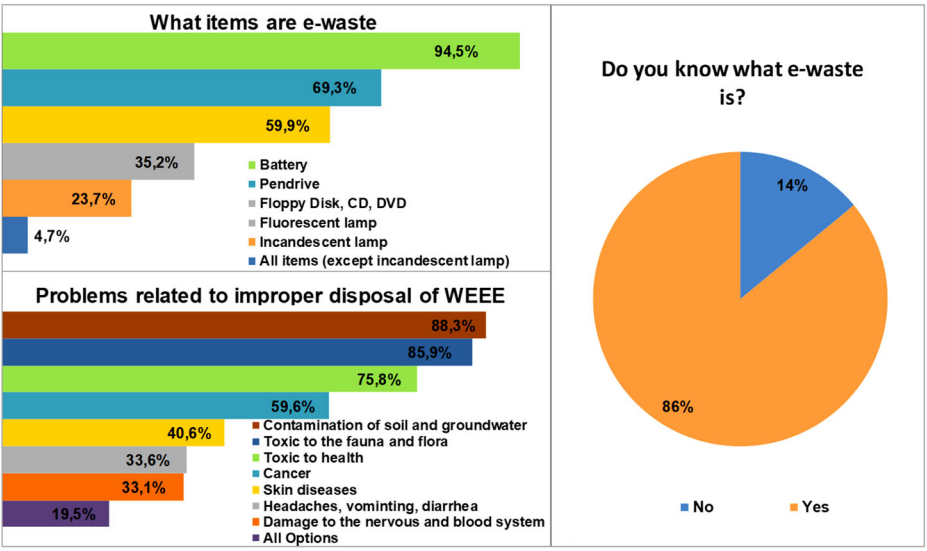

Fig. 3 Degree of knowledge about WEEE

Finally, the participants were asked if they knew of any collection points in SJDR where they could dispose of their WEEE. Most people questioned (97%) expressed interest in learning how to properly dispose of WEEE.

After conducting the interviews the AR team had obtained enough information to start designing the collection plan. They also realized that, even though most of interviewees were well educated, they still had doubts about WEEE classifications and the environmental risks WEEE can cause. The interviews showed that the public was interest in learning how to correctly dispose of WEEE. The AR team then met with officials from the office of the environmental Secretary in SJDR to present the results of the survey.

Public officials explained that one of the reasons for not having an WEEE recycling program in place was the lack of a selective collection system. All generated waste was collected by conventional trucks, and was not subjected to any type of separation process. After collecting the waste, it was sent to the city landfill without any special treatment. Such practices go against the guidelines set forth in the BNPSW. They public officials also informed the team that WEEE programs must include several participants, not only the city administration since the administration changes with each election, making it difficult to continue programs. Officials stated that they believed the program would last longer if it were connected to the University. The process mentioned by public officials was confirmed by the AR team in a visit to the municipal landfill.

After having considered all the points set forth by the stakeholders, Action Planning then began. The AR team decided they would collect WEEE from the public via a voluntary delivery event (collection day). The day chosen for the event was a Saturday by recognizing that most people do not work Saturdays, and take the day to go downtown to shop etc. The setting for the event was set at the city plaza located on a busy downtown street near to several shops with sufficient parking space available. The recycler also agreed to the date and the time. The recycler did not agree, however, to accept light bulbs, since he did not specifically work with any company capable of recycling this type of waste. Additionally, there is another company in SJDR that collects these bulbs.

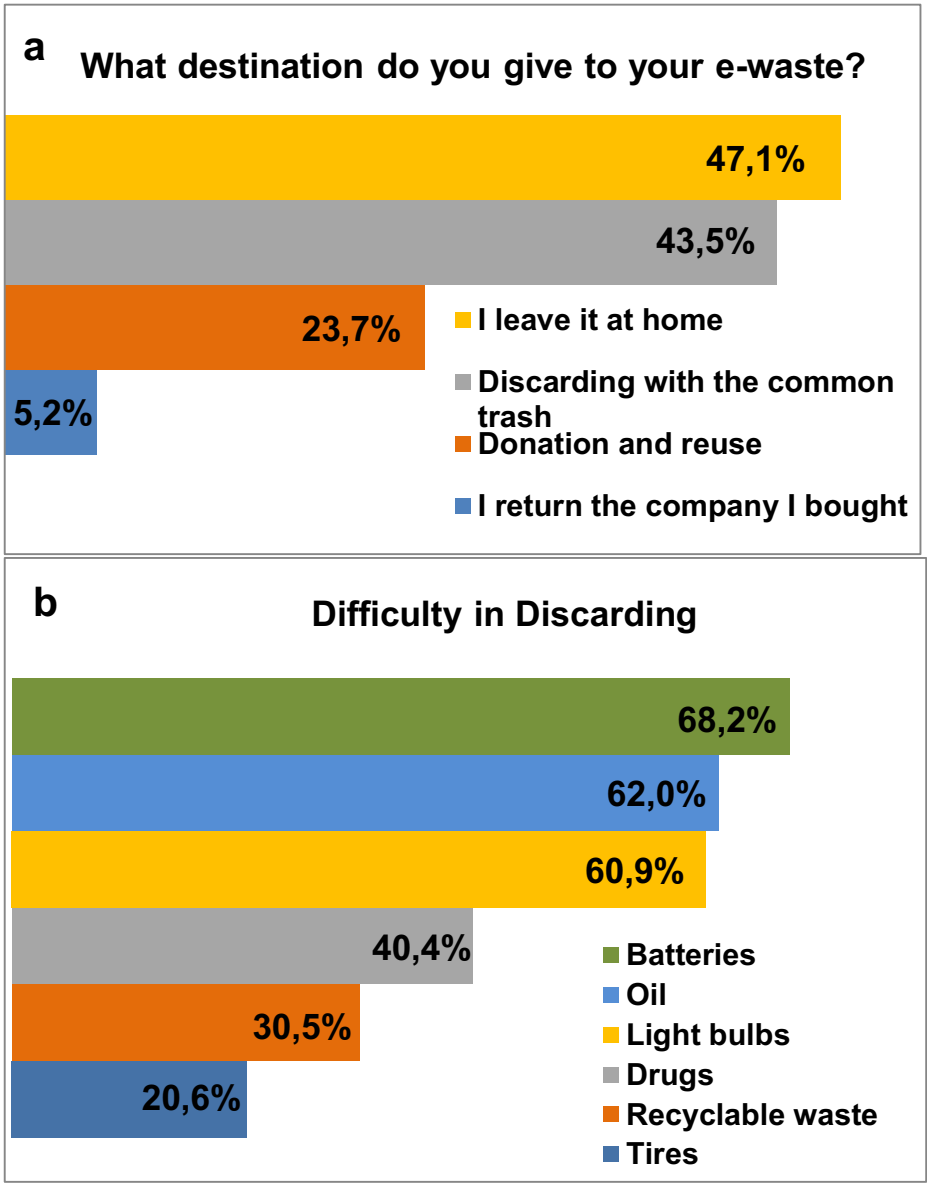

Fig. 4 Waste disposal and difficulty of disposal

A public awareness campaign was devised to advertise the collection and to maximize public participation. The campaign was advertised via pamphlets, posters, radio, and through social media networks.

Action Implementation

After the planning phase the AR team then set out to put the plan into action. Actions were divided into two stages: actions that preceded the collection day, and actions aimed at

disseminating information to the public and clarifying their doubts about the planned WEEE collection day.

Disclosure of WEEE Collection

As observed from the questionnaires, the public was very interested in learning how to properly dispose of their WEEE. However, they did not have adequate knowledge on the subject. To clarify these doubts and to promote the event, leaflets and posters were distributed to establishments in the commercial center of the city with the information about the collection day (Fig. 5).

When distributing the leaflets the AR team had another opportunity to clarify any doubts with the public. The team participated in local radio programs and gave interviews to reach a wider audience. During the interviews the team talked about how the collection process would work and emphasized the importance of properly disposing WEEE. The team sought to emphasize the role of the public in the WEEE management process, and to highlight the social, economic, and environmental advantages of WEEE recovery programs.

The objective of this phase was to make the population of São João del Rei aware of the importance of correctly disposing WEEE through public awareness campaigns. This was done in hopes of getting as many people as possible to take their WEEE to the designated location on collection day.

After receiving positive public reaction towards the program, the environmental Secretary committed his full support to the AR team. Despite such a positive show of support, in practice the AR team had problems in dealing with city administration. City hall only allowed the collection event to take place after the AR team requested and filed for a formal permit, complicating the feasibility of the event, proving itself to be somewhat of a weak link in the process.

Collection Day

The WEEE collection took place on Saturday, July 8, 2017 from 8:00 am to 4:00 pm at the Coreto Plaza located in downtown São João del Rei, MG, Brazil. The AR team remained at the site receiving WEEE delivered from the public. Participation in the event was greater than expected.

First, the recycler went to the university campus and collected all of the waste stored in the warehouse. Later, at 5 pm, he drove to Coreto Plazato and collected the WEEE delivered form the public. All of the collected material then underwent a sorting process and was adequately allocated according to its material composition.

Results of the Action Research

The action research generated important results for understanding the actual situation of WEEE management in SJDR. The main result of the action research cycle was understanding the difficulties and needs to make WEEE management efficient. These difficulties were the lack of unity and disinterest of the stakeholders in the implementation of the guidelines established by the BNPSW. Also, it was identified with the action research that the population, although interested, still does not have enough knowledge to fulfill their role in the

Fig. 5 Pamphlets used for advertising

management of this waste. During the Collection Day, it was possible to collect a large amount of waste that would not have been properly disposed if the AR team had not proposed a collection day. The acquired knowledge made it possible the proposition of a model for the management of WEEE. The quantification and classification of collected waste and the management model are presented in Sects. 4.1 and 4.2, respectively.

Collection Day

After implementing the action plan the team began to analyze the results. Table 1 shows data as to the number of items collected.

By analyzing the data in Table 1, one can see that a wide variety of items were collected in the campaign. Also, the fact that many chargers and cellphones were collected indicates that these devises are a major cause for increasing levels of generated WEEE. One can clearly see the effect of planned obsolescence at work. It is interesting to note that many diskettes and items like VCRs were collected, even though these items have been obsolete for quite some time. This further validates the argument that many people end up storing these items at home because they do not have a suitable place to discard them. This was also observed in the questionnaires. The numbers also show that the public tends to actively participate in WEEE processes only when campaigns are well advertised and structured. Structuring a plan and properly advertising it was only possible after having studied the population's characteristics, further highlighting the importance of questionnaires in the AR process.

The higher than expected participation rates show that advertising and awareness campaigns using posts in the city, radio advertisements, etc. were successful. Clarifying doubts about the WEEE campaign and applying questionnaires were determining factors in engaging the public in the campaign. We determined that public awareness campaigns are more effective when the parties involved maintain direct contact with the team, resulting in increased public confidence in the event.

The AR team received positive feedback from the public both during and after the event. The campaign sparked the interest of managers in the neighboring city Coronel Xavier Chaves, as well as the Association of Cities in the Micro-Region of Campos das Vertentes (AMVER). AMVER provides services to 18 cities, including São João del Rei.

Table 1 Materials collected during the campaign and their quantities

Item	Quantity (pieces)	Item	Quantity (pieces)
Cellphones/Smartphones	46	Video Cassettes	7
Chargers	75	Fax Machines	1
Telephones	11	CD Players	1
Intercoms	4	Sound Devices	1
CPUs	11	Speakers	5
Monitors	7	Cameras	6
Keyboards	20	GPS	2
Mouses	23	Electronic Locks	1
Stabilizers	8	Flashlights	2
Modems	7	Sandwich Makers	1
Recorders	13	Blenders	2
Tablets	3	Ironing Machines	3
Notebooks	2	Drinking Fountains	1
Printers	12	Hairdryers	1
Scanners	1	Hair Straighteners	1
Televisions	12	Batteries	100 kg
Controls	38	Electronic Waste Boxes	130 kg
Receivers	24		
DVDs	3		

The association contacted the AR team for details on how collection worked, to learn where and how the waste was allocated, and to form a partnership. AMVER also discussed the possibility of extending the program to neighboring cities. A regional television station became interested in the collection program and offered to cover and publicize future collection events. This first collection made it clear that there is demand for collecting, commercializing, and recycling WEEE, and that people are open to new recycling options. It is therefore necessary to create WEEE recycling programs that conduct regular and periodic collections, especially because those who participated in this collection actually requested such periodic collections.

One interesting note is that the public was not sure which materials to deliver at the collection event despite the awareness campaign. When members of the public arrived at the collection site to deliver their unused devices and saw the variety of waste being delivered, many returned home to collect more waste and returned again to the collection site to leave their waste. Others who could not return asked when the next collection would be. This highlights the need to invest more in public awareness campaigns.

Model

A model was proposed after the first collection in SJDR to continue the program and guarantee its operation. This model is presented in Fig. 6. In the model, a Voluntary Delivery Point (VDP) would be established at the university so the public can deliver their WEEE and store it at a designated area within university until the minimum weight requirement set by the recycler can be met. The model called for further collections similar to that conducted first by the AR team to be carried out periodically.

The program begins by (1) establishing partnerships between the university, City Hall and recyclers, after which time the AR team (2) formulates the WEEE collection program. The public must participate in collections if the program is to work correctly. This implies that (3) the event be promoted via pamphlets, posters, radio, social media networks, or even informational lectures at schools. After being informed of the campaign, the public can then (4) separate and deliver their WEEE to the collection point. To increase public commitment and awareness about programs, periodic collections should be carried out in the city center (5). If the amount of collected waste is insufficient to pay for transportation costs, then (6) public awareness campaigns should continue. Otherwise, (7) collection will be scheduled with the recycler. (8) The recycler will separate and recycle the waste. Seeking to continually improve the program (9) the entire process should be evaluated after it is carried out. If necessary, (10) improvement actions should be implemented to (11) restructure the program.

In the city of Canoas WEEE disposal programs also worked using Voluntary Delivery Posts (VDPs) managed by cooperatives together with the city government (Furtado and Rodrigues 2017), albeit the quantity collected was smaller. These authors emphasized that, even though the city had an action plan for dealing with solid waste and had invested in collecting solid waste, RL for WEEE had not been well defined. Lack of community awareness about collection points was a determining factor in the low volume of WEEE collected by the cooperative. This, as we have shown in Step 3, is a crucial step in our model. This step calls for advertising campaigns, town hall discussions, public awareness campaigns regarding sustainability and WEEE programs, along with steps that call for verifying that the program is continually improving.

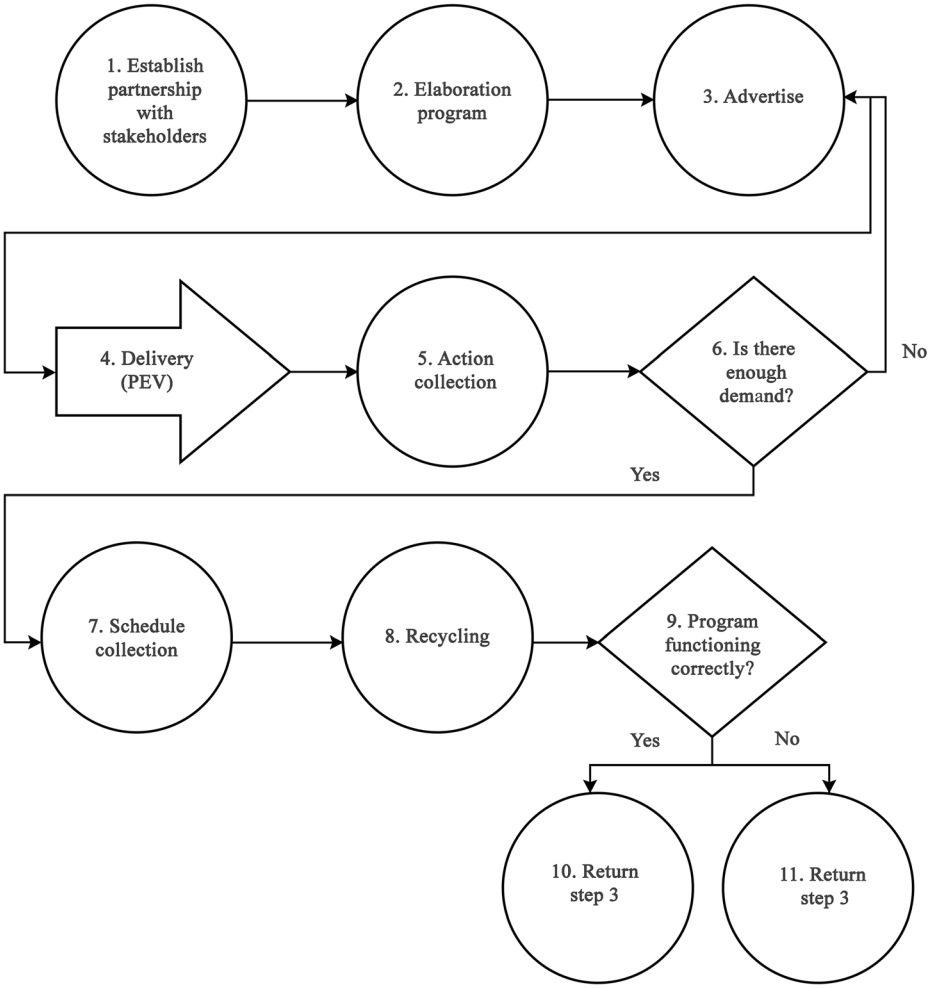

Fig. 6 Proposed WEEE model

Discussion

The Action Research proved to be efficient to identify the main difficulties in RL for WEEE. We identified that the main difficulties were related to joint ventures between municipal administration, recyclers, population and other members of the supply chain. According to Fagundes et al. (2017), RL operations for products at the end of their useful life need to integrate all these actors to be efficient. In this way, it was noticed that the reverse logistics system of WEEE in São João del Rei was not efficient because there were several stakeholders involved that were not dedicated to WEEE management. We observed this in our study as the city administration made certain aspects of the process more bureaucratic, thus demanding more effort from other participants. This study shows that developing actions for recycling WEEE in the city of SJDR was only made possible given the active participation of the University and the researchers there, along with the collaborative participation of the public.

Furtado and Rodrigues (2017) emphasize the difficulties in implementing shared management plans dealing with the end-of-life cycle for products. It is clear that the private sector is not interested in spending their financial resources to meet the BNPSW demands. According to Migliano et al. (2014) manufactures and retailers cannot come to an agreement as to who should cover the transportation costs associated with recycling. Furthermore, the government has not created incentives for collaboration and does not exercise its fiscal and legal powers effectively to implement these measures. Additionally, city authorities tended to create barriers, as was observed in this study.

Action Research as a methodology for dealing with this particular situation proved to be efficient. AR was successfully implemented for the case under study, resulting in an increase in the base of knowledge, bringing about positive changes, which according to Bhatnagar (2017), are the two main objectives for any AR project. Throughout the development of research, no serious obstacles were encountered that could have compromised the AR. Simultaneous research with public institutions, the population, and the private sector do however require special attention. García-Unanue et al. (2015), Holgersson and Melin (2015) and Paes et al. (2017) mention that bureaucracy and lack of flexibility make practical research in public organizations very difficult. This assumption was confirmed in this study. Nevertheless, the study produced satisfactory results being that it was capable of evaluating the actions implemented so that future projects may also apply these cycles to obtain even greater results in less time (Fagundes et al. 2017).

This study stands out from those previously conducted (Bernardo and da Silva 2017; Fagundes et al. 2017; Paes et al. 2017), in that it deals with reverse logistics (RL) for WEEE for an entire city. Action Research (AR) as a methodology is capable of acting on difficulties associated with implementing programs that promote a mixture of conceptual methods with theories and practical methods. When difficulties were identified at each step the researchers dedicated time to analyze existing literature and search for more adequate solutions. This academic foundation assisted in taking faster decisions. One can conclude that both the AR team and AR itself were determining factors in the success of the program.

AR allowed us to propose an independent model for implementing an WEEE recycling program together with the participation of city management. However, the project would have been more efficient if the city administration had more actively participated in the process. The city council could have contributed, for example, by providing a truck to collect the waste. If this had been the case, WEEE collection would not have been restricted to the availability of a particular recycling company. Active participation in the program would have allowed public officials to fulfill their responsibilities under the BNPSW, which holds governments, and companies in the electronics sector responsible for allocating their waste, along with the public, resulting in shared responsibility.

The main objective of this study was to propose a model for WEEE collection, and this was achieved. The Action Research steps were successfully concluded, positively contributing to the body of knowledge by identifying more efficient ways to manage processes. However, more AR cycles are necessary to better structure programs and increase public participation and awareness about WEEE.

In this way, the current study presents some limitations such as the need for the elaboration of more action research cycles and the participation of the municipal administration. Other limitations identified are the lack of knowledge of the stakeholders about the management of WEEE, the unavailability of a recycling company, and the absence of a partnership with a university or other public agency. These limitations may render the application of the model impossible. The lessons learned from this AR study and from this project serve as examples for other cities that need to enact or improve their own reverse logistic processes for WEEE.

Conclusions

Action Research (AR) made it possible to analyze the feasibility of implementing a reverse-logistics (RL) program for WEEE, and contributed successfully to generating actions that positively contributed to the body of knowledge. The lack of public awareness concerning WEEE was evident. Although most of those interviewed (85.7%) believed that they knew what WEEE is, only 4.7% could actually distinguish WEEE from non-WEEE. Only 5.2% of the respondents answered that they properly dispose of their WEEE. Among those interviewed, 47.1% of respondents said they leave their WEEE at home, and 43.5% had either already discarded their WEEE properly or discarded it along with other common waste. Public awareness campaigns are essential to inform the public and dispel doubts as to how one should properly dispose of their WEEE. During this Action Research cycle, public awareness campaigns had a direct positive impact on public participation in the WEEE collection program implemented in this study.

The collection program had positive results being that it resulted in a significant increase in collected waste, and increased public interaction with the AR team. The public had also expressed their dissatisfaction with the WEEE situation in São João del Rei in general. In total, 1710 kg of WEEE were collected.

Public officials were not very active throughout the whole process. Lack of city administration participation can make it difficult to implement programs or make them altogether unfeasible. We emphasize that proposed models alone do not guarantee improvements in WEEE management in the city. All parties must assume their responsibilities and participate actively in management, since collaborative participation is the basis for a sustainable model.

Finally, it is worth mentioning that this Action Research study proved to be very useful in dealing with this type of problem, and we recommended that Action Research be used again when structuring Reverse Logistics for different types of waste. The practical focus of this methodology brings benefits to society directly linked to solid waste management. The unique characteristics of institutions should not be limiting factors. As observed in this study, it is possible to obtain results that are satisfactory for both public and private entities. Conditions must be created so that processes are not only good in theory, but also in practice. This study outlines how Action Research can help accomplish this.

Acknowledgments The authors would like to thank CAPES, CNPq and FAPEMIG, for their financial support of the projects used to develop this study.

References

Araújo MG, Magrini A, Mahler CF, Bilitewski B (2012) A model for estimation of potential generation of waste electrical and electronic equipment in Brazil. Waste Manag 32:335–342. https://doi.org/10.1016/j.wasman.2011.09.020

Ayvaz B, Bolat B, Aydın N (2015) Stochastic reverse logistics network design for waste of electrical and electronic equipment. Res Conserv Recycl. https://doi.org/10.1016/j.resconrec.2015.07.006

Babu BR, Parande AK, Basha CA (2007) Electrical and electronic waste: a global environmental problem. Waste Manag Res 25:307–318. https://doi.org/10.1177/0734242X07076941

Bernardo M, da Silva LR (2017) Using action research to implement selective waste collection program in a Brazilian City. Syst Pract Action Res 30:593–608. https://doi.org/10.1007/s11213-017-9416-9

Bhatnagar VR (2017) Systemic development of leadership: action research in an Indian manufacturing organization. Syst Pract Action Res 30:339–376. https://doi.org/10.1007/s11213-016-9398-z

Brazil (2010) Law no. 12,305, of August 2, 2010. Establishes the National Policy for solid waste and provides other requirements. Casa Civil. http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/l12305.htm. Accessed 11 June 2018

Cardoso G, Neto DO, De Jesus A et al (2017) Resources, conservation & recycling economic and environmental assessment of recycling and reuse of electronic waste: multiple case studies in Brazil and Switzerland. Resour Conserv Recycl 127:42–55. https://doi.org/10.1016/j.resconrec.2017.08.011

Cullen J, Tsamenyi M, Bernon M, Gorst J (2013) Reverse logistics in the UK retail sector: a case study of the role of management accounting in driving organisational change. Manag Account Res 24:212–227. https://doi.org/10.1016/j.mar.2013.01.002

de Oliveira CR, Bernardes AM, Gerbase AE (2012) Collection and recycling of electronic scrap: a worldwide overview and comparison with the Brazilian situation. Waste Manag 32:1592–1610. https://doi.org/10.1016/j.wasman.2012.04.003

Dias P, Machado A, Huda N, Bernardes AM (2018) Waste electric and electronic equipment (WEEE) management: a study on the Brazilian recycling routes. J Clean Prod 174:7–16. https://doi.org/10.1016/j.jclepro.2017.10.219

Fagundes LD, Amorim ES, da Silva LR (2017) Action research in reverse logistics for end-of-life Tire recycling. Syst Pract Action Res 30:553–568. https://doi.org/10.1007/s11213-016-9408-1

Furtado IS, Rodrigues JTMC (2017) A Gestão dos Resíduos de Equipamentos Eletroeletrônicos no Município de Canoas-RS. VII Congresso Brasileiro de Engenharia de Produção. Aprepro. http://www.aprepro.org.br/conbrepro/2017/anais.php. Accessed 15 June 2018

García-Unanue J, Felipe JL, Gallardo L (2015) Using action research to achieve the implementation of cost accounting: the case of the public sports organizations at local level. Syst Pract Action Res 28:111–123. https://doi.org/10.1007/s11213-014-9322-3

Garlapati VK (2016) E-waste in India and developed countries: management, recycling, business and biotechnological initiatives. Renew Sust Energ Rev 54:874–881. https://doi.org/10.1016/j.rser.2015.10.106

Gil AC (2008) Métodos e técnicas de pesquisa social. Atlas, São Paulo

Govindan K, Kannan D, Mathiyazhagan K (2013) Analysing green supply chain management practices in Brazil' s electrical/electronics industry using interpretive structural modelling. Int J Environ:37–41. https://doi.org/10.1080/00207233.2013.798494

Hameri AP, Paatela A (2005) Supply network dynamics as a source of new business. Int J Prod Econ 98:41–55. https://doi.org/10.1016/j.ijpe.2004.09.006

Holgersson S, Melin U (2015) Pragmatic dilemmas in action research: doing action research with or without the approval of top management? Syst Pract Action Res 28:1–17. https://doi.org/10.1007/s11213-014-9316-1

IBGE (2015) Demographic census 2010. Brazilian Institute of Geography and Statistics – IBGE. https://www.ibge.gov.br. Accessed 28 March 2018

Kiddee P, Naidu R, Wong MH (2013) Electronic waste management approaches: an overview. Waste Manag 33:1237–1250. https://doi.org/10.1016/j.wasman.2013.01.006

Mello CHP, Turrioni JB, Xavier AF, Campos DF (2012) Pesquisa-ação na engenharia de produção: proposta de estruturação para sua condução. Production 22:1–13. https://doi.org/10.1590/S0103-65132011005000056

Migliano JE, Demajorovic J, Xavier LH (2014) Shared responsibility and reverse logistics systems for e-waste in Brazil. J Oper Sup Chain Manag 7:91–109

Nnorom IC, Osibanjo O (2008) Overview of electronic waste (e-waste) management practices and legislations, and their poor applications in the developing countries. Resour Conserv Recycl 52:843–858. https://doi.org/10.1016/j.resconrec.2008.01.004

Orlins S, Guan D (2016) China's toxic informal e-waste recycling: local approaches to a global environmental problem. J Clean Prod 114:71–80. https://doi.org/10.1016/j.jclepro.2015.05.090

Oteng-Ababio M (2012) When necessity begets ingenuity: E-waste scavenging as a livelihood strategy in Accra, Ghana. African Stud Q 13:1–21

Paes CE, Bernardo M, da Silva LR, Leal F (2017) Management of waste electrical and electronic equipment in Brazilian public education institutions: implementation through action research on a university campus. Syst Pract Action Res 30:377–393. https://doi.org/10.1007/s11213-016-9399-y

Pereira M, Silveira MA (2014) A necessidade de adaptação às regulações ambientais da política nacional de resíduos sólidos: do fabricante ao consumidor organizacional no setor de equipamentos eletromédicos. RAI – Rev Adm e Inovação 11:88–109. doi: https://doi.org/10.11606/rai.v11i4.100274

Qu Y, Zhu Q, Sarkis J et al (2013) A review of developing an e-wastes collection system in Dalian, China. J Clean Prod 52:176–184. https://doi.org/10.1016/j.jclepro.2013.02.013

Silveira MA (2013) Strategic management of innovation towards sustainable development of Brazilian electronics industry. J Technol Manag Innov 8:174–183

Souza RG, Rosenhead J, Salhofer SP et al (2015) Definition of sustainability impact categories based on stakeholder perspectives. J Clean Prod 105:41–51. https://doi.org/10.1016/j.jclepro.2014.09.051

Souza RG, Clímaco JCN, Sant'Anna AP et al (2016) Sustainability assessment and prioritisation of e-waste management options in Brazil. Waste Manag 57:46–56. https://doi.org/10.1016/j.wasman.2016.01.034

Sthiannopkao S, Wong MH (2013) Handling e-waste in developed and developing countries: initiatives, practices, and consequences. Sci Total Environ 463–464:1147–1153. https://doi.org/10.1016/j.scitotenv.2012.06.088

Townsend TG (2011) Environmental issues and management strategies for waste electronic and electrical equipment. J Air Waste Manage Assoc 61:587–610. https://doi.org/10.3155/1047-3289.61.6.587

Westbrook R (1995) Action research : a new paradigm for research in. Int J Oper Prod Manag 15:6–20. https://doi.org/10.1108/01443579510104466

Affiliations

Roberta Alves [1] · Karen Lana Alves Ferreira [1] · Renato da Silva Lima [2] · Flavia Tuane Ferreira Moraes [2]

Karen Lana Alves Ferreira
karenalvesf20@gmail.com

Renato da Silva Lima
rslima@unifei.edu.br

Flavia Tuane Ferreira Moraes
flaviatuane@yahoo.com.br

[1] Research Group on Transport, Innovation, Mobility and Sustainability (TIMS), Mechanical Engineering Department (DEMEC), Federal University of São João Del Rei (UFSJ), Praça Frei Orlando, 170 – Centro, São João Del Rei, MG 36307-060, Brazil

[2] Research Group on Logistics, Transport and Sustainability (LogTranS), Industrial Engineering and Management Institute (IEPG), Federal University of Itajuba (UNIFEI), Ave. BPS 1303 – Pinheirinho, Itajuba, MG 37500-903, Brazil