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ORIGINAL PAPER

Management of Waste Electrical and Electronic Equipment in Brazilian Public Education Institutions: Implementation Through Action Research on a University Campus

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Abstract One of the problems facing public education institutions in Brazil is the question of the correct handling and treatment of waste electrical and electronic equipment (WEEE). Being that these institutions are part of the public sector, they should adhere to Decree no. 99,658/1990 for the disposal of their goods. However, this decree is not completely in accordance with the Brazilian National Solid Waste Policy (PNRS), especially when considering the regulations for disposal of public goods. Thus, these institutions have no WEEE management model which encompasses not only the Decree but also the PNRS. An example of this situation can be found at the Federal University of Itajubá (UNIFEI) in Minas Gerais, Brazil. Due to the lack of such a management model, the university warehouse is at full capacity and unable to receive additional electronic equipment. Therefore, the objective of this study is to create a management model for WEEE to be used at public education institutions using the guidelines set forth in both the Decree and the PNRS. An action research investigation was performed at UNIFEI which relied upon two improvement and learning cycles to deal with all the WEEE found at the university. The first was undertaken at the university warehouse and the second at other sectors within the institution. In addition to the practical results obtained by properly disposing of 474 WEEE products, this study showed that action research is an adequate management tool for public institutions looking to deal with problems of this nature, being that these institutions are almost always subject to bureaucratic controls with respect to

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their public property, and expected to follow rigorous legislation that is often times controversial.

Keywords Waste electrical and electronic equipment (WEEE) · Management of waste electrical and electronic equipment · Brazilian National Solid Waste Policy (PNRS) · Reverse logistics

Introduction

According to Veit and Bernardes (2015), a large majority of Waste Electrical and Electronic Equipment (WEEE) that is thrown away annually brings with it enormous environmental impacts which make the management of this type of waste one of the main environmental problems facing the world today (Afroz et al. 2013; Zing et al. Zeng et al. 2015). Around 40 million tonnes of WEEE are generated every day (Menikpura et al. 2014), representing approximately 5 % of all waste generated in the world (Huisman et al. 2008). Rapid changes in information technology and communication, the increase in the versatility of these devices, and the reduced prices of these products have been the main reasons for the shortened lifespan of electronic products and electrical equipment; in turn, there has been an increase in the generation of electronic waste (Tanskanen 2013; Zeng et al. 2013).

For Orlins and Guan (2015) inadequate management of WEEE is a constant worry, not only due to the rapid growth in waste generation, but also because WEEE products contain many materials that must be specially treated at the end of their lifespan, such as lead, mercury, arsenic, chromium, and cadmium.

Developed countries have already established laws that govern the improved management of WEEE, such as the European Union Directive for WEEE, which clarifies the responsibilities of manufacturers, governments, and consumers pertaining to WEEE management (Qu et al. 2013). In developing countries, proper management of e-waste has been widely studied (Chi et al. 2014; Kiddee et al. 2013; Yin et al. 2014), with existing regulations in place that include making producers responsible for managing the post consumer waste of their products (Widmer et al. 2005), as well as legislation restricting the use of toxic substances in the manufacturing process of electrical and electronic equipment (Lim and Schoenung 2010). In Brazil the National Solid Waste Policy (PNRS), enacted in 2010, establishes that manufacturers, importers, distributors, and businesses that deal with electrical and electronic equipment and their components are required to structure and implement reverse logistic systems that permit the return of their electrical and electronic equipment after consumer use (Souza et al. 2015). However, according to Kiddee et al. (2013), the existence of a law does not guarantee better management of electronic waste, being that inadequate legislation has already affected the efficiency of WEEE management. In Brazil's case, even with existing laws on the matter, deficiencies still exist relating to WEEE management; take for example, the incompatibility between the regulative norms dealing with the proper procedures for electronic waste disposal and the PNRS. This is the dilemma that Brazilian public education institutions face.

These institutions are public sector organizations, and as such must adhere to Decree no. 99,658/1990 for disposing of their goods (Presidência da República 2010a). However, this decree proposes inadequate forms of disposal when compared to the environmental norms set forth in the PNRS. In other words the Decree and the PNRS are in conflict regarding the

forms of disposal to be used by Brazilian public education institutions for their WEEE. For example, one of the proposed forms of disposal outlined in the Decree is the formal abandonment of a public asset; however, this particular method of disposal is incompatible with other obligations prescribed by the PNRS. Furthermore, in the event that an organization does not comply with the obligations set forth in the PNRS, this institution would be subject to fines, among other penalties. For this reason, many institutions still lack an adequate management model for waste electrical and electronic equipment that not only takes into consideration the Decree but also the PNRS in guidelines for the discarding process. An example of this reality can be found at the Federal University of Itajubá (UNIFEI), Minas Gerais, Brazil, that, due to the lack of such a management model for WEEE, it is unable to properly dispose of its waste electrical and electronic equipment.

Therefore, the objective of this study is to create a management model for waste electrical and electronic equipment for public education institutions in Brazil, which considers the criteria for proper WEEE disposal set forth in both Decree n°. 99,658/1990 and the National Solid Waste Policy. For this reason, action research was implemented at UNIFEI with the goal of incorporating all the information gained into the development of a model. All those involved in the development of the action research were members of the university. Those directly responsible for carrying out the action research will be referred to in this paper as the action research (AR) Team. The team was composed of 4 researchers from the Industrial Engineering and Management Institute that work in the area of Reverse Logistics and Waste Management. Both the AR Team and the University Administration made decisions pertaining to the execution of the action research. Other players involved in the research project were employees from the Central Administration of the University, from the warehouse, the Campus Mayor, the IT support director, and individuals from other academic departments. The action research was only made possible because there was direct support from the top management at the university, which was looking for a solution for the treatment and disposal of the accumulated electronic waste. The action research was conducted cost free for the university, because all stakeholders were employees and researchers from the same school, and being that the study was also conducted as a master's dissertation.

The action research relied upon two improvement and learning cycles so that all 474 WEEE products at the university could be treated. The first improvement and learning cycle was undertaken at the university warehouse; the second was conducted throughout multiple sectors of the university.

Waste Electrical and Electronic Equipment

Waste Electrical and Electronic Equipment (WEEE) also called electronic waste, or e-waste, is electrical and electronic equipment, pieces, and parts that reach the end of their useful life cycle (Dwivedy and Mittal 2012). For Oteng-Ababio (2012), WEEE products refer to electrical and electronic material that enters the waste flow process and is destined for reuse, resale, recycling, or final disposal.

According to Chancerel and Rotter (2009), due to the large-scale variety of electrical and electronic equipment, all with different functions, sizes, and components, WEEE is considered rather heterogeneous. This heterogeneity makes the recovery process of WEEE challenging (Kumar et al. 2005). In conjunction with these aforementioned characteristics there is also the fact that, with WEEE, there is a general lack of recycling incentives in

place, high prices involved with service and maintenance, with the treatment of the chemical elements therein contained, and a general lack of available replacement components for obsolete equipment (Lim and Schoenung 2010). Thus, for Khetrival et al. (2007), conventional waste management policies cannot be applied to the WEEE flow.

For Menikpura et al. (2014), recycling is the most adequate strategy for managing WEEE flow, being that a considerable quantity of materials is collected, which will in turn reduce the need to extract virgin raw materials. As for Dwivedy and Mittal (2012), reuse should be prioritized in WEEE management.

The issue of proper e-waste management has been debated by many interested groups around the world, including international organizations, governments, academia, industry, and non-governmental agencies (NGOs) (Tanskanen, 2013). Developing countries typically have greater challenges with e-waste (Nnorom and Osibanjo, 2008). The following points highlight what are, according to Nnorom and Osibanjo (2008), the reasons for the existence of ineffective management of WEEE in developing countries, which were also observed in the action research conducted at UNIFEI:

- There is a lack of awareness among consumers, collectors and recyclers about the potential hazards of WEEE;
- absence or ineffective take-back programs for WEEE;
- lack of interest in e-waste management by multi-national companies in developing countries;
- absence of legislation dealing specifically with e-waste or ineffective/lax implementation of existing regulations.

According to Widmer et al. (2005), the existence of relevant laws regarding the management of waste electrical and electronic equipment is the main parameter to be considered when elaborating an adequate and efficient waste management system. It is necessary to understand the extent to which the law details how such a management system should be made.

The Brazilian National Solid Waste Policy (PNRS) and Brazilian legislation pertaining to the disposal of public goods

The National Solid Waste Policy (PNRS) entered into effect in 2010, after more than 20 years of debate in Brazil. This laws joins together a whole set of principles, objectives, instruments, guidelines, goals, and actions adopted by the Federal government, be them in isolation or in cooperation with the States, the Federal District, Municipalities, or private companies, that seek to establish a management system for solid waste (Presidência da República 2010b). The law establishes specifications for proper waste disposal, including specifications for elements with toxic components, such as batteries, tires, fluorescent lamps, electrical and electronic equipment, and pesticide containers. Even thought the PNRS does not specify how to discard waste electrical and electronic equipment, it does make it mandatory for manufacturers, importers, distributors, and businesses to implement post consumption reverse logistics systems for some types of waste, among them waste electrical and electronic equipment (Souza et al. 2015).

Regulations for the disposal of waste electrical and electronic equipment for public administration organizations is formalized in Decree no. 99,658/1990, which establishes rules for discarding public goods. This decree presents four classifications for public goods

that direct this process. The classifications are: idle, recoverable, uneconomic, and unrecoverable. A public good is classified as idle when it is in perfect working condition yet is not being taken advantage of; as recoverable when it can be recovered; as uneconomic when it presents a costly recovery, or poor performance, due to its prolonged use or obsolescence; and as unrecoverable when it can no longer be used for its intended purposes due to the loss of its characteristics, or due to the large and unviable cost of recovery.

Regarding the ways in which a public good can be discarded, the decree proposes four options: transfer, cession, alienation, and uselessness/abandonment. Transfer is defined as the transferring of a public good between units of the same organization or entity, wherein there is a transfer of responsibility. Cession is defined as the ceding of a public good to other public administration organizations or entities, wherein there is a free transfer of ownership and transfer of responsibility. Alienation is defined as the transferring of a public good by means of sale, exchange, or donation. A sale should occur only for public goods that have been classified as irrecoverable or uneconomic, and should be performed by means of a competition, auction, or invitation. An exchange is only permitted between public administration organizations or entities. A donation is permitted solely for the purposes of social interest, and is to be performed at no cost to the public. The organization to which the goods are to be donated shall be chosen according to the classification the public good that is given by the Decree (idle, recoverable, uneconomic, and unrecoverable). Finally, in the case of uselessness or abandonment, a public good is classified as useless or abandoned after withdrawing the economically usable parts that it may contain. It is worth mentioning that this only occurs after verifying that it would be impossible or inconvenient to alienate the public good that has been classified as unrecoverable.

It has been perceived that Decree no. 99,658/1990 proposes inadequate forms of disposal for public goods when considering environmental questions. It is also inadequate when concerning the social responsibility of public organizations, as is the case with the donation of equipment classified as unrecoverable to other institutions, and the abandonment of goods in violation of Law no. 9,605/1998—the Brazilian Environmental Crimes Law (Presidência da República 1998). Thus, it has been noted that there is a need to encounter ways to dispose/discard public goods that not only adhere to the Decree but also to existing environmental legislation such as the PNRS.

The Action Research

Action research was the research methodology chosen for this study, being that there is a real need for an adequate management model capable of handling the waste electrical and electronic equipment found at public education institutions in a way that complies with the regulations set forth in the PNRS as well as Decree no. 99,658/1990; moreover, the lack of such a model represents a real organizational problem and not one created simply for investigational purposes. The study also included decisions and actions on behalf of the professionals involved in the disposal of the WEEE at the university. Furthermore, the creation of a management model for waste electrical and electronic equipment for the university will allow for changes in the organization, as well as generate knowledge (Coghlan and Shani 2014).

According to Susman and Evered (1978), action research occurs in five phases: diagnosis, action planning, action implementation, assessment, and finally learning. In the learning step the conclusions are drawn, and the generation of knowledge occurs, which

can take the form of a conceptual or theoretical model. For Coughlan and Goghlan (2002), action research involves three steps: a pre-phase, the principal phases, and the metaphases. The pre-phase seeks to understand the context of the object of study. In this phase the research team is formed, along with the members of the organization who will participate in the research in a cooperative manner: acting, implementing, evaluating, and building the insider knowledge of the organization (Bartunek and Louis 1996), all together known as the AR team. The principal phases form cycles that involve data collection, data analysis, action planning, action implementation, and assessment. The metaphase occurs during the whole cycle of the principal phases. The metaphase relates to monitoring and learning. According to Mello et al. (2012) within each phase of action research an improvement and learning cycle may occur. This cycle is composed of four steps: Planning (P), Implementation (I), Observation and Assessment (O&A), and Refection and Action (R&A), and seeks to evaluate results and prepare a rational base for new plans.

The AR team felt there were useful parts from each of these models, though no single model by itself seemed sufficient. The learning phase, where the theoretical model is generated (Susman and Evered 1978), the understanding the context and the object of study phase (Coughlan and Couglan 2002), and the learning and improvement cycles (Mello et al. 2012) were all fundamental phases for the development of this work. Therefore we adapted the phases proposed by Susman and Evered (1978), Coughlan and Goghlan (2002) and Mello et al. (2012), which are presented in Fig. 1. The first step was to understand the context of the object of study. The second step was for the AR team to collect data and formulate an action plan. The third step was to implement the actions according to the two improvement and learning cycles. Finally, the AR Team evaluated the data and performed the learning phase.

Understanding the Context and the Object of Study

The present study was initiated by the Campus Administration of UNIFEI. This sector holds the highest position within the university. The head of the Campus Administration

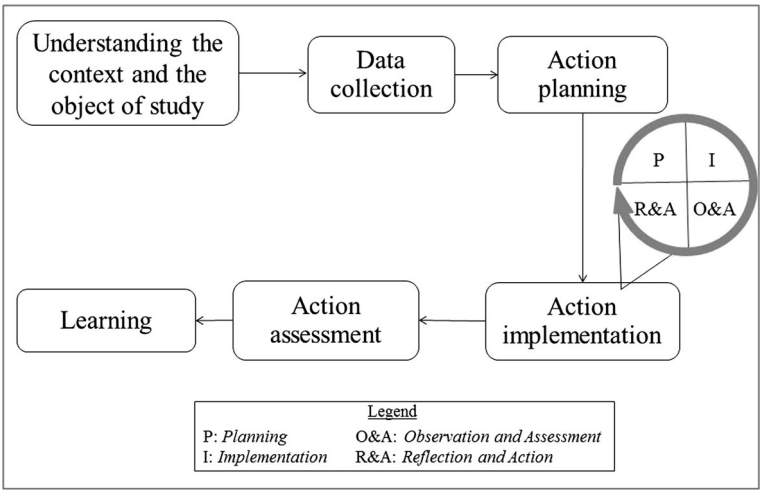

Fig. 1 The steps utilized in action research. *Source* adapted from Susman and Evered (1978), Coughlan and Goghlan (2002) and Mello et al. (2012)

identified the problems that the university was encountering and held a meeting with 4 researchers from the Industrial Engineering and Management Institute, specialists in Reverse Logistics and Waste Management, so that these problems could be resolved, and consequently the action research plan began. These four researches were given full responsibility for the execution of the action research and constituted the Action Research Team (AR team). The initial step of understanding the context and the object of study was conducted by the researchers, who then met with the heads of the Campus Administration, with the Campus Mayor, as well as with the IT Support Department. Additionally the team visited the warehouse and other university departments that contain WEEE in need of disposal.

The Campus Administration and Mayor, and IT Support Department are the sectors responsible for discarding goods within the university. The Campus Administration is responsible for internal and external audits on the management of assets; the Campus Mayor is responsible for discarding university property; and the IT Support Department is responsible for acquiring new computer equipment.

The heads of each department explained that, like many other public education institutions in Brazil over the past few years, the Federal University of Itajubá is currently expanding, restructuring, and increasing the number of courses it offers. Therefore, in order to attend to this new and greater demand, many new pieces of equipment have been acquired, including electrical and electronic equipment, primarily to substitute the obsolete items that were no longer functioning. However, the old electrical and electronic equipment has not been discarded for some years now, due to the difficulties imposed by legislature. Because of this, the amount of waste electrical and electronic equipment being stored in the warehouse of the institution, as well as within various other departments at the university has been increasing, exhausting the storage space of the warehouse. Figure 2 shows the state of the warehouse at the university.

One particular reason for difficulty regarding legislation has to do with the fact that UNIFEI is a federal public administration organization, and being so, the university must adhere to Decree no. 9658/1990 so that it can get rid of its own goods and assets, among them electrical and electronic equipment. Besides this, like any other Brazilian organization, UNIFEI must also properly dispose of its waste in compliance with the PNRS. Given this, the two basic questions undertaken by this study were:

(1) What is the correct form of disposal for the public goods of Brazilian public education institutions?

Fig. 2 Photo of the electrical and electronic equipment at the university warehouse

The correct form of disposal for the public goods of public education institutions is one that is consistent with both Decree no. 9658/1990 (transfer, cession, alienation, and uselessness/abandonment), and the environmental obligations outlined in the PNRS. In other words, proper disposal is defined as the form of disposal which has legal basis and which meets existing environmental obligations.

(2) What is the management model that utilizes adequate forms of disposal for public goods when dealing with the waste electrical and electronic equipment of public education institutions?

Such a management model should present the forms of disposal identified in the first research question as available options for WEEE disposal for public education institutions. In addition, the use of this model should allow for the correct disposal of all WEEE by the institution, no matter the physical characteristics of the waste.

After the AR team had defined their initial questions, other important participants in the action research were identified by the team in conjunction with the head of the Campus Administration. In addition to the researchers, the AR Team was also composed of Campus Administration officials, staff from the office of the Campus Mayor, and staff from the maintenance team of the IT Support Department. In other words, the AR team worked together with employees from various sectors of the university, all of whom had regular participatory roles in the operational disposal of university property, and so each employee on the project team was, in a way, acting in alignment with their normal functions at the university.

Data Collection

First, officials from Campus Administration collected data related to the WEEE registration (number, name, specification of equipment). Next, these same officials classified the waste according to Decree no. 9658/1990 with help from the AR Team. The possibility of discarding the waste according to Decree no. 9,658/1990 and the PNRS was considered. Given the Decree, four disposal opportunities were identified: donation of goods to other federal agencies or other institutions; sale by auction; renunciation of ownership of the items by non-use or abandonment; and finally exchange with private companies. Regarding the PNRS two alternatives were identified: reverse logistics in conjunction with the manufacturers; and hiring environmental services to break down, treat, recycle, and dispose of the equipment.

Action Planning

In this phase WEEE disposal was planned by AR team, together with the Campus Administration, according to the norms set forth in the Decree and the PNRS, and planned with respect to the classification each WEEE item received. The following relationships were established. Equipment classified as idle and recoverable would be disposed of by transfer and/or donation. Equipment classified as uneconomic or unrecoverable would be disposed of by auction, reverse logistics, and/or by hiring an environmental service.

Action Implementation

In order to classify the materials, the Campus Administration and the Campus Mayor performed the following actions: finding the property/asset registration number; printing

the property/asset registration report for the WEEE; comparing the WEEE with the information contained in the property/asset registration report; and filling out a spreadsheet with a report describing the physical conditions of the WEEE.

After the Campus Administration and the Campus Mayor had classified all of the WEEE at the university, the AR team performed two learning and improvement cycles. The first improvement and learning cycle was performed at the university warehouse, because it was where the majority of the WEEE was stored. The second cycle was performed at the various other departments and sectors of the university. The steps for the first improvement and learning cycle are described below.

Planning

In this step the AR team and the Campus Administration officials planned how the WEEE stored at the university warehouse would be disposed of. This planning was done according to how the WEEE had been classified.

Implementation

Employees from the office of the Campus Mayor separated the WEEE stored at the warehouse into two groups: idle and recoverable, and uneconomical and unrecoverable.

The first group was destined for transfer and/or donation. The equipment was first recovered by maintenance staff employees of the IT Support Department so that it could be transferred and/or donated. After recovering some of the WEEE in the first group, employees of the office of the Campus Mayor transferred a few pieces of equipment from one sector of the university to another, and employees of the Campus Administration donated the rest to another federal institution.

The second group was destined for either auction, or a reverse logistics service, and/or destined to be given over to an environmental service. Only two companies visited the warehouse at UNIFEI to verify the condition of the equipment, and neither participated in the auction. Being that it was impossible to conduct an auction, the process moved on to the reverse logistics service, and to hiring an environmental service. In order to perform reverse logistics, the services available were considered together with the producers of the WEEE based on the brands and models that had been identified. This was done through company visits and via e-mail correspondence. The team and Campus Administration officials sent a document containing all the available information on the WEEE held at the university to environmental service providers soliciting their services for treating the waste, however some difficulties were encountered at this stage.

Observation and Assessment

As for the companies' lack of interest in participating in the auction, it can be concluded that transportation and decontamination costs associated with some of the items could be to blame. This is because companies that buy equipment at auction are financially responsible for these expenses, and both expenses would have most likely been high: the transportation cost, due to the size and weight of the items; and the decontamination cost, due to the physical condition (uneconomical and unrecoverable) of the items.

As for using a logistics service and hiring an environmental service, the AR team and Campus Administration officials perceived that the waste electrical and electronic

equipment would need to be given over to private companies, something not covered by Decree no. 99,658/1990.

Reflection and Action

The AR Team and Campus Administration officials noted that the only remaining possibility for disposal that would be in accordance with the Decree would be abandonment. However, this option is at odds with the PNRS. The solution that the AR team, Campus Administration officials, and employees found was to release the WEEE assets. This is an action performed by the IT Support Department maintenance staff. Instead of asset abandonment, the decision was made to hire an environmental service and legally release the assets on the grounds that the waste presented an ecological risk. An environmental service company was hired by the Campus Administration officials to handle the WEEE present at the warehouse.

The AR team drafted a chapter on procedures for the management of WEEE for the university's Manual of Procedures for the Release of Assets. The team then distributed the manual at a meeting with all of the employees from the Campus Administration, the Campus Mayor's office, and the IT Support Department. Afterwards, the AR team then began the second improvement and learning cycle. The steps of the second cycle were performed in a way similar to those of the first cycle; however, the second was performed with various other sectors of the university, and so the AR team was able to count on the participation of the employees from each of the aforementioned sectors during the second cycle. These employees helped classify and separate the equipment found at the various other sectors. After the second cycle, another meeting was held with the objective of publishing the procedures for the correct disposal of WEEE. The employees from sectors where WEEE had been discarded during the second cycle were present at this meeting.

Assessment

In this phase the AR team assessed the implementation of actions taken in the previous phase. They perceived that there were no major difficulties in carrying out the actions, and only encountered minor difficulties when actually separating the waste, which were:

- Difficulties with the comparison of physical goods with the information contained in the property/asset registration report. This was because the property/asset registration report informed the registration number of property/assets referring to not just one particular good, but rather to a whole group of goods, for example, a CPU, a monitor, a mouse, and not simply just the CPU located in the warehouse. Moreover, different brands were also found in some of the groupings (Microtec, IBM, Itautec and AOC) while other groupings only specified the brands of the CPUs. To solve this problem, the AR team and management staff of the Campus Administration and Campus Mayor's office put the components that were in the warehouse into specified groups.
- Difficulties with the way the spreadsheet had been filled out. This was because various pieces of equipment did not have a report describing their physical characteristics. Other pieces of equipment had this report; however, given the time that the equipment had been stored, the reports were not always updated to include new and relevant information, and so these items were reassessed. Other items were registered as having reports, however these reports were not found. To solve these problems employees

from the IT Support Department evaluated the WEEE and made up to date reports as to the physical conditions of the waste.

Regarding the two improvement and learning cycles, the AR team realized that the second cycle could be performed faster and with less difficulty than the first, given the knowledge generated from this first cycle.

Learning

By assessing the actions performed in the earlier stage, the AR team perceived that it would be necessary for the waste electrical and electronic equipment to arrive at the warehouse with a report describing the physical characteristics in such a way as to permit the integration of the information obtained from all of the other sectors. This would allow the entire process to run more smoothly. The AR team also identified the need for better storage practices for WEEE, because the physical characteristics of the waste would impact their classification and thus their final destination. Furthermore, the AR team noted that it would be necessary to establish WEEE collection cycles along with the various other sectors so that the employees from the office of the Campus Mayor could properly discard the waste.

After the completion of the action research, the AR team followed up on the disposal processes of the newly arrived WEEE at the university warehouse.

Results

By means of action research, we were able to analyze all the forms of disposal proposed by the Decree in relation to the obligations proposed by the PNRS, and so, were also able to answer the first basic research question, which was to identify the correct form of disposal for the WEEE at public education institutions. Of the four forms of disposal presented by the Decree, two were identified as suitable: transfer and alienation (by means of donation or auction). The AR plan was also performed with two learning and improvement cycles, and so, all of the WEEE present at UNIFEI was divided into two groups. The first group comprised all the WEEE that was present in the university warehouse, and was disposed of in the first learning and improvement cycle. The second group of waste comprised waste that was found in various other departments of the university, and was discarded in the second cycle. In short, via action research, it was possible to properly allocate (considering the Decree and the PNRS) all the WEEE at UNIFEI. In total, this AR plan led to the proper disposal of 474 items of WEEE, complying with both the Decree and the PNRS. Of the 474 WEEEs treated:

- 32 were recovered. Of the 32 recovered, 8 were transferred to new sectors, and 24 were destined for donation;
- 251 were donated to other federal institutions; and.
- 215 were treated by a hired environmental service. By hiring this service 1787 kg of waste electrical and electronic equipment was properly disposed of. After contracting the service, the management company responsible for tracking the waste forwarded the WEEE tracking and disposal report. Table 1 describes the WEEEs and shows the final destination of each.

By means of the knowledge generated from the action research project, the AR team was able to write a chapter about WEEE management procedures for the university's

Table 1 Description of the WEEEs and their final destinations

Description	Quantity (kg)	Destination
Cables/wires	10	Recycled
Electronic boards	272	Recycled
Copper scraps	30	Recycled
Scrap-iron	285	Recycled
Recyclable batteries	60	Recycled
Unrecyclable plastics	210	Controlled landfill
Cathode ray tubes	920	Controlled landfill
Total	1787	

Manual of Procedures for the Release of Assets, and it was possible to answer the second research question: develop a management model for waste electrical and electronic equipment, which could allow for the repeatability of these activities both for UNIFEI and for other public education institutions in Brazil that may also lack an adequate management model for WEEE.

Management Model for Waste Electrical and Electronic Equipment

After correctly disposing of the WEEEs located at UNIFEI via the action research project, a management model was constructed for WEEEs at the university. The model is presented in Fig. 3.

Upon becoming unusable (1) and upon announcing the new disposal cycle for WEEEs at the warehouse (2), each organ should separate their electrical and electronic equipment (3). This equipment should be sent (4) to the maintenance sector so that a report can be written that classifies the equipment (5). If the equipment is irrecoverable (6) the maintenance sector should take out recoverable components (7) to be used in the recovery of other equipment (8). If the equipment is recoverable (9), the maintenance sector should repair the equipment using the pieces recovered from irrecoverable units. After repair, the equipment will become idle (10). Idle equipment destined for reuse should then be announced via an institutional e-mail, requiring any interested parties to claim the equipment within 5 business days (11). If there are interested parties (12) the equipment will then be transferred via a "release of assets" upon which time responsibility will also be transferred (13) and the equipment will be sent (14) to be reused (15). If there are no interested parties, the equipment should be stored temporarily in specified warehouse areas, until it is released along with its report (16). Idle equipment, along with uneconomic or recoverable equipment may be donated to other federal organizations (17). After donation, the equipment should be sent to the interested federal organization (18) and the assets should then be deducted from the balance sheet of the university (19). There, at the other federal organization, this equipment can be reused (20) or used for other purposes; such as research (21). Idle equipment may also be donated to other organizations (22). After donating, this equipment should be sent to the interested organization (23) and the assets should then be deducted from the balance sheet of UNIFEI (24). The equipment can then be reused at the other institution (25). The irrecoverable equipment should be auctioned off (26). If an auction cannot be held (27), the items should then be renounced, given their non-usability (28). An environmental service should be hired to properly dispose of the items (29). The items should then be taken from the university by this specialized

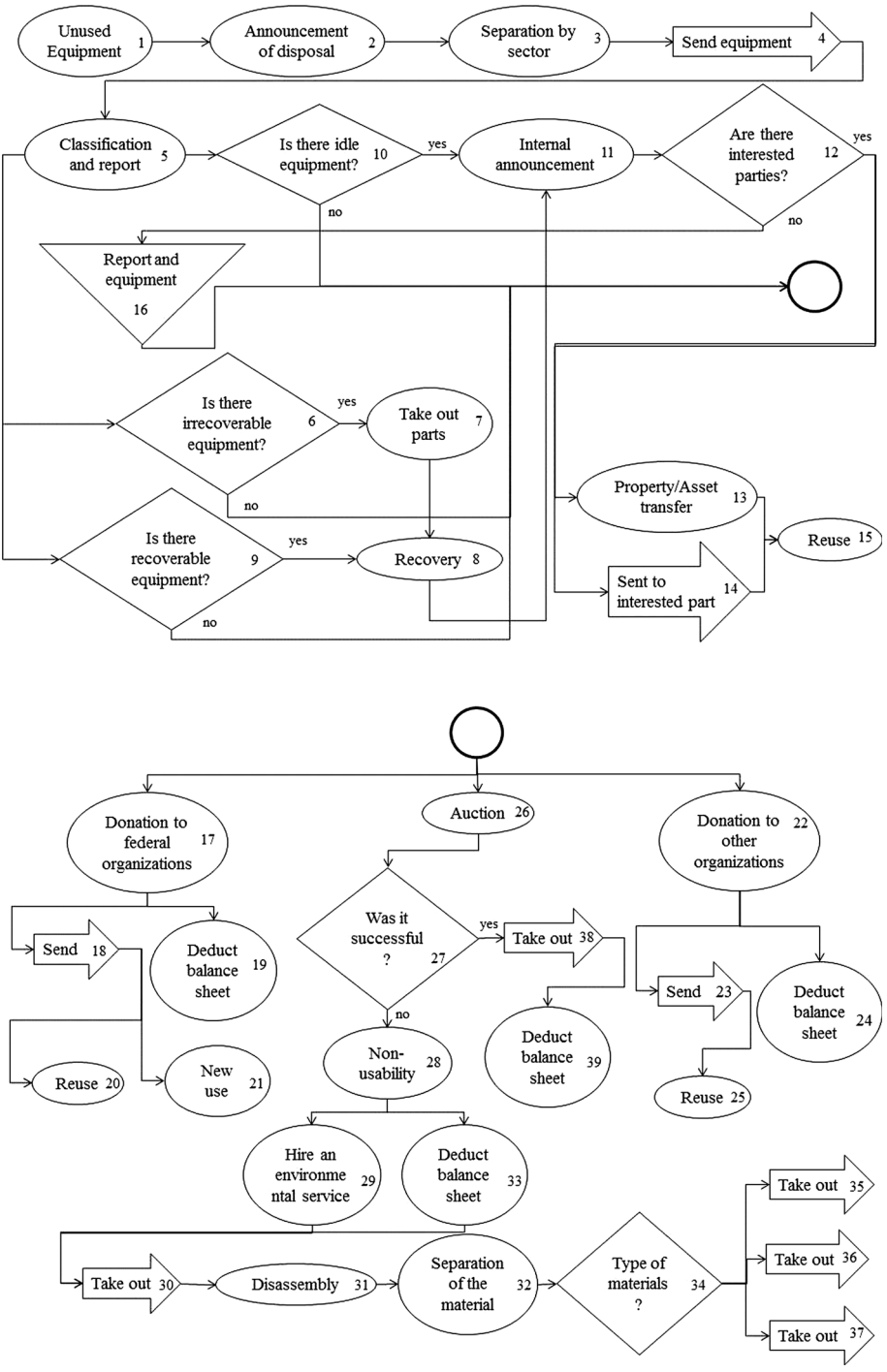

Fig. 3 Management model for waste electrical and electronic equipment

environmental service (30) and their materials should be sent to be disassembled and separated. At the same time the assets should be deducted from the balance sheet (33). Depending on the type of material, the items can be sent to specialized recyclers (35), authorized incinerators (36) or controlled landfills (37). If an auction can be held (38) the items are to be taken by the buyer (38) and the assets are to be deducted from UNIFEI's balance sheet (39).

Discussions

The AR team did not encounter any major difficulties in implementing the action research plan; rather, the action research project resulted in notable collaboration and success. This may be due to three realities related to this study:

- The employees of the main sectors responsible for the disposal of university property also participated in the AR team, and their roles within the project team aligned with their functions at the institution.
- Action research was carried out through two learning and improvement cycles within the implementation phase of the actions. Therefore, all of the successes and failures that occurred in the first cycle could be replicated and avoided, respectively.
- The research problem and the ensuing interest in resolving this problem arose from the Head of the Campus Administration, the main sector of the institution. Thus, the close involvement of the employees of the Campus Administrations allowed for greater dedication in solving problems.

Furthermore, the use of action research as a method of research was relevant to the problem's solution for two main reasons:

- Action research is about undertaking action and studying that action as it takes place (Coghlan and Brannick 2014). Thus, being that there are four available disposal options set forth in the Decree, action research allowed for the practical testing of these four options in relation to obligations set forth in the PNRS, and so it was possible to identify the correct forms of disposal for WEEE for public education institutions in Brazil.
- Action research is understood to be a process that is concerned with bringing about change in organizations, in developing self-help competencies in organizational members (Shani and Pasmore 1985). Being so, action research led to organizational and individual learning, resulting in organizational changes, improving WEEE disposal processes at the university.

Organization change is particularly important for public institutions, being that, according to Holgersson and Melin (2015), in public organizations the work practice surrounding the environment in general is complicated. Nevertheless, in descriptions of action research no distinction is usually made between action research in private vs. public organizations (Holgersson and Melin 2015). Therefore, we emphasize the need to consider the factors that promote organizational change when conducting action research in bureaucratic organizations, like public institutions. For example, greater involvement on behalf of the managers in the execution of action research is one of these factors. A manager is the professional responsible for organizational change, and it is his or her commitment and support in conducting action research that will promote the incorporation

of knowledge and learning generated through the action research conducted by staff. The commitment of the Head of the Campus Administration in conducting this action research was a success factor in this way, not only in the case of UNIFEI, but also for other action research studies implemented at public institutions (García-Unanue et al. 2015; Liu 2009).

Conclusions

The objective of this present study was to create a management model for WEEE for public education institutions in Brazil which takes into consideration both Decree no. 99,658/1990 and the PNRS. To do this, an action research project was undertaken at the Federal University of Itajuba, with the intent of incorporating all obtained knowledge into the elaboration of a model.

By identifying correct forms of disposal for WEEE at the Federal University of Itajubá, we were able to construct a management model that will direct future actions pertaining to waste of electrical and electronic equipment at UNIFEI. We noticed that, because of the model's flexibility in meeting differing needs and situations, it could not only serve as a guide for the actions of other public educational institutions, but also serve as a guide for other public institutions that suffer from the same lack of a suitable WEEE management model under the Decree and the PNRS. It is noteworthy that the proposed model does not guarantee an improvement in the management of waste electrical and electronic equipment within the institution. It will also be necessary to promote organizational changes that can make it easier for all of those involved in this process to adhere to the model, being that this is fundamental to the sustainability of the model. As a result of this research the AR team drafted a chapter on procedures for the management of WEEE for the university's Manual of Procedures for the Release of Assets, with the intent of promoting sustainable and organizational changes. Various meetings were held with employees from diverse sectors of the university, all with the intent of promoting the manual. The importance of environmental, social, and economic sustainability for the university was highlighted during those meetings, as well as the important role that each employee plays in properly disposing of WEEE. One can say that these actions contributed to sustainable organizational change, especially when considering that, after the implementation of the AR plan, the university warehouse continued to use the models herein proposed, and in doing so was able to properly dispose of six more lots of WEEE.

Finally, we believe that this study helps show how action research can be used in public institutions, often subject to bureaucratic and strict control of public assets. More than simply seeking to manage waste (electronic waste in this case) there is the added difficulty of managing this waste according to the various existing laws, which are often contradictory. Through this action research, we can prove that management is possible, and we believe that the method applied here can be applied to other public institutions and for the management of other types of waste.

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References

Afroz R, Masud MM, Akhtar R, Duasa JB (2013) Survey and analysis of public knowledge, awareness and willingness to pay in Kuala Lumpur, Malaysia—a case study on household WEEE management. J Clean Prod 52:185–193

Bartunek JM, Louis MR (1996) Insider/outsider team research. Sage, Thousand Oaks

Chancerel P, Rotter S (2009) Recycling-oriented characterization of small waste electrical and electronic equipment. Waste Manag 29:2336–2352

Chi X, Wang MYL, Reuter MA (2014) E-waste collection channels and household recycling behaviors in Taizhou of China. J Clean Prod 80:87–95

Coghlan D, Brannick D (2014) Doing action research in your own organization, 4th edn. Sage, London

Coghlan D, Shani AB (2014) Creating Action research quality in organization development: rigorous, reflective and relevant. Syst Pract Action Res 27:523–536

Coughlan P, Coghlan D (2002) Action research for operations management. Int. J. Oper. Prod. Manag. 22(2):220–240

Dwivedy M, Mittal RK (2012) An investigation into e-waste flows in India. J Clean Prod 37:229–242

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. Syts Pract Action Res 28:111–123

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

Huisman J, Magalini F, Kuehr R, Maurer C, Ogilvie S, Poll J, Delgado C, Artim E, Szlezak J, Stevels A (2008) Review of directive 2002/96 on waste electrical and electronic equipment (WEEE). United Nations University, Bonn 2008

Khetrival D, Krauchi P, Widmer R (2007) Producer responsibility for e-waste management: key issues for consideration—learning from the Swiss experience. J Environ Manag 90(1):1–13

Kiddee P, Naibu R, Wong MH (2013) Electronic waste management approaches: an overview. Waste Manag 33:1237–1250

Kumar V, Bee DJ, Shirodkar PS, Tumkor S, Bettig BP, Sutherland JW (2005). Towards sustainable product and material flow cycles: identifying barriers to achieving product multi-use and zero waste. In: Proceedings of international mechanical engineering congress and exposition—IMECE 2005, Orlando

Lim SR, Schoenung JM (2010) Toxicity potentials from waste cellular phones, and a waste management policy integrating consumer, corporate, and government responsibilities. Waste Manag 30:1653–1660

Liu Y (2009) Implementing and evaluating performance measurement initiative in public leisure facilities: an action research project. Syst Pract Action Res 22:15–30

Mello CHP, Turrioni JB, Xavier AF, Campos DF (2012) Action research in production engineering: a structure proposal for its conduction. Produção. 22(1):1–13

Menikpura SNM, Santo A, Hotta Y (2014) Assessing the climate co-benefits from waste electrical and electronic equipment (WEEE) recycling in Japan. J Clean Prod 74:183–190

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

Orlins S, Guan D (2015) China's toxic informal e-waste recycling: local approaches to a global environmental problem. J Clean Prod. doi: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 Afr Stud Quart 13(1):1–21

Presidência da República (1998) Decree no. 9,605, of February 12, 1998. Establishes sanctions applicable to crimes against the environment and provides other requirements. Casa Civil, Brazil

Presidência da República (2010a) Law no. 12,305, of August 2, 2010. Establishes the National Policy for Solid Waste and provides other requirements. Casa Civil, Brazil

Presidência da República (2010b) Decree no. 99,658, of October 30, 2010. Regulates within the federal public administration, the reuse, moving, alienation and other forms of disposal materials. Casa Civil, Brazil

Qu Y, Zhu Q, Sarkis J, Geng Y, Zhong Y (2013) A review of developing an e-wastes collection system in Dalian. China J Clean Prod 52:176–184

Shani (Rami) AB, Pasmore WA (1985) Organization inquiry: Towards a new model of the action research process. In: Warrick DD (ed) Contemporary organization development: current thinking and applications. Scott Foresman, Glenview [Reproduced In: Coghlan D, Shani (Rami) AB (eds) (2010) Fundamentals of organization development, vol 1. Sage, London

Souza RG, Rosenhead J, Salhofer SP, Valle RAB, Lins MPE (2015) Definition of sustainability impact categories based on stakeholder perspectives. J Clean Prod 105:41–51

Susman GI, Evered RD (1978) An assessment of the scientific merits of action research. Adm Sci Quart. 23(4):582–603
Tanskanen P (2013) Management and recycling of electronic waste. Acta Mater 61(3):1001–1011
Veit HM, Bernardes AM (eds) (2015) Electronic waste: generation and management. In: Electronic waste: recycling techniques. Springer, Porto Alegre, Brazil, pp 3–12
Widmer R, Oswald-Krapf H, Sinha-Khetriwal D, Schnellmann M, BÖni H (2005) Global perspectives on e-waste. Environ Impact Assess Rev 25:436–458
Yin J, Gao Y, Xu H (2014) Survey and analysis of consumers' behaviour of waste mobile phone recycling in China. J Clean Prod 65:517–525
Zeng X, Li J, Stevels ALN, Liu L (2013) Perspective of electronic waste management in China based on a legislation comparison between China and the EU. J Clean Prod 51:80–87
Zeng X, Song Q, Li J, Yuan W, Duan H, Liu L (2015) Solving e-waste problem using an integrated mobile recycling plant. J Clean Prod 90:55–59