

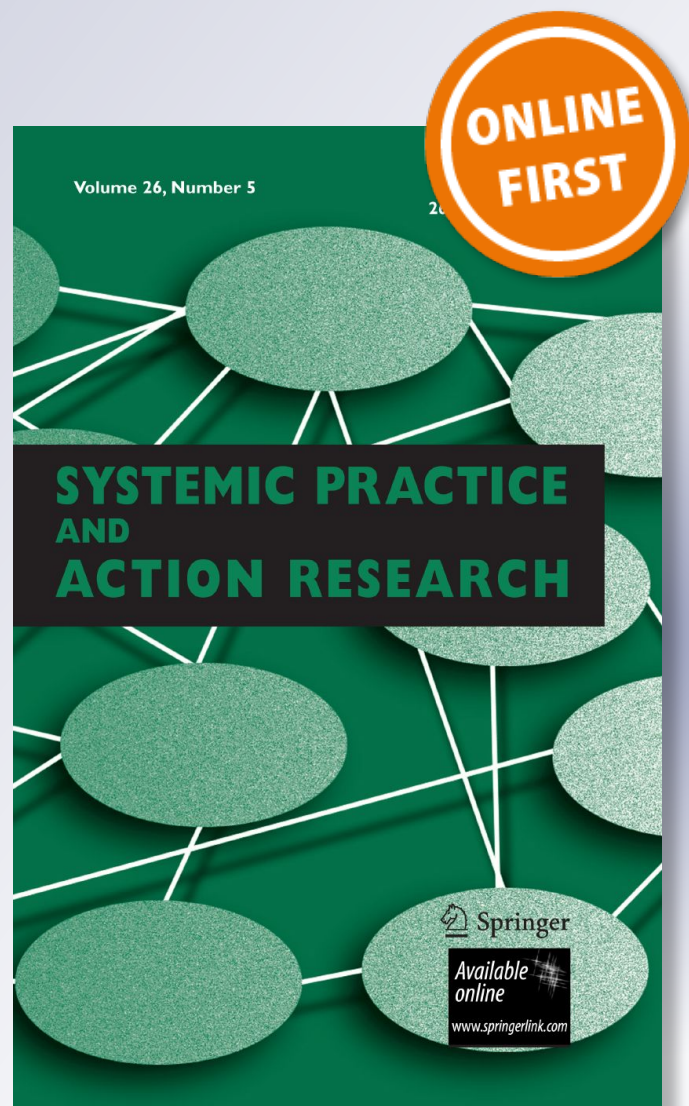
Using Action Research to Implement Selective Waste Collection Program in a Brazilian City

**Marcella Bernardo & Renato da Silva
Lima**

**Systemic Practice and Action
Research**

ISSN 1094-429X

Syst Pract Action Res
DOI 10.1007/s11213-017-9416-9



Your article is protected by copyright and all rights are held exclusively by Springer Science +Business Media New York. This e-offprint is for personal use only and shall not be self-archived in electronic repositories. If you wish to self-archive your article, please use the accepted manuscript version for posting on your own website. You may further deposit the accepted manuscript version in any repository, provided it is only made publicly available 12 months after official publication or later and provided acknowledgement is given to the original source of publication and a link is inserted to the published article on Springer's website. The link must be accompanied by the following text: "The final publication is available at link.springer.com".

Using Action Research to Implement Selective Waste Collection Program in a Brazilian City

Marcella Bernardo¹  • Renato da Silva Lima²

© Springer Science+Business Media New York 2017

Abstract The objective of this paper is to study and report upon the elaboration of a selective waste collection program in a Brazilian city through action research; the overarching goal is that all knowledge generated may serve as a basis of information and reference to aid in decision making for similar programs globally. The municipality chosen was São Lourenço in the state of Minas Gerais. The implementation of the selective waste collection program happened over the course of multiple improvement and learning cycles, and enabled many environmental, economic and social benefits for all of the project's stakeholders. Eighty-nine tons of potentially recycled material were sent to recycling processes rather than being disposed of in a landfill. No great difficulties were observed for the use of action research as a method, but some challenges were encountered and overcome during the whole process, due to the lack of structure and confidence on part of the population, in relation to the selective collection program. The choice for action research as the methodology and the use of improvement and learning cycles proved to increase the project's overall efficiency, making it possible to make decisions more quickly, generating better results, and enabling replications of good decisions and correction of errors from one cycle to the next.

Keywords Urban solid waste · Solid waste management · Selective waste collection · Action research

✉ Marcella Bernardo
ber@biba.uni-bremen.de

Renato da Silva Lima
rslima@unifei.edu.br

¹ Bremer Institut für Produktion und Logistik GmbH (BIBA), Universität Bremen, Hochschulring 20, 28359 Bremen, Germany

² Industrial Engineering and Management Institute (IEPG), Federal University of Itajubá (UNIFEI), Ave. BPS 1303 – Pinheirinho, Itajubá, MG 37500-903, Brazil

Introduction

The generation of Urban Solid Waste (USW) in Brazil in 2014 was approximately 78.6 million tons, a 2.9% increase from 2013, and 3.7% higher than the population growth rate of the country during this period. Furthermore, in spite of having reached a recyclable materials collection coverage of 90.6% throughout the country, almost half (41%) of the USW collected in 2014 did not receive correct disposal and was sent to dumps or controlled landfills lacking the necessary mechanisms for environmental protection and population health (ABRELPE 2014). Unusable USW typically ends up in dumps or controlled landfills, which take a heavy toll on the environment, causing floods, air and soil pollution; as well as having social and economic impacts. Thus, one of the great concerns about USW is its management, considering the wide range of consequences which occur in multiple realms.

In 2010, a Brazilian law (number 12.305) was approved, which instituted the National Policy on Solid Waste (PNRS) (BRASIL 2010). The law defines the principles, objectives, goals and instruments related to USW Management (USWM). According to Bufoni et al. (2014), many concepts are incorporated into PNRS for correct USWM, such as:

- sectoral agreements, act of contractual nature entered into between public and private entities, aiming at implementing shared responsibility for certain products' life cycle;
- product lifecycle and shared responsibility;
- final environmentally-adequate disposal, minimized final destination in landfills and dumps (focus is on reutilization, recycling, recuperation);
- energy generation from solid waste;
- reverse logistics, instrument defined by a set of actions, procedures and means intended for the feasibility of collection and restitution of solid waste to the entrepreneurial sector, or other final environmentally-adequate destination; and
- Selective waste collection.

The national policy presented new challenges in terms of implementing and improving selective waste collection in Brazilian municipalities. To meet the standards of the new law, all cities must have selective waste collection programs; only 927 of 5670 (17%) currently have satisfactory selective waste collection programs (CEMPRE 2014a). Moreover, according to Campos (2014), in municipalities where selective waste collection already exists, it has been noted that they are not mature and have low efficiency, contributing in a limited fashion to USWM.

The way in which selective collection is implanted is important for all of the stakeholders, starting with the responsible public organ and reaching the population. It must be founded in technical, economic, environmental and legal (Toso and Alem 2014), seeing that the lack of conformity might interrupt the execution of the selective collection program.

However, there is a lack of examples in the literature to be followed for public organizations when starting these programs. Thus, it is important for selective waste collection to be studied and reported on, in order to indicate what the main barriers for implementation are, what factors can lead to failure, and to improve efficiency as well as stimulate future programs by showing the associated economic, social and environmental benefits (Lima and Silva 2013; Carvalho et al. 2011).

To generate and capture greater knowledge about how the implementation can and should not occur, it is important to accompany and document these collection programs in their initial

phases as they put actions in place to meet the PNRS requirements. In doing so, it is possible to identify what hurdles may exist and also best practices. Such factors can be studied using action research, which is a methodology which seeks to deal with a real social or collective problem, but which also generates and captures knowledge (Coghlan and Shani 2014). Thus, accompanying a selective waste collection program in its initial phases using action research promotes changes in the municipality (action) and also generates knowledge. Thus, the objective of this present paper is to study and report on the planning and implementation of a selective waste collection program through action research. The knowledge generated might serve as a basis of information and references which aid in decision-making for public authorities who need to start similar programs or improve existing ones.

The article is structured as follows: after this introduction, [Selective Waste Collection](#) Section presents the theoretical background on selective waste collection. Then, [Methodology](#) Section reviews the methodology, followed by details on the implementation of the selective waste collection in [Implementation of the Selective Waste Collection Program](#) Section. [Findings](#) Section deals with discussion of the study, and in [Conclusions](#) Section offers final conclusions.

Selective Waste Collection

Selective waste collection is one of the steps in urban solid waste management and involves sorting out recyclable materials (paper, glass, plastic and metal) from the other material. A selective waste collection process is seen as an alternative to diminish the environmental impacts caused by USW because it helps cut the volume of waste which goes into landfills and consequently should increase the landfill's life expectancy (Lima and Silva 2013). According to Rada et al. (2013), one of the objectives of selective waste collection is to improve environmental conditions through reutilization and recycling, reducing costs associated with the resources necessary to obtain new material.

During selective waste collection implementation projects, there are two key questions: 1) who will act as the collection agent; that is, who will perform the collection? and 2) which selective waste collection model will be used? In relation to the collection agent, there are three options in Brazil: Municipal Government, Private Businesses, or Recyclable Waste Pickers Associations/Cooperatives. In 43% of Brazilian cities, the municipal government is responsible for selective waste collection; 37% depend on private companies; 51% support or maintain cooperatives or associations for collection of recyclable materials. In respect to the collection model, there are two options: Door-to-Door and Voluntary Delivery Points (VDP), also known as Ecopoints. The more common is Door-to-Door, with about 80% of Brazilian municipalities using this strategy; approximately 45% of all cities use some kind of VDPs/Ecopoints (CEMPRE 2014a). It is worth highlighting that the collection models are not mutually exclusive and more than one collecting agent may exist within the same municipality, like a hybrid model. The choice between models and agents can bring both benefits and challenges which should be considered during planning and implementation. Another point to examine is efficient collection route planning, seeing that collections costs are significant (Zsigraiova et al. 2013).

Starting in the decade of 2010, there has been an increased amount of academic research related to selective waste collection in Brazil. Chaves et al. (2014) evaluated the sustainability of PNRS with the Global Agenda 21 and the challenges of implementing the PNRS in municipalities. According to the authors, one weakness in the implementation of USWM and selective waste collection is the limited attention given to environmental education

mechanisms. Bringham et al. (2011) and Ferri et al. (2015) corroborate this affirmation. Bringham et al. (2011) focuses on the selection and validation of reference indicators to enable the monitoring of the performance of programs for selective collection, and one indicator classified as of high importance was the social participation in the selective collection programs. Ferri et al. (2015) proposed a reverse logistic network for urban solid waste management to solve the challenge of managing these wastes in an economic manner considering the PNRS requirements and the inclusion of recyclable waste pickers. The authors argue that USWM and efficient selective collection programs are dependent on environmental education. Furthermore, regardless of the organizational structure for coordinating the selective collection programs, all actors involved in the process of value creation must be considered.

Besen et al. (2014) also highlights this barrier in analysing the impact of PNRS on selective waste collection in the Metropolitan Region of Sao Paulo. The authors conclude that one of the main problems is that the services provided by the cooperatives are not compensated financially in a coherent fashion, and that the cooperatives need to become technically capacitated and be financially sustainable in order for them to provide the service. Campos (2014) considers that selective waste collection in Brazil is based on blatant exploitation of the work force of waste pickers by local governments and by recycling industries. The author investigated the technical, environmental, social, and operating conditions of the materials recovery facilities deployed in Brazil and describes the challenges related to the management of waste in accordance with the PNRS.

In these and other studies about selective waste collection (Rutkowski and Rutkowski 2015; Ferri et al. 2015); Besen et al. 2014 and Campos 2014), the causes and consequences of the difficulties of these implementations are analyzed, but there is no discussion about how these hurdles were or could be overcome. As the motivation for this study is focused on the action and generation of knowledge, the most adequate research method is Action Research.

Methodology

Action research was chosen as the methodology for this study, seeing that in selective waste collection context, two real necessities were identified. First, due to the context created by the PNRS legislation, all Brazilian municipalities must institute selective waste collection. Second, because it is a new development, there is a need to generate more knowledge about these initiatives in order to help future and existing projects become more efficient.

In order to conduct an action research study, Mello et al. (2012) propose a model adapted from Westbrook (1995) and Coughlan and Coughlan (2002). In this model, there are five phases to each cycle: Planning Action Research (1), Data Collection (2), Data Analysis and Action Planning (3), Implementation (4) and Results Analysis (5). The planning phases is comprised of two stages: selection of the unit to be studied and the action research team. Furthermore, one of this study's key assumptions is that each one of the five phases can occur in improvement and learning cycles, which aim to evaluate the results obtained and prepare a knowledge base for new (re)planning cycles. In Paes et al. (2016) and Fagundes et al. (2017), the authors argue that the use of improvement and learning cycles was one of the main contributors to the success of action research. The cycle is composed of four stages, Planning (P), Implementation (I), Observation and Assessment (O&A) and Reflection and Action (R&A).

Thus, this study was conducted according to the proposal from Mello et al. (2012), being that in the implementation phase, multiple improvement and learning cycles occurred. The steps are shown in Fig. 1. It is worth mentioning that during the Reflect and Act (R&A) stage, analyses of the main challenges found in each cycle were conducted, as well as the identification and execution of actions to resolve those difficulties, always using current literature about selective waste collection as a guideline.

Implementation of the Selective Waste Collection Program

The following sections present the phases of implementation of the selective waste collection program in the city through action research, detailing each of the distinct steps: Planning Action Research; Data Collection; Data Analysis and Action Planning; Implementation through Improvement and Learning Cycles and Results Analysis.

Action Research Planning

As previously stated, the planning portion of action research involves two phases: selection of the unit under study and definition of the team. The criterion established for selection of the studied unit was to select a city that did not already have a selective waste collection program and which had an ongoing project in initial phases. The city of São Lourenço, located in the state of Minas Gerais, was selected. In the city, there is a selective

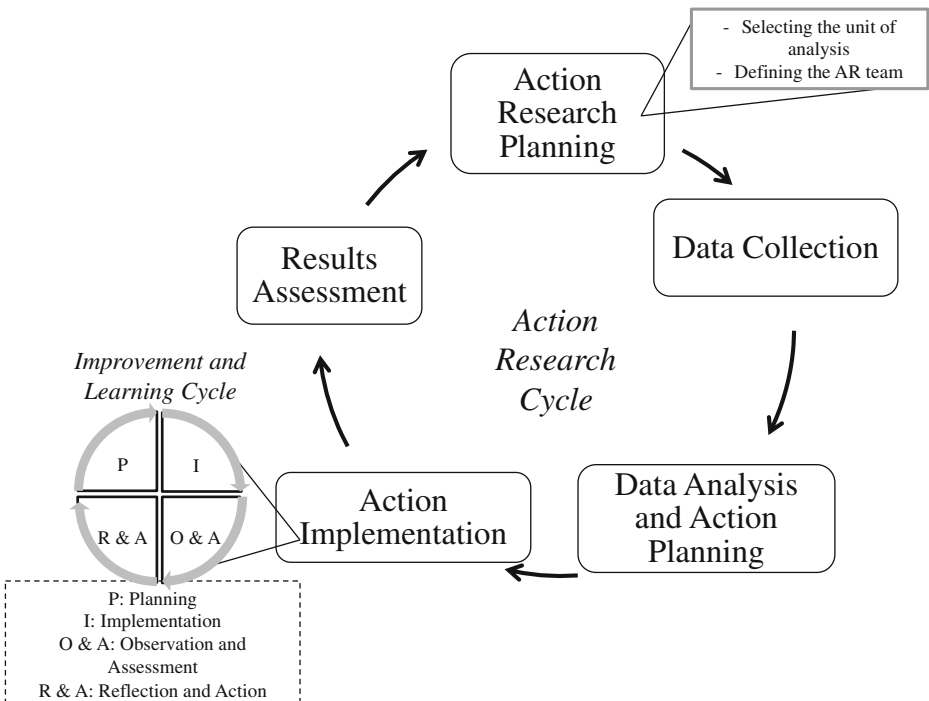


Fig. 1 Steps utilized in action research. Source: adapted from Mello et al. (2012)

waste collection cooperative called São Lourenço Productive Material Recyclers Cooperative (COOPRECI), which is responsible for the selective waste collection in the city. In December 2014 an agreement was signed with the Autonomous Water and Sewer Service (SAAE), the NGO “All for São Lourenço” (*Todos por São Lourenço*) and COOPRECI. With the agreement, the SAAE donated financial resource to the NGO with the goal of installing a new selective waste collection program in the city. After signing the deal, the NGO sought out the Logistics, Transport and Sustainability Research group (LogTranS) from the Federal University of Itajubá (UNIFEI) to support the new project, given that those involved did not possess a substantial level of technical knowledge for implementing a new selective collection program. The LogTranS representatives presented the idea of using AR in order to do so, counting on the commitment of the group to support the project’s implementation. The idea was immediately accepted and it was possible to start the research planning.

As the NGO was responsible for the financial resources and the project, their director defined who would make up the AR team. The idea was to have at least one representative from each organization involved in the project. Thus, the COOPRECI manager, LogTranS researchers and two NGO members were defined as the action research team. Once this was defined, the next step was to collect data.

Data Collection

To collect data on COOPRECI and the selective waste collection activity at the city, visits were conducted at the cooperative’s sorting warehouse, along with document analysis of both the cooperative and the NGO during, interviews and meetings with the NGO, and a week’s worth of observation of the truck route. The data collection phase took place over one month.

In this phase, COOPRECI had three collection members, one driver and one manager. The collectors worked in two shifts, starting in the morning and coming back in the afternoon to sort, press and weigh the recycled materials; the manager had been selected by All for São Lourenço to provide general support to the cooperative members. The truck was made available by the city hall and has a 20-ton capacity. The city hall also paid the driver’s salary.

During the week of observation, it was possible to map the two truck routes: the Monday, Wednesday and Friday route, and the Tuesday-Thursday route. To do this, a portable GPS device was used, storing data related to: velocity of the truck, time spent on each route, quantity and locations for stopping on each route, and which neighborhoods were on each route. In following, these data were transferred to TransCAD® software (academic version 6.0), using Mapsource® to convert the geographic information. Both routes started and ended at COOPRECI. After collecting the necessary data, the next phase was data analysis and action planning.

Data Analysis and Action Planning

During data collection, it was noted that the collectors did not possess Personal Protection Equipment (PPE) such as uniforms, gloves or boots; there was no sorting table and no form of control for the material which was collected and sold. With no uniforms, the collectors could not be identified and associated with the cooperative by the population, which according with some interviewed residents, made it more difficult for residents to perceive and collaborate with the project. The lack of gloves and boots brought health

risks to the collectors, who were occasionally cut or scratched during the collection and sorting processes. The lack of a sorting table also presented challenges for separating the material because it had to be spread out on the ground, which was inefficient and presented ergonomic challenges for the collectors. Finally, the lack of control of the quantity of material sorted and sold made managing the cooperative's performance more difficult. Materials collected during the month were sold at the beginning of the following month, and always to the same regional recycling company. It was also noted that the number of collectors involved with the cooperative was not sufficient CEMPRE (2014b), the cooperative counted on three members during the data collection phase.

Furthermore, with the observation of the truck and route mapping, the data showed that the selective waste collection was poorly structured. The truck only passed through a select number of streets and neighborhoods, on the same days as the conventional trash collection; there were also no set times for collection, which reduced the amount of recyclable material collected. Based on the documented sale of material in February 2015, the researchers calculated that approximately 3200 kg of recyclable materials were collected in January, 2015. According to the Solid Waste Diagnostics (SNIS 2013), this is a limited quantity in a city the size of São Lourenço; for cities within the same population range, the average amount of recyclable materials collected is almost twice that of the studied municipality, at 6026 kg per month.

Based on this analysis, the researchers' conclusion was that there was no structured selective waste collection program, but rather a mixture of activities related to selective waste collection. It was also noted that the cooperative operated in a precarious fashion, making it financially unsustainable; that is, the money earned from collected and pressed recyclable material was not covering costs.

The next step was action planning. In conjunction with the NGO, the following actions were planned based on some key questions:

- *Which selective waste collection model would be used?* Two models were used; Door-to-Door in 27 neighborhoods and VDP/Ecopoints in the downtown area. The Nestlé company *Waters* donated these collection points;
- *Which days and times would the selective waste collection occur?* It was established that the schedule would alternate (every other day) with conventional trash pick-up, and it would occur from 7:00 a.m. to 12:00 p.m. The selective collection activity that existed before the implementation was done during the morning hours, which is why this time was maintained. In the afternoon, the cooperative members worked at their headquarters, pressing recyclable materials.
- *Which days would the collection happen in each neighborhood?* A schedule was created for implementation. The 27 neighborhoods would be reached by door-to-door collection, and would be divided into seven groups, with each neighborhood having a different implementation date. The first group represented only one neighborhood, which would be the pilot neighborhood. This neighborhood was selected as the pilot due to its small size, and for having already participated in a selective collection program that existed prior to this project. The other neighborhood groups were selected due to the proximity and size. Nearby neighborhoods which belonged to the same group and each group had five neighborhoods. Each neighbourhood group would serve as one improvement and learning cycle for action research. The AR team chose a period of approximately one month between the days of implementation in

each neighbourhood group in order for there to be sufficient time for the improvement and learning phases between groups.

- *What types of communication would be used for the new program?* The NGO members chose the door-to-door distribution of pamphlets, Internet alerts, and local radio and newspaper as the means of communicating the program to each neighborhood.

After the planning phase, next came the action implementation.

Action Implementation

The implementation phase was carried out over seven improvement and learning cycles. As previously stated, in each cycle, there was an expansion of the selective waste collection program. Figure 2 shows the scheduled implementation for the seven neighborhoods during the improvement and learning cycles. In the first cycle, the program was implemented in only one neighborhood; the other groups each had four or five neighborhoods. The activities from the first cycle are described below.

Planning (P)

In this phase, the pilot neighborhood implementation was planned considering questions such as which route would be used, and the location for the VDP/Ecopoints received from Nestlé Waters. TransCAD® was used to plan the route (Mapa and Lima 2012). To choose the VDP locations, the criterion established by the action research team was that they be central points in the city. For monitoring and collection at the VDPs, the team defined that they should be monitored everyday by the cooperative manager during the first months after installation, and the cooperative should collect every Monday. After planning these actions for the first cycle, implementation was the next phase.

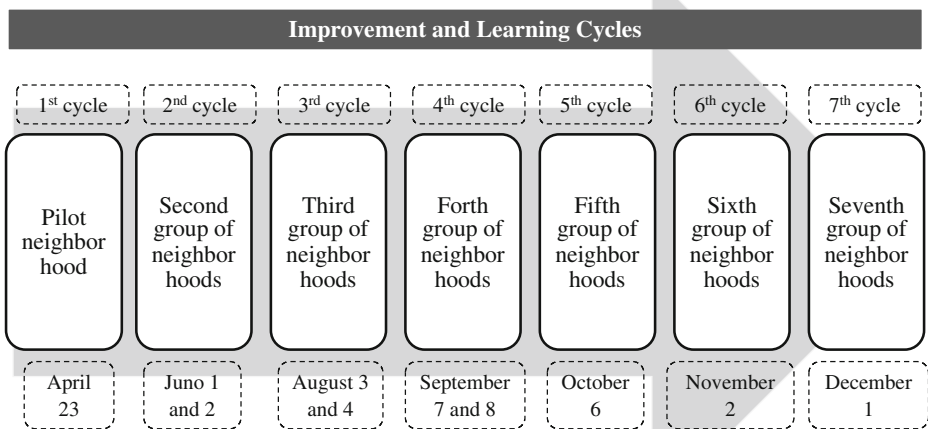


Fig. 2 Neighborhood implementation schedule

Implement (I)

First, a meeting was held with the action research team and collection members in order to deliver the PPE (gloves, uniforms and boots), present the new plan for the pilot neighborhood and the monitoring/collection plan for the VDPs. During this meeting, a new day was selected for the VDP collections because, according to the collection members, Monday was not an ideal day for this activity. They argued that the ideal weekday was Friday, as the VDPs would be empty before the weekend, which is a period of more frequent use; in turn, this would diminish the risk of materials being placed around, but outside of the VDPs.

The implementation of the pilot neighborhood collection and VDP installation were carried out. The action research team was present for both activities. After this phase was completed, the next step involved observation and evaluation of the first improvement and learning cycle.

Observe and Assess (O&A)

During this phase, the action research team monitored the selective waste collection execution by the cooperative throughout its first month. During this time, the following questions were observed: If the whole neighborhood was being served by the program; if the entire population was aware of its activities; and if there was any gain or loss in the program's participation. One of the researchers interviewed city residents from different streets in the pilot neighborhood and noted that some streets were not being reached by the cooperative and some residents still did not know about the program. These results concluded that there was a diminishing participation on part of the neighborhood's population. The cooperative manager communicated during this timeframe that the VDPs were not being used. He argued that when interviewing certain individuals in the neighborhood near the VDP, most of them did not know what the VDPs were used for. When this phase closed, the next steps were reflection and action.

Reflect and Act (R&A)

During this phase the action research team planned and executed actions which could correct the problems found during the previous stage. In order to improve upon the observations, the LogTranS found studies in the literature about awareness and population participation in selective waste collection (Rutkowski and Rutkowski 2015; Ferri et al. 2015; Bringhenti et al. 2011). Nevertheless only Rutkowski and Rutkowski (2015) propose methods for mobilizing the population. According to the authors, mobilization mobilisation includes distribution of educational pamphlets and other advertising materials about waste separation, and instructional materials telling households and businesses the days, time, and frequency of recyclables collection. Based on this, more campaigns were elaborated to mobilize population. New pamphlets with instructions on separating the recyclable material and the schedule for the collection, were distributed door-to-door by the cooperative members during the pilot deployment. Furthermore, one of the researchers and one collector from the cooperative were interviewed on the city's radio station. In order to reinforce the regularity of collection in the neighborhood, the action research team held a meeting with the cooperative members to emphasize the importance of regular service throughout the neighborhood, explaining that there would be greater participation by the population and, in turn, greater results. Finally, to try to solve the problem of VDPs, instructive pamphlets on their existence and use were then distributed in the city's downtown region.

After finishing the first cycle, the rest of the cycles were carried out. All knowledge generated in each cycle served as a basis for making decisions related to the following phases. The main activities carried out during each cycle appear in Table 1.

The activity “Planning New Routes” was pertinent to all cycles, as each cycle corresponded to the expansion of the program to new groups of neighborhoods. Thus, the routes needed to be modified. Figure 3 presents the two final routes for the selective waste collection truck to serve São Lourenço municipality; the blue route occurs on Monday, Wednesday and Friday, and the green route on Tuesday and Thursday. Moreover, the stops on each route are presented, which are places where the truck must wait for the collectors while they work through each of the adjacent streets.

Results Assessment

After the selective waste collection began to operate, all 27 neighborhoods were integrated into the collection schedule. Moreover, other environmental, economic and social benefits were obtained, which appear in Fig. 4 and are discussed below.

Increased Monthly Average Volume per Collector, by Cooperative

Compared to the average values collected per month by the collectors and cooperative as a whole, after the second cycle these values passed the average established by SNIS (2013) and CEMPRE (2014b). This result is related to the start of awareness campaigns, which contributed to an overall participation increase by the population and for having supplied basic conditions for improving each collector’s work (gloves, boots, sorting table, better truck regarding adequate capacity, etc.), which ensures greater efficiency from the entire program.

Greater Profits for Each COOPRECI Collector

A monthly average of \$185.17 was made per month by each collector. Although this is a slightly higher monthly average than the national numbers (IPEA 2013), from the fifth cycle forward, all COOPRECI collectors started to receive a stipend, to make their salaries equivalent to the Brazilian minimum wage. Thus, the payment received by the collectors was no longer dependent on population participation, which reinforces the profession as a recyclable material collector.

Reduced Material Sent to Landfill as Final Destination

It was estimated that around 89 tons of material were collected during the execution of the first cycle of improvement and learning. Thus, this material was collected and sold to a recycling company, and not destined to a landfill or dump.

Limited the Release of Atmospheric Pollutants

The study done by IPEA (2010) shows the breakdown of atmospheric pollutants which are not released into the environment, corresponding to each ton of recycled material for the five main recycled materials. Using this study and the quantity of each of the five materials sold by COOPRECI, it is estimated that 2.3 tons of pollutants did not reach the atmosphere during the seven action research cycles.

Table 1 Main activities during improvement and learning cycles

Cycles	Planning (P)	Implement (I)	Observe and assess (O&A)	Reflect and act (R&A)
2nd cycle	<ul style="list-style-type: none"> - Planning new routes for the new neighborhoods - Meeting with the collectors for mapping their needs 	<ul style="list-style-type: none"> - Renting a better truck regarding adequate capacity - Implementation in the second group of neighborhood 	<ul style="list-style-type: none"> - Monitoring the execution of the selective waste collection in the new neighborhoods - Monitoring the utilization of the VDPs 	<ul style="list-style-type: none"> - Literature review - Raising population's awareness about the program in the neighborhoods
3rd cycle	<ul style="list-style-type: none"> - Planning new routes for the new neighborhoods. - Meeting with the collectors for mapping their needs 	<ul style="list-style-type: none"> - Implementation in the third group of neighborhood - Purchasing a sorting table 	<ul style="list-style-type: none"> - Monitoring the execution of the selective waste collection in the new neighborhoods - Monitoring the utilization of the VDPs 	<ul style="list-style-type: none"> - Literature review - Interviewing the population aiming to find a new location for one of the VDP - Transferring one of the VDP for a new location - Raising population's awareness about VDPs' utilization
4th cycle	<ul style="list-style-type: none"> - Planning new routes for the new neighborhoods. - Meeting with the collectors for mapping their needs 	<ul style="list-style-type: none"> - Implementation in the fourth group of neighborhood - Meeting with collectors of São Lourenço and one Tetrapak's employee aiming to attract more collectors to the COOPRECI and qualify them 	<ul style="list-style-type: none"> - Monitoring the execution of the selective waste collection in the new neighborhoods - Monitoring the utilization of the VDPs 	<ul style="list-style-type: none"> - Literature review - Meeting with the collectors aiming to emphasize the importance of regular service throughout the neighborhoods - Raising population's awareness about the program in the neighborhoods - Raising population's awareness about VDPs' utilization
5th cycle	<ul style="list-style-type: none"> - Planning new routes for the new neighborhoods. - Meeting with the collectors for mapping their needs - Obtaining financial resource to improve the collectors' income 	<ul style="list-style-type: none"> - Implementation in the fifth group of neighborhood - Increasing the payment received by the collectors (stipend) 	<ul style="list-style-type: none"> - Monitoring the execution of the selective waste collection in the new neighborhoods - Monitoring the utilization of the VDPs 	<ul style="list-style-type: none"> - Literature review - Establishing a more frequently VDPs collections - Raising population's awareness about the program in the neighborhoods
6th cycle	<ul style="list-style-type: none"> - Planning new routes for the new neighborhoods. 	<ul style="list-style-type: none"> - Implementation in the sixth group of neighborhood - Meeting with some cooperatives situated close to São Lourenço aiming to promote these cooperatives and COOPRECI 	<ul style="list-style-type: none"> - Monitoring the execution of the selective waste collection in the new neighborhoods - Monitoring the utilization of the VDPs 	<ul style="list-style-type: none"> - Literature review - Raising population's awareness in the neighborhoods

Table 1 (continued)

Cycles	Planning (P)	Implement (I)	Observe and assess (O&A)	Reflect and act (R&A)
7th cycle	- Planning new routes for the new neighborhoods.	<ul style="list-style-type: none"> - Increasing the payment received by the collectors - Implementation in the seventh group of neighborhood - Meeting with the local education authority to create a new educational campaign about the selective waste collection program in the schools - Increasing the collectors' income through the financial recourse obtained 	<ul style="list-style-type: none"> - Monitoring the execution of the selective waste collection in the new neighborhoods - Monitoring the development of the educational campaign in the schools 	<ul style="list-style-type: none"> - Literature review - Raising population's awareness in the neighborhoods - Setting a new VDPs layout, allowing them to store all three types of recycled material together

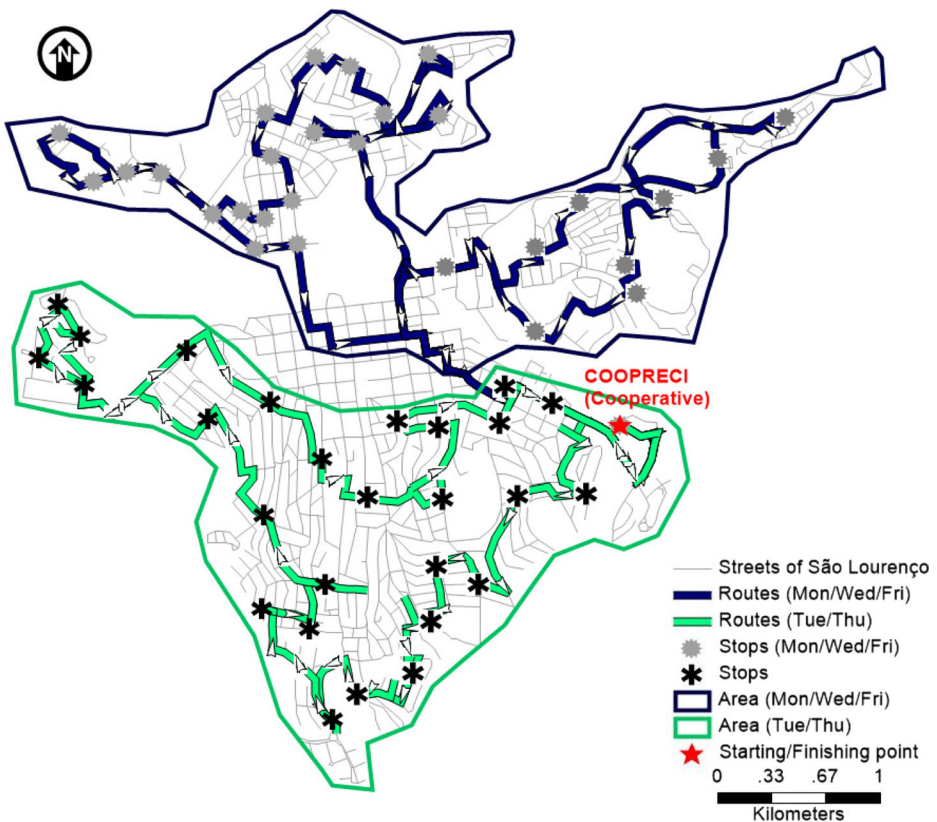


Fig. 3 Final routes for the selective waste collection to serve São Lourenço

Improvement and Learning Cycles											
	1 st cycle	2 nd cycle			3 rd cycle	4 th cycle	5 th cycle	6 th cycle	7 th cycle		
Month	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.		
Number of neighborhoods served	02	06	06	06	11	15	19	24	28		
Area served	Km ²	-	0,53	3,16	3,16	3,16	4,11	5,44	7,30	9,81	
	(%)	-	04	27	27	27	35	47	63	85	
Number of collection members	03	07	04	06	06	05	07	06	07		
Average volume collected per collection member	1.382	1.358	1.573	1.746	1.822	1.909	1.738	1.919	1.724		
Income (\$)	-	144,80	123,76	148,66	149,89	139,74	139,74	242,46	242,46		
Total amount sold (kg)	6.911	9.510	6.295	10.480	10.933	9.549	12.166	11.516	12.070	Total	
Total amount sold per recycled material type (main types)	Steel (kg)	0	0	08	12	10	0	07	09	25	71
	Alum. (kg)	77	53	20	25	10	07	21	25	32	270
	16.978	88	120	1.572	2.661	2.463	2.025	2.953	2.564	2.532	16.978
	Plastic (kg)	1.034	820	894	920	820	806	1.029	867	1.105	8.925
Glass (kg)	0	0	267	250	150	211	274	236	292	1.680	

Amount of air pollutants avoided (kg)	Production process benefits (\$/ton)	Cost related with SWM (\$)
0,34	61,84	24,67
276,90	939,69	9,38
20,20	108,92	590,15
0,00	375,38	288,33
2.016,00	40,30	58,39
2.313,43	5.328,34	970,95

Fig. 4 Results obtained through action research

Financial Gain Generated

Using again the study from IPEA (2010), it was calculated that an economy of \$4357.39 was generated from the selective waste collection project. This financial gain generated by recycling is positive and benefits:

- The city government. The IPEA (2010) study shows the benefits associated with final waste disposal, considering that the material was sent for recycling, and not to a final disposition in a landfill, avoiding the average cost of the landfill per ton. In doing so, the city government minimizes financial losses with the disposal of material in landfills/dumps;
- Private businesses. In IPEA (2010), the economic benefits are calculated by the difference between the cost of the material for production of goods, from virgin raw material and the costs of production material from secondary raw material. Then, regarding private business, the financial gain calculated it is related to the use of recyclables as raw material to diminish production costs and reduce the use of pollutants;
- Population. Based on the production coefficient from the virgin raw material and secondary raw material, which includes the source and quantity of energy used for production in a ton of material, (IPEA 2010) the consumption of energy and carbon emissions are estimated. Thus, it can be inferred that there are fewer impacts on the environment due to energy consumption and greenhouse gas emission.

Findings

Challenges faced during the implementation of the selective waste collection program were: level of awareness and participation from the population in the selective waste collection program; lack of proper structure in the cooperative; and lack of worker benefits and materials for the cooperative collectors. These barriers were also highlighted in other studies present in the literature (cited in [Selective Waste Collection](#) section). But there is one aspect in which this

study differs from previous literature: aside from analyzing the motives and consequences, whether through literature review or meetings with the action research team, many actions were implemented to improve on previous lessons learned. That is, the objective went beyond analysis and into action on the hurdles and challenges faced. The ability to act on these difficulties on implementing the selective waste collection program is due to the methodology of action research. It can be asserted that not only the agreement of all AR Team members but also the use of action research were the main factors for success in the entire program.

Firstly, because the action research is a mixture of conceptual and theoretical methods, as defined by Filippini (1997); that is, it promotes a literature analysis to raise a series of points for planning and action research. Thus, when the challenges were found in each stage at the Reflect and Act (R&A) step, researchers took the time to analyze existing literature and seek out more adequate solutions, as well as making faster decisions which were supported by academic research. In other studies where action research is used, literature reviews for possible solution occurring action research are highlighted (Liu 2009; Charoen et al. 2008; Liu and Pan 2007; Tepe and Haslett 2002). Secondly, the action research deployment in multiple cycles allowed for knowledge to be generated in each iteration, which served as a basis for following cycles and enabled that good decisions and bad decisions were replicated and corrected, respectively, as the program was rolled out in different neighborhoods. That being stated, the use of improvement and learning (or simply, action research cycles) during the study is an interesting option not only for new systems (Paes et al. 2016), but also for expansion and improvement of existing projects.

Conclusions

This study reported on the implementation of a selective waste collection program in a Brazilian municipality through action research. Through the use of action research, it was possible to implement the recyclable materials collection program in the city of São Lourenço, which helped the city conform to the new PNRS statute. Knowledge was generated about how the implementation could and should occur, and highlighting the main barriers and best practices for the process. Many benefits were identified by all those involved in the project, including the reduction of 2.3 tons of atmospheric pollutants from being released into the environment, and the collection of 89 tons of recyclable material, which didn't end up in a landfill. The selective waste collection program is up and running, thus the benefits of the program are ongoing.

It is worth mentioning that when selective waste collection programs are implemented, the initiation of the process should be gradual and done in phases so that resources are obtained, the right decisions are reinforced and the errors are identified, rather than frustrating the community, the collectors and other parties involved. In this study, improvement and learning cycles were used to conduct the action research; the research team used a pilot neighborhood and then continued with the expansion to other neighborhoods, which contributed to the project's success.

No great hurdles or challenges were observed in the utilization of action research as a method. However, some difficulties were encountered and overcome during the process as a whole, such as: awareness and participation from the population in the selective waste collection program; lack of proper structure in the cooperative; and lack of worker benefits and materials for the cooperative collectors.

Regarding limitations of the study, it is important and worth highlighting that no other methods were tested, aside from AR. The satisfactory results which were obtained provide us with a sense that the method is suitable for implementing selective collection programs as was done in São Lourenço. Nonetheless, the objective of this study was not to compare the performance of alternative methods. We also cannot affirm how the application of the same method in different cities, with different population sizes and characteristics, would be. However, the experience gained through this case enables us to affirm that it would be possible to replicate in other cities, as long as there is an openness and interest in the use of AR from public officials. Thus, as a suggestion for future studies, the replication of this method in other cities and comparison to its implementation with other methods, such as Participative Research, would be beneficial to build the body of knowledge and advance the discourse on these subjects.

Acknowledgements The authors would like to thank CAPES, CNPq and FAPEMIG, for their financial support given to the many projects that helped develop this study.

References

- ABRELPE (2014) Brazilian association of public cleaning companies and special waste. Perspective about solid waste in Brazil. <http://www.abrelpe.org.br/Panorama/panorama2014.pdf>. Accessed 10 Apr 2016
- Besen GR, Ribeiro H, Gunther WMR, Jacobi PR (2014) Selective waste collection in the São Paulo metropolitan region: impacts of the national solid waste policy. *Ambiente & Sociedade* 17(3):253–272. doi:10.1590/S1414-753X2014000300015
- Brazil (2010). Law n°. 12,305, of August 2, 2010 Establishes the National Policy for Solid Waste and provides other requirements http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/112305.htm Accessed 11 Sept 15
- Bringhenti JR, Zandonade E, Günther WMR (2011) Selection and validation of indicators for programs selective collection evaluation with social inclusion. *Resour Conserv Recycl* 55:876–884. doi:10.1016/j.resconrec.2011.04.010
- Bufoni AL, Carvalho MS, Oliveira LB, Rosa LP (2014) The emerging issue of solid waste disposal sites emissions in developing countries: the case of Brazil. *J Environ Protect* 5:886–894. doi:10.4236/jep.2014.510090
- Campos HKT (2014) Recycling in Brazil: challenges and prospects. *Resour Conserv Recycl* 85:130–138. doi:10.1016/j.resconrec.2013.10.017
- Carvalho MS, Rosa LP, Ferreira ACS (2011) The issue of sustainability and disclosure. A case study of selective garbage collection by the urban cleaning service of the city of Rio de Janeiro. *Brazil-COMLURB Resour Conserv Recycl* 55:1030–1038. doi:10.1016/j.resconrec.2011.05.015
- CEMPRE (2014a) Corporate commitment to recycling. CICLOSOFT Research <http://cempreorgbr/ciclossoft/id/2> Accessed 10 Jan 16
- CEMPRE (2014b) CEMPRE inform number 134 March/April 2014: challenges and opportunities. <http://cempreorgbr/cempre-informa/id/15/pro-catador-premio-reconhece-programas-de-coleta-seletiva-eficientes> Accessed 20 Apr 16
- Charoen D, Raman M, Olfman L (2008) Improving end user behaviour in password utilization: an action research initiative. *Syst Pract Action Res* 25:55–72. doi:10.1007/s11213-007-9082-4
- Chaves GLD, Santos JL Jr, Rocha SMS (2014) The challenges for solid waste management in accordance with agenda 21: a Brazilian case review. *Waste Manag & Res* 32(9):19–31. doi:10.1177/0734242X14541987
- Coghlan D, Shani AB (2014) Creating action research quality in organization development: rigorous. Reflective and Relevant *Syst Pract Action Res* 27:523–536. doi:10.1007/s11213-013-9311-y
- Coughlan P, Coghlan D (2002) Action research for operations management. *Int J Oper Prod Manag* 22(2):220–240. doi:10.1108/01443570210417515
- Fagundes LD, Amorim ES, Lima RS (2017) Action research in reverse logistics for end-of-life tire recycling. *Syst Pract Action Res*. doi:10.1007/s11213-016-9408-1
- Ferri GL, Chaves GLD, Ribeiro GM (2015) Reverse logistics network for municipal solid waste management: the inclusion of waste pickers as a Brazilian legal requirement. *Waste Manag* 40:173–191. doi:10.1016/j.wasman.2015.02.036

- Filippini R (1997) Operations management research: some reflections on evolution, models and empirical studies in OM. *Int J Oper Prod Manag* 17(7):655–670. doi:10.1108/01443579710175583
- IPEA (2010) Research Institute of Applied Economics. Research about ambiental services payment for solid waste management. http://www.Mma.Gov.br/estruturas/253/_arquivos/estudo_do_ipea_253.Pdf. Accessed 01 Dec 15
- IPEA (2013) Social situation about waste pickers. http://www.ipeagovbr/agenzia/images/stories/PDFs/situacao_social/131219_relatorio_situacao_social_mat_reciclaivel_brasil.pdf Accessed 30 Sept 15
- Lima RMSR, Silva SMCP (2013) Evaluation of a municipal program of selective collection in the context of the national policy of solid waste. *Acta Sci* 35(4):645–653. doi:10.4025/actascitechnol.v35i4.16095
- Liu Y (2009) Implementing and evaluating performance measurement initiative in public leisure facilities: an action research project. *Syst Pract Action Res* 22:15–30. doi:10.1007/s11213-008-9103-y
- Liu LYJ, Pan F (2007) The implementation of activity-based costing in China: an innovation action research approach. *The Br Rev* 39:249–264. doi:10.1016/j.bar.2007.05.003
- Mapa SMS, Lima RS (2012) Combining geographic information systems for transportation and mixed integer linear programming in location-allocation problems. *Gest Prod* 19:119–136. doi:10.4236/jsea.2014.710076
- Mello CHP, Turrioni JB, Xavier AF, Campos DF (2012) Action research in production engineering: a structure proposal for its conduction. *Production* 22(1):1–13. doi:10.1590/S0103-65132011005000056
- Paes CE, Bernardo M, Lima RS, Leal F (2016) Management of waste electrical and electronic equipment in Brazilian public education institutions: implementation through action research on a university campus. *Syst Pract Action Res*. doi:10.1007/s11213-016-9399-y
- Rada EC, Ragazzi M, Fredizzi P (2013) Web-GIS oriented system viability for municipal solid waste selective collection optimization in developed and transient economies. *Waste Manag* 33:785–792. doi:10.1016/j.wasman.2013.01.002
- Rutkowski JE, Rutkowski EW (2015) Expanding worldwide urban solid waste recycling: the Brazilian social technology in waste pickers inclusion. *Waste Manag Res* 33(12):1084–1093. doi:10.1177/0734242X15607424
- SNIS (2013) National System of sanitation information. Diagnostic about urban solid waste management. <http://www.snis.gov.br/PaginaCarrega.php?EWRErterterTERTer=93>. Accessed 10 Feb 2016
- Tepe S, Haslett T (2002) Occupational health and safety systems, corporate governance and viable systems diagnosis: an action research approach. *Syst Pract Action Res* 15(6):509–522. doi:10.1023/A:1021064704360
- Toso EAV, Alem D (2014) Effective location models for sorting recyclables in public management. *Eur J of Oper Res* 234(3):839–860. doi:10.1016/j.ejor.2013.10.035
- Westbrook R (1995) Action research: a new paradigm for research in production and operations management. *Int J Oper Prod Manag* 15(12):6–20. doi:10.1108/01443579510104466
- Zsigraiova Z, Semiao V, Beijoco F (2013) Operation costs and pollutant emissions reduction by definition of new collection scheduling and optimization of MSW collection routes using GIS. The case study of Barreiro, Portugal. *Waste Manag* 33:793–806. doi:10.1016/j.wasman.2012.11.015