

## Article

# A Procedure to Transform Recycling Behavior for Source Separation of Household Waste

Kamran Rousta <sup>1,\*</sup>, Kim Bolton <sup>1</sup> and Lisa Dahlén <sup>2</sup><sup>1</sup> Swedish Centre for Resource Recovery, University of Borås, Borås 501 90, Sweden; Kim.Bolton@hb.se<sup>2</sup> Waste Science and Technology, Luleå University of Technology, Luleå 971 87, Sweden; Lisa.Dahlen@ltu.se

\* Correspondence: Kamran.Rousta@hb.se; Tel.: +46-33-4354-4644

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**Abstract:** Household waste separation at the source is a central part of waste management systems in Sweden. Resource recovery of materials and energy increased substantially after separate collection was implemented in the 1990s. A procedure to transform recycling behavior for the sorting of household waste—called the recycling behavior transition (RBT) procedure—was designed and implemented in a waste management system in Sweden. Repeated use of this procedure, which will assist in the continual improvement of household sorting, consists of the following four consecutive steps: (i) evaluating the current sorting behavior; (ii) identifying appropriate interventions; (iii) implementing the interventions, and; (iv) assessing the quantitative effect of the interventions. This procedure follows action research methodology and it is the first time that such a procedure has been developed and implemented for the sorting of household waste. The procedure can easily be adapted to any source separation system (which may have different local situations) and, by improving the source separation, will increase the resource recovery in the waste management system. The RBT procedure, together with its strengths and weaknesses, is discussed in this paper, and its implementation is exemplified by a pilot study done in Sweden.

**Keywords:** recycling behavior; resource recovery; source separation; household waste

## 1. Introduction

Household waste separation at the source was introduced in Sweden in the early 1990s. Here household waste refers to all waste that is collected in curbside collection systems, the packaging materials in bring systems, and hazardous waste, electronics, bulky waste, *etc.* which are collected at recycling centers. There is not a single system for the entire country, but different regions provide different collection systems for the inhabitants. Source separation increases both the rate of recycling of recyclable materials and of biological treatment of food waste. Material recycling has more than doubled, and biological treatment has more than quadrupled, since source separation was implemented in Sweden. In 2014 the country generated about 4.55 million tons of household waste, of which 36% was treated by material recycling, 16% by biological methods, 47% was used for energy recovery, and 1% was landfilled [1]. This illustrates that an effective source separation scheme can increase resource recovery from household waste.

Although waste separation at the source is a common and economical way for separating the recyclable fractions, effective participation by inhabitants is required to increase the correct sorting of the recyclables and food waste [2]. Many previous studies have investigated factors that determine the sorting behavior of inhabitants to better understand this phenomenon. A wide range of factors have been studied, and the factors that are chosen for a particular study often depend on the researcher's interest and discipline, the case and situation, the scope of the study, and the method used for the study. Some studies found that intrinsic factors, such as attitudes towards recycling and environmental

concern, affect sorting behavior (e.g., [3–8]). Other studies showed that convenient and easy access to recycling facilities are decisive factors (e.g., [9–12]).

Other studies developed a model and framework to explain how different factors affect recycling behavior. For example, the motivation-ability-opportunity-behavior model explains that motivation is necessary but not sufficient for environmentally friendly behavior, but that ability and opportunity to behave in the correct manner are also required [13]. For source separation of household waste, situational factors such as convenient and easy access to recycling stations are opportunities, and knowledge of why and how to sort the waste, as well as past experiences and habits of sorting, are the examples of ability. In a similar study, Barr (2002) [14] presented a conceptual framework of environmental behavior. Barr (2002) [14] explained that environmental values of inhabitants do not have a direct impact on behavior. Instead, behavioral intention is needed as a bridge between environmental values and behavior, and this bridge has a central role in his framework. Situational factors and psychological variables can influence both intention and behavior, and are included in the framework, but are not as central as behavioral intention. Context, knowledge, and experience are examples of situational factors, whereas intrinsic motivation, subjective norms, and altruism are examples of psychological variables.

The studies done by Thøgersen (1994) [13] and Barr (2002) [14] (which were previously discussed above), used recycling behavior (*i.e.*, waste sorting at the source) to exemplify how their model and framework can explain which factors are most important for environmental behavior. Both studies found that factors such as information about the waste sorting scheme and accessibility to the collection facilities played a crucial role in determining the behavior.

Pieters (1991) [15] examined recycling behavior by combining a survey study with measurements of the recyclable materials in the waste stream. The aim was to identify which factors determine inhabitants' participation in waste separation schemes. In contrast, Tucker *et al.* (1999) [16] used a mathematical model to simulate the household waste management behavior. In another study, Tucker (2001) [17] developed a hypothesized cause-effect model of recycling. Intention to recycle plays the central role in this model, and intention can be influenced by pro-recycling attitudes, social norms, and specific barriers such as perceived obstacles and perceived effectiveness. This model also emphasizes the fact that intention to recycle is not sufficient to cause recycling. Similar to Barr (2002) [14] and Thøgersen (1994) [13], this model also considers the factors, called personal difficulties, which hinder the transformation of intention into actual recycling behavior. The studies mentioned above describe the various factors and determinants that influence recycling behavior, and the importance of these different factors depends on the concept of the study, the method used in the study, and where the study was conducted.

Almost all of the above studies have been performed under specific circumstances and in a limited geographical area. It is difficult to generalize the findings to source separation schemes in different places in the world. Wilson *et al.* (2012) [18] compared waste management in 20 cities and clearly showed that there is not a single solution that is suitable for all management systems and cities. Depending on the available facilities, the length of time that the recycling scheme has been implemented, the structure of the waste management system, relevant policies, *etc.* different factors could influence the recycling scheme and its improvement in different ways. Results from previous studies provide a wide range of factors that can improve recycling behavior (*i.e.*, to create effective interventions). However, no study has introduced a procedure for designing relevant interventions and assessing their effect on recycling behavior. The procedure described in this work is based on the action research routine including *look* (gathering data and describing situation), *think* (analyzing and theorizing), and *act* (implementation action and evaluate its effectiveness) [19]. This is the first procedure that combines interventions with their assessment. In addition, the procedure can be used in any source separation scheme anywhere in the world. No matter which kind of waste collection system is implemented, procedures for continuous improvement of the system (quality management tools) are needed. Therefore, it is relevant to develop a procedure to investigate

and design interventions for improvement of source separation systems and to assess their effect in an objective and quantifiable manner.

### *Objectives*

The aim was to create, test, and evaluate a procedure for continuous improvement of any source separation system for household waste. Possible changes in sorting behavior do not depend on the procedure itself, but on the intervention that is used and how it is implemented. The procedure, called recycling behavior transition (RBT) in this paper, identifies the extent of the missorting of household waste and interventions that can improve the sorting; it develops and implements the intervention and then assesses the effect of the intervention. The objectives of the study are summarized in three research questions:

1. How should the current sorting behavior be evaluated?
2. How should the appropriate interventions to improve this behavior be identified?
3. How should the effect of interventions be assessed?

## **2. Methods and Materials**

Although the procedure is novel, it is based on established scientific methods (such as pick analysis and interview techniques). The scientific merits of these methods have been discussed in detail in the literature (e.g., [20–22]) and hence this is not a focus of the present contribution. Instead, we discuss the ways that these methods are combined in the RBT procedure, and exemplify the methods and their combination by presenting results when the procedure was implemented in a residential area in Sweden.

### *2.1. Design of the Study*

The RBT procedure was tested in a pilot residential area in Sweden with the intention to test the method and to improve waste sorting behavior. The first step was to identify the prevailing sorting behavior, which was examined by measurement of waste composition by sampling and manual sorting (pick analysis). In the second step, factors that hindered correct sorting were identified using two types of interviews with the inhabitants: semi-structured and structured interviews. Although it is possible that these hindrances can be identified by other means, such as literature surveys, interviews have the advantage in that they include the inhabitants in the identification of appropriate interventions which increases the probability that the chosen intervention will be effective. Next, based on the interview results, interventions in the waste collection system were designed and implemented. Finally, another pick analysis was conducted to investigate the effect of the interventions. The pilot area and methods used are presented in more detail below.

### *2.2. Description of the Pilot Area Used to Test the Procedure*

The pilot area that was selected for testing the procedure is not relevant to the procedure and, as mentioned above, the procedure can be implemented in any area that has waste sorting at the source. In spite of this, a description of the pilot area is provided since this is needed if the results presented here are to be compared with results from other areas.

The pilot area that was selected is a residential area in the city of Borås, which lies in the southwest of Sweden. This area was chosen since the waste separation scheme was not functioning as well as in other parts of the city [23]. According to Statistics Sweden [24], the pilot area had 447 inhabitants with a diverse socio-demographic background who lived in nine apartment buildings (a total of 208 apartments). Approximately 67% of the inhabitants were born outside of Sweden and immigrated to Sweden more than three years before the procedure was implemented [24]. 31% of the inhabitants were aged from 25 to 44 years and 20% were 45 to 64 years old. It was mainly inhabitants from these age groups that were involved in the interviews in Step 2 of the procedure. Approximately 63% of the

citizens in this area had low income (less than 15,600 Euro per year). In addition, approximately 58% had upper secondary school or higher education, and 33% of the residents owned a car [24].

The source separation system used in the city was established in 1991. It is based on sorting food waste in black bags and combustible waste in white bags (combustible waste is all household waste which is neither food, recyclable, nor hazardous). The waste sorted in the black bags is intended for production of biofuel and that in the white bags for combustion. The black and white plastic bags are distributed free of charge to all households. Both bags are supposed to be located in the kitchen so that they are easily accessible. To maintain low costs for the logistics, both bags are collected at the same time and placed in a single container. They are subsequently separated in an optical sorting machine at material recovery facilities. This type of optical sorting is not commonly used in Sweden. Recyclable materials, such as paper packaging, plastic packaging, metal packaging, glass packaging, and newsprints, should be sorted in a bring system (*i.e.*, they should be taken to recycling stations). The nearest complete recycling station to the pilot area was one and a half kilometers away. However, newsprints and glass packaging could be sorted in separate containers that were located immediately behind the apartment buildings. Other materials, such as bulky and hazardous wastes, should be delivered to one of the five recycling centers; the nearest one being located about two kilometers from the apartment buildings. Collection of the packaging materials at recycling stations, and bulky waste and hazardous waste at recycling centers, is a common part of Swedish waste management system. In these systems, inhabitants should bring their waste to these places and sort them in the appropriate containers.

### 2.3. Methods

A combination of quantitative and qualitative methods is needed in the RBT procedure. These are described below.

#### 2.3.1. Waste Composition Study (Pick Analysis)

Measuring the amount of different fractions in the waste streams (e.g., in the black and white bags) and characterizing them is called pick analysis. The method used was developed by Dahlén *et al.* (2008) [20] and has been published as a manual by the Swedish Waste Management Association [25,26]. Pick analyses were conducted in November 2011, November 2013, and November 2015 (*i.e.*, before and after interventions in the waste collection system). November was chosen since there are no special days (such as holidays) in Sweden during this month. It can therefore be assumed that the waste collected in this month was representative of ordinary waste generation during the year. The pilot area had twenty-eight 660 liter wheeled bins for collection of the white bags (intended for combustible waste) and black bags (intended for food waste). The white and black bags are collected in the same bins (*i.e.*, the bins are not separated into those dedicated for black or white bags). Seven of the bins were randomly selected each week in November, giving a total of 28 samples. Table 1 shows the details of sampling for these two pick analyses. The size and number of samples used in this study ensure the statistical certainty of the results according to the description of the method [20].

**Table 1.** Details of sampling for pick analysis.

Date	Unit of Sample	No. of Samples per Week	Total Samples	Total Weight (kg)
November 2011	Waste in a 660 liter bin	7	28	1732.9
November 2013	Waste in a 660 liter bin	7	28	1699.0
November 2015	Waste in a 660 liter bin	7	28	1592.5

The samples were collected for the pick analysis, and the rest of the waste in the area was weighed each week in order to estimate the total waste that was generated. Waste characterization and weighing of waste fractions in the samples were conducted separately for the white and black bags. The weight of the plastic bags themselves (white and black) was excluded from the pick analysis. Categories,

subcategories, and fractions of the waste that was weighed during the pick analysis, as well as where it should be sorted, are shown in Table 2. The categories used in the pick analysis were chosen according to the municipality's instructions for waste sorting, which are similar to those used in other Swedish cities. Any other material than food waste in the black bags and combustible waste in white bags was regarded as missorted fractions.

**Table 2.** Waste fractions and categories used in the pick analyses.

Category	Subcategory	Fractions	Sorting Instruction
Food	Food	Leftover food, fruits, vegetables, <i>etc.</i>	Black bag
Packaging, newsprints	Paper packaging	Cardboard, paper packaging	Recycling station
	Plastic packaging	Plastic film packaging, foam plastic packaging, dense plastic packaging	
	Glass packaging	Colored and clear glass packaging	
	Metal packaging	Metal packaging	
	Newsprint	Newsprint, advertisements, paperbacks, writing/drawing papers	
	Deposit bottles <sup>1</sup>	PET <sup>2</sup> , Aluminum cans and glass bottles with deposit	
Combustible	Diapers	Diapers, pads	White bag
	Textile fabrics	Clothes, shoes, different textiles	
	Combustible waste	Wood, small non-packaging plastic, garden waste, wood, non-packaging paper, cat sand, tissues, envelopes, Christmas cards, small baby tools, pens, cigarette butts, vacuum cleaner bags, <i>etc.</i>	
Other	Non-packaging plastic	Big parts	Recycling center
	Non-packaging metal	Any metal parts	
	Non-packaging glass	Broken glass	
	Other non-combustibles	Ceramics, broken mug, bricks, <i>etc.</i>	
Hazardous	Medicines <sup>3</sup>		Recycling center
	Batteries		
	Small electronics	Mobile phones, clocks, battery chargers, <i>etc.</i>	
	Light-bulbs		
	Other hazardous	Glues, chemicals, full sprays	

<sup>1</sup> Deposit bottles should be collected in large supermarkets. <sup>2</sup> PET (polyethylene terephthalate) bottles are usually used for beverages. <sup>3</sup> Medicines should be collected in pharmacies.

The amounts of correctly and incorrectly sorted waste were analyzed using the MINITAB software (Minitab Ltd., Coventry, UK) to determine the average amounts of missorted materials in kg per household per week, as well as the statistical relevance of any changes in sorting behavior due to the interventions. The results from the first pick analysis revealed the prevailing waste sorting behavior in the pilot area. The results from the second and third pick analyses, which were conducted after each of the two interventions, were compared with each other and with the results from the first pick analysis using the two sample *t*-test with 95% confidence interval. Hence, the second and third pick analyses quantitatively assessed the effect of the interventions.

### 2.3.2. Interview

The results from the first pick analysis were used to design interview templates. The goals of the interviews were to identify hindrances for correct waste sorting and the changes (interventions) in the waste collection system that would enable and motivate improved sorting. To do this, two types of interviews were designed: semi-structured interviews and structured interviews. They are described in detail below.

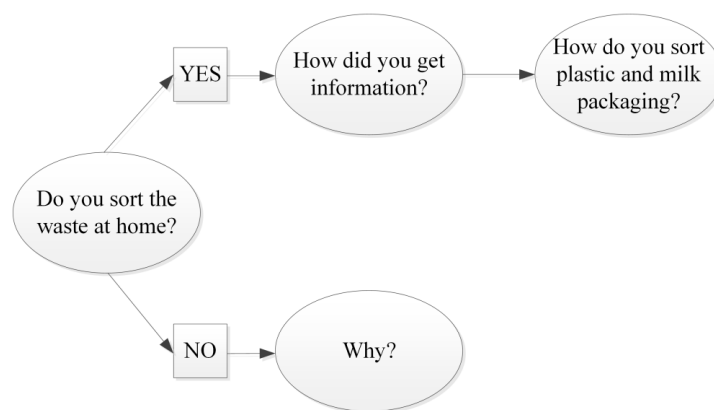
### Semi-Structured Interview

Qualitative interviews, such as semi-structured interviews, are usually performed to obtain deep insight into how people understand a phenomena, and therefore the number of interviewees is not important [21,22]. Semi-structured interviews are used to gather information about peoples' situations, to collect statements about their opinions, and to explore their motivation and experiences [27]. The initial aim of the semi-structured interviews was to understand why inhabitants sort their waste as shown by the pick analysis, if they think that they need to improve their sorting behavior, and, if so, what they think is needed to improve their sorting. To do this, eight interviewees who were comfortable with participating in the research interview were identified. This was done by sending an invitation letter to all inhabitants as well as asking inhabitants via a contact person. The interviews were conducted three to five months after the first pick analysis (over a two month period) at the University of Borås, and lasted between 50 and 65 min. A practical exercise for sorting waste was also conducted during the interview (*i.e.*, asking the interviewees how they sort different kinds of waste fractions in four alternatives: white bags, black bags, recycling stations, or recycling centers). This was designed to get a better understanding of their knowledge regarding the sorting of waste. The interviewees were asked to describe how they felt about sorting their waste and the waste management system in the city, how they understood the need for sorting and the system, and what is required for better participation in the system. The interviewees were free to discuss their ideas and comments. All the interviews were taped and transcribed. They were subsequently analyzed to identify key words, paragraphs, or themes. The results obtained from these semi-structured interviews were used to design a short (less than five minutes), face-to-face structured interview.

### Structured Interview

The semi-structured interviews identified the interventions that some of the inhabitants perceived were needed in the system. In order to ascertain if these perceptions were shared by a broad range of inhabitants, a structured interview was designed. The aim of this short interview was not to perform a separate survey (via a questionnaire) but rather to complement the semi-structured interviews. The structured interview was done by the same author who conducted the semi-structured interviews. The interviews were done three months after the semi-structured interviews and over a three day period so that a larger number of people could participate. The time of the interviews was not pre-planned, but instead the interviewer met inhabitants (not children) as they were conducting their daily activities. They were asked if it was convenient for them to participate in the interview and, if so, the interviewer introduced himself and asked the age of the respondent. The respondents were then asked to give short answers to the questions provided to them. There were two types of questions. One type had "yes" or "no" alternatives and the other type questioned how and why the inhabitants sorted their waste. If an answer about "how" specific waste should be sorted was incorrect, it was followed with a "why" question in order to investigate the reason of the incorrect sorting. The questions were limited to sorting of plastic and paper packaging, since the pick analysis showed that these were the types of packaging that were missorted the most. To keep the interview as short as possible and in order to minimize the information on sorting that could be given to the interviewee (which could affect the outcome of the subsequent pick analysis), milk packaging was used as an example of paper packaging. Figure 1 shows the flowchart for the questions used in this structured interview.





**Figure 1.** Flowchart of the questions in the structured interview.

### 2.3.3. Interventions in the Pilot Study

As discussed below, three interventions were designed. These interventions were chosen since, based on the results of the interviews, it was hypothesized that they would lead to improvements in the collection system. This hypothesis was tested in the pilot area. The interventions are described in Section 3.1.3 to clarify their relation to the interview results.

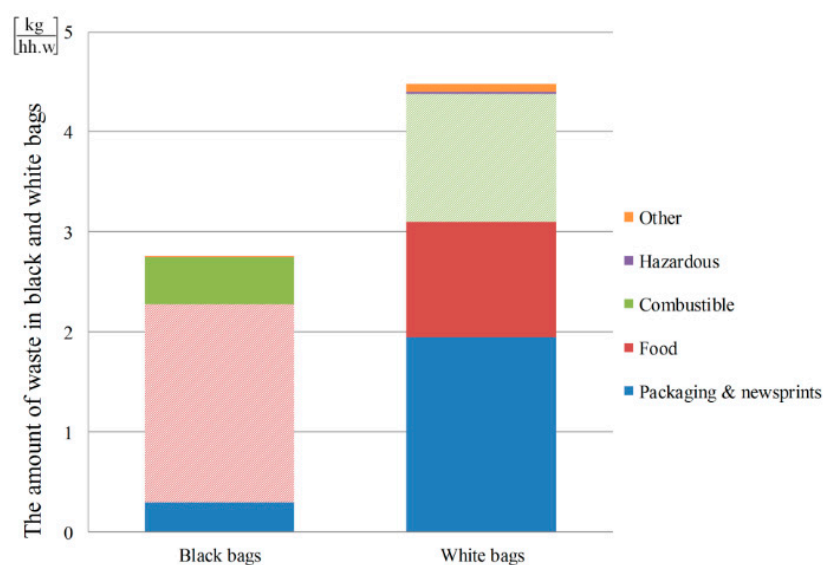
## 3. Results and Discussion

Implementation of the RBT procedure in the pilot area has been completed. The results obtained from the procedure are discussed below. The way that this procedure can be generalized for any source separation system is also discussed.

### 3.1. Pilot Area

#### 3.1.1. First Pick Analysis—Evaluation of the Current Sorting Behavior

Figure 2 shows the average waste composition per household per week in the black and white bags.



**Figure 2.** Composition of waste (kg per household per week) in black and white bags before the interventions (2011). The striped regions show that waste that is intended for each bag (food waste in the black bag and combustible waste in the white bag).

The total waste in the black bags, intended for food waste, was 2.8 kg per household per week (kg/hh/w) whereas in white bags (intended for combustible waste), it was 4.5 kg/hh/w. The striped areas in Figure 2 show the part of the waste that was sorted correctly. Seventy-one percent of the waste in the black bags and 29% of the waste in the white bags was sorted correctly. The total missorted ratio, obtained by summing the missorted fractions in both bags and dividing the sum by the total waste in both bags, was 55%, which is an indicator that should be decreased. The dominating waste fraction in the white bags was missorted packaging and newspapers, and was 1.9 kg/hh/w (43%). The second largest missorted fraction in the white bags was food waste (26%), which was often the food that remained in the packaging when it was discarded. This type of waste is illustrated in Figure 3.



**Figure 3.** Photo from the first pick analysis (2011) showing missorted food waste with packaging found in the white bags (neither food nor packaging are intended for in the white bags).

There were 0.019 and 0.004 kg/hh/w hazardous waste in the white and black bags, respectively. This missorted waste was dominated by small electronics, light bulbs, and batteries. Other missorted fractions were food waste in the white bags and combustibles in the black bags.

The results obtained from this research, and which revealed the current sorting behavior, raised the following questions: Do the households know how to sort packaging properly? If they do know, do they want to improve their sorting and, if so, what do they need to improve their sorting of packaging waste? What information would be helpful to clarify what should be sorted in the black and white bags? These questions formed the basis for the semi-structured interviews.

Hence, the results obtained from the first pick analysis answered the first research question given in Section “Objectives” (*i.e.*, how should the current sorting behavior be evaluated)?

### 3.1.2. Interviews for Identifying Appropriate Interventions to Improve Sorting Behavior

#### Semi-Structured Interview

Of the eight inhabitants that were interviewed, seven had immigrated to Sweden between 1985 and 2007 and were not Swedish citizens. Seven were between 25 and 50 years old and the eighth was 75 years old. There was a wide range in education levels—some of the inhabitants were illiterate and one had a doctoral degree. Six of them were employed, one was unemployed, and one was retired. Hence, the socio-economic background of the interviewees was typical for the pilot area (which was discussed in the Introduction). All of the interviewees could speak and understand Swedish, but sometimes a translator took part in the interview to avoid misunderstandings. The backgrounds of interviewees are listed in Table 3.



**Table 3.** Interviewees' backgrounds.

Person	Sex	Age	Arrival Date <sup>a</sup>	Years Lived in the City	Occupation	Family Members
1	F	25	2007	2	No	1
2	F	39	1990	15	Yes	5
3	F	50	1992	18	Part time	1
4	F	38	1997	10	Yes	4
5	F	40	1985	7	Yes	1
6	F	45	1997	16	Yes	2
7	M	40	2006	5	Part time	1
8	F	76	Born in Sweden	57	Retired	1

<sup>a</sup> Year of immigration to Sweden.

Most of the respondents had moved to the city from different countries, bringing with them different experiences of how to handle household waste. There was no organized source separation of waste in some of the immigrants' home countries. For example, one interviewee (#6) had used food waste as animal feed or fertilizer. These people had to learn how to participate in a new waste management system. In addition, there was a large variation in the motivation for participating in source separation schemes. Some of the reasons that were given for participating were resource conservation, respect for regulations, they felt that their participation was a valuable part of the waste treatment system, keeping a clean environment, their knowledge of the post-sorting processes, social norms, and that their participation gave them a sense of satisfaction. One interviewee (#1) stated: "This is the regulation for sorting the waste and I should respect it. This is what people usually do in Sweden". This means that she found waste separation as a norm in Swedish society and that this social norm can be a motivation to participate. Another interviewee (#8) said that "In the beginning, I didn't think too much about the environment. I found out that we have to sort our waste from some information leaflet. Knowing how useful it is for the environment and that I can contribute to the next generation, my children and grandchildren whom I love, means a lot to me". She continued, "At the moment, I cannot do much to protect my environment. This little job, sorting my waste, hopefully can be my part for protect environment for my children and grandchildren". Knowing what happens with the sorted waste was also a motivating factor. As expressed by one person (#6): "I always sort glass since I have learned that glass is the material that you can recycle millions of times and it motivates me to sort it." Similarly, another interviewee (#1), who had lived in Sweden for just four years, said: "When I see they produce biogas from food waste that I sort in the black bags and drive the buses, I understand my job is valuable". One respondent (#7) stated: "I do this because I want to keep my surroundings clean".

According to Thøgersen (1994) [13], these motivational factors cannot be the only reasons for correct source separation by the inhabitants. They also need situational factors such as easy access to facilities as well as knowledge of how to separate at the source. One of the aims of the semi-structured interviews was to investigate what the inhabitants perceive is needed to improve participation in source separation. Hence, once the motivational factors that influence the inhabitants sorting behavior were known, the questions focused on what actions were required from the inhabitants. This was the reason for the practical exercise (explained in the Methods section) given during the interviews, which was conducted to reveal if the interviewees knew how to correctly sort different fractions of waste. After sorting each material, whether it was correct or incorrect, they were asked to explain the reason for their choice of sorting. Most of them sorted food waste in the black bags, which was correct. Also, batteries were sorted correctly because the interviewees perceived them as being environmentally harmful. However, fractions such as newspapers, plastic-, paper-, metal-, and glass-packaging, *etc.* were often discarded in the white bags rather than being sorted and taken to recycling stations. This is in agreement with the results of the pick analysis, where about 43% of the waste in the white bags was packaging. There were some fractions, such as light bulbs, that the interviewees knew should not be in the white bags, but they were not certain where they should sort it. They were also uncertain of how

to sort other fractions such as ceramics and non-packaging glass. These findings are in agreement with the studies of Henriksson *et al.* (2010) [28] who also found that people are uncertain about how to sort certain waste fractions correctly [28].

The results discussed above indicate that lack of information and knowledge may hinder the correct sorting of waste. The interviews also revealed that distance to the recycling stations was perceived as a hindrance. For example, one interviewee (#5) did not know that plastic bags such as potato chips packaging should be sorted in recycling stations. Further, even if she had been aware of how to correctly sort the waste, the distance that she needed to take the waste to the recycling station was important. She believed that improved sorting would be facilitated if there was a recycling station close to her home, preferably in the basement of the apartment building. This was also expressed by another person (#6) who put paper and plastic packaging in the white bags: “I know that I should separate them, but we don’t have a recycling station close to home”. In this case, the interviewee had the knowledge but still chose not to go to the recycling station. She continued: “... my child asked me why we don’t sort the milk packaging. My answer was that we have no container close to our home”. Some of the interviewees said that they were aware that they should sort fractions such as metal packaging, but they did not do so since the recycling station was two km away and they did not have access to a car. Even one interviewee (#8), who sorted all fractions correctly, stated: “I am able to walk to recycling station two km away to sort my waste now. I am thinking, after some years, when walking is hard for me, I may put all packaging in the white bags instead, because of this distance”. Hence, it was concluded that decreasing the distance to the recycling station was a relevant intervention. Other studies have also revealed that distance to sorting facilities is a significant factor for participation in recycling systems [9,10,29].

After moving to Sweden, the respondents learned about waste management in different ways. It was not primarily through information leaflets, but by talking to and observing colleagues, neighbors, and family members. Most of the respondents could not remember whether they had received any written information. Only one interviewee (#8), who was born in Sweden, indicated that she had received written information 10 years ago. It is possible that, even though information may have been distributed, several of the interviewees may not have been able to read it due to language barriers or that it was distributed at an inappropriate time (e.g., when they were focused on adjusting to a new home, city, and country). All interviewees, apart from two respondents (#5, #8), claimed that language was still a barrier when seeking information, in spite of the fact that they had lived in Sweden for more than 15 years. In addition, five of the interviewees were illiterate when arriving in Sweden. If the information had been sent to them soon after their arrival it would not have been possible for them to understand it. This is why they gained knowledge through informal communication with friends, neighbors, and colleagues. One person (#2) stated: “When I got a job five years ago I saw that they sort every waste fractions in my workplace. I found that I have to do it at home too”. Another person (#5) said: “When I moved to my apartment, I saw two bags in my kitchen, one for food waste and the other combustible. It is obvious that I throw the food waste in black and all others, even packaging in the white when I don’t have any other information”. Lack of education can be another barrier. Many of the interviewees felt that education is essential when trying to find the right information. They also thought that the best place for learning is at school. When the information is insufficient it has a negative impact. Insufficient information can lead to incorrect sorting habits that can be difficult to change. One person (#2) said: “It is very important that one learns the right things from the beginning, because it is very hard to change the wrong habits after a while.” Another interviewee emphasized that it is important to have information as early as possible in order to develop a correct habit. As expressed by one interviewee (#5): “Maybe sorting the garbage is hard in the beginning, but after a while you don’t have to think about it, you do it as a norm, as a habit. It’s part of my culture now. The more information you can understand and make your own the faster it will become a routine for you”.

Hence, the interviews revealed that information and knowledge about how and why to sort the waste are important factors. If this is not communicated via formal authorities, it can be informal

communication between friends, neighbors, family members, and colleagues. However, there is no guarantee that this informal information is correct. Some of the incorrect sorting of the respondents was due to incorrect informal information. The type of information and the time of communication are also important. For example, some interviewees sorted diapers in the black bags and they claimed that there was a sticker on the trash cans for food waste which showed that diapers should be sorted in these bags. These claims were, in fact, correct. The system for handling the black bags was changed from composting to biogas production in 2006, but the information (stickers) from the 1990s (for composting) was still on the trash cans. This indicates that simple information, such as stickers on trash cans, which is accessible at the time of disposal, has a large influence on the sorting behavior. Hence, information should be distributed at the appropriate time, and it should be continuously available or at least available at the time and place where waste is discarded.

The main findings from the semi-structured interviews are:

- The interviewees were willing to sort the waste.
- The interviewees had different motivations to sort the waste.
- Decreasing the distance to collection points for recyclables can be a relevant intervention.
- There was a lack of knowledge of how to sort the waste.
- Designing different types of information that is communicated at the appropriate time and place, via formal and informal channels, may also be a relevant intervention.

These findings are in agreement with the Thøgersen, Barr, and Tucker models [13,14,17] which show that inhabitants' intention to recycle should be accompanied with other factors in order to form the recycling behavior.

### Structured Interview

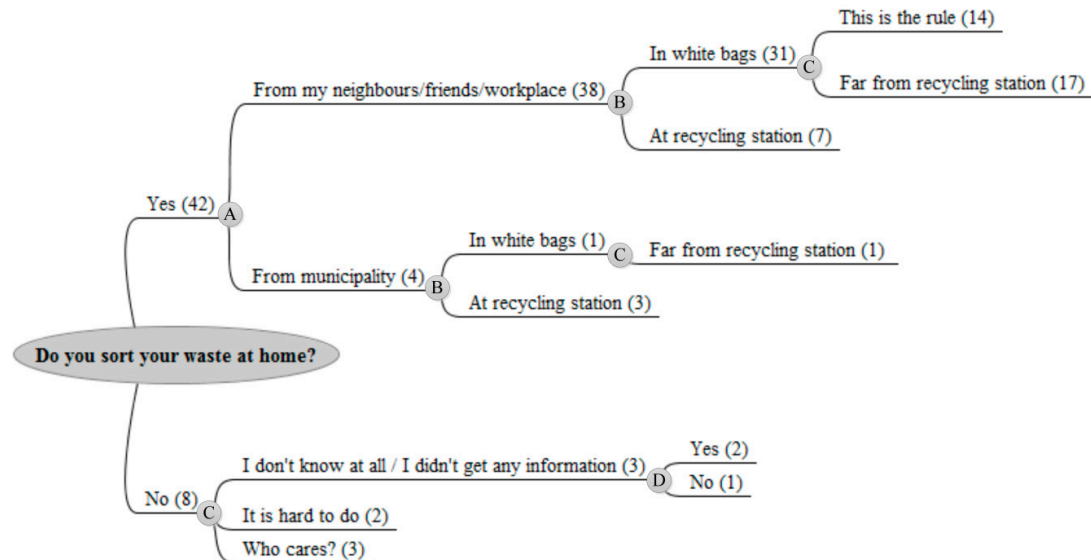
The semi-structured interviews showed that (1) distance to recycling stations and (2) different types of information about how to sort waste, including the communication of this information, may be relevant interventions for improving waste source separation in this pilot area. To validate the relevance of this hypothesis for a larger number of households, a structured and short interview template was designed and conducted with 50 people (20 male and 30 female). All of the interviewees were between 20 and 50 years old. These 50 people constituted 25% of the population in this age range in this area (Swedish Statistics, 2012) and they were from 50 different households. This population therefore covered about one quarter of the total number of households in the pilot area. Figure 4 shows how respondents replied to the different questions in this short interview.

The majority of respondents, 42 out of 50 (84%), claimed that they sort their waste. We will refer to these people as recyclers. Only 8 out of 50 (16%) were non-recyclers. Among recyclers, only 24% claimed that they sorted the packaging correctly at the recycling stations. The remainder, 76%, threw packaging in the white bags, which is incorrect sorting. The main reason that was given for the incorrect sorting was the distance to the recycling station (42%), and the other reason was that they thought that their behavior was correct (*i.e.*, that had incorrect information about how to sort this type of packaging (33%)). It is not clear if the distance to the recycling station would be a barrier for the latter group once they obtain the correct sorting information. Some respondents had other reasons such as: "I don't have a car" and "I have just a little amount waste". The recyclers obtained information from informal channels (from neighbors, friends, and their workplaces) more often (90%) than from formal channels (from the municipality). This shows that this area has a strong social network to distribute this type of information. Three out of eight non-recyclers claimed that they did not sort due to a lack of information. Difficulty and lack of motivation for sorting were the reasons for the other five non-recyclers.

The result of the short, structured interviews was consistent with the findings of the semi-structured interviews. Therefore, to improve source separation in the pilot area the following

interventions could be relevant: (1) decreasing the distance to the recycling station and (2) combining correct and appropriate information with effective communication channels.

Hence, the results obtained from the interviews answered the second research question given in Section “Objectives” (*i.e.*, how should the appropriate interventions to improve this behavior be identified?).



**Figure 4.** Results of the structured interviews with number of respondents indicated in parentheses. Nodes A to D represent questions: (A) How did you get information? (B) How do you sort plastic and milk packaging? (C) Why? (D) Do you want to sort if you get information?

### 3.1.3. Effect of Interventions

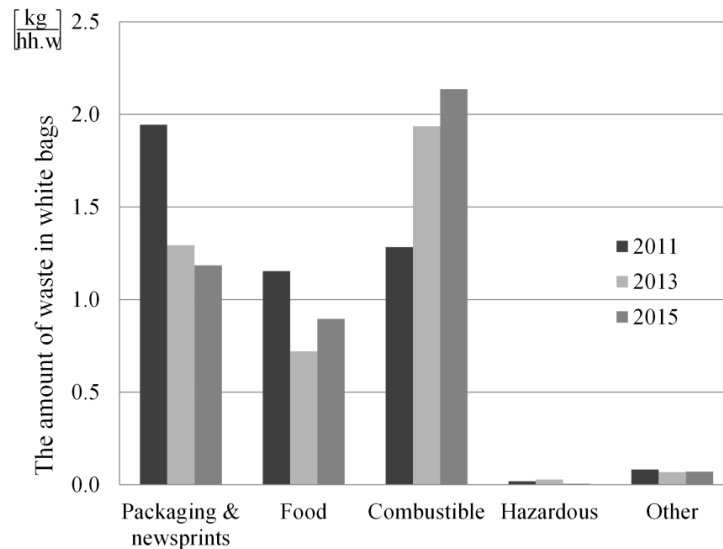
Based on the interview results, three interventions were implemented from 2012 to 2015. These are listed in Table 4.

**Table 4.** Interventions from 2012 to 2015.

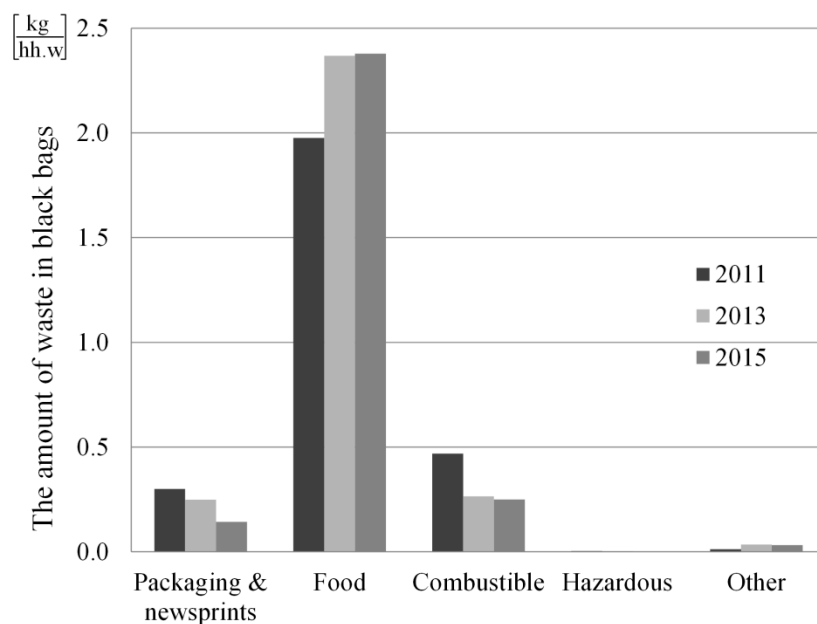
Date	Intervention
June 2012	(a) Placing new stickers for black bags trash cans which clearly show that food waste should be sorted in the black bags.
June 2013	(b) Building a property close collection area for recyclables, called an environmental room, behind the apartment building to decrease the distance to the recycling station to 50 meters. The environmental room enabled the sorting of packaging, batteries, small electronics, light bulbs, and clothes.
2014–2015	(c) Communicating different types of information including: Installation of a picture on the containers for white and black bags showing where and how to sort this waste in the containers (2014). Sending written information, feedback and a “thank-you letter” three times to all households in the pilot area (2014). Having informal dialogues about using the environmental room and on how to improve the sorting in black bags (2015).

The second pick analysis was performed after implementing interventions (a) and (b), and the third pick analysis was conducted after intervention (c). The results are compared with those of the first pick analysis (2011) in Figures 5 and 6. It should be noted that two interventions were performed between the first and second pick analyses. Intervention (a) was expected to primarily

influence sorting in the black bags, whereas intervention (b) was expected to influence recycling in the environmental room and in both bags. Since the white bags (intended for combustible waste) contained more recyclables than the black bags (Figure 1) intervention (b) was expected to influence the sorting in the white bags more than in the black bags.



**Figure 5.** Comparison of waste sorting behavior before and after the interventions. The data shows waste fractions in the white bags, which are intended for combustibles (kg/hh/w).



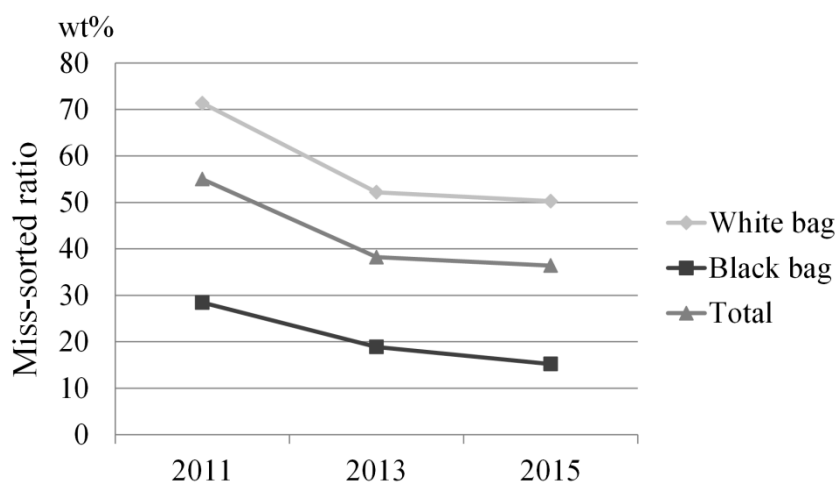
**Figure 6.** Comparison of waste sorting behavior before and after the interventions. The data shows waste fractions in the black bags, which are intended for food waste (kg/hh/w).

The amount of missorted packaging in the white bags decreased (33%) between 2011 and 2013, which is when the property close collection was established (intervention (b)). After intervention (c) in 2015, this decrease was 39% (Figure 5). Although there was an increase in the missorted food waste in the white bags between 2013 and 2015, there was an overall decrease between 2011 and 2015. The decrease in packaging and newsprints between 2011 and 2015 is statistically significant, as is the decrease in food waste between 2011 and 2013. The increase in food waste between 2013 and 2015, and

the subsequent decrease between 2011 and 2015 are not statistically significant. The interventions did not lead to any statistically meaningful changes in the sorting of hazardous or other waste, but the hazardous waste decreased by 68% in the white bags in 2015 compared to 2011.

Missorted combustible waste in black bags (intended only for food waste) decreased (by 44%) by intervention (a), when visible information on the trash cans for black bags was provided, and by a further 3% in 2015 (Figure 6). Similarly, missorted packaging and newsprint decreased between 2011 and 2015 (52%). These two changes are statistically significant. Similarly to the white bags, there were no significant changes in the amounts of hazardous or other forms of waste.

In summary, the aim of the interventions was to decrease the missorting ratios in the pilot area. Figure 7 shows the missorted ratios in white bags, black bags, and in the total waste generated in the pilot area (*i.e.*, the average of the white and black bags).



**Figure 7.** Comparison of missorted ratios in weight percent (wt %) before and after the interventions.

The total missorted ratio decreased from 55% to 38% after interventions (a) and (b), and decreased further to 36% after intervention (c). Figure 7 also shows that the magnitude of the reduction in the black bags between 2013 and 2015 is larger than for the white bags. Although this difference is statistically insignificant, it indicates that intervention (c) may have had the desired effect, since the focus of the informal communication was to improve sorting in the black bags. The results show that interventions (a) and (b) decreased the missorted ratio significantly. Although there was a continued decrease in the missorted ratio after intervention (c), it cannot be concluded that this is due to the intervention (the decrease may have continued even if intervention (c) had not been implemented).

Figure 7 shows that intervention (c) had less impact compared to interventions (a) and (b). There may be several reasons for this. One is that 56 of the households had inhabitants that moved into the pilot area during the project, of which 33 had inhabitants that came in 2015. Since no formal information regarding the use of the environmental room was directed towards the households after 2013, many of the new inhabitants only had access to information via informal channels. In addition, new inhabitants—especially those that moved in during 2015—may not have had time to build a social network that is necessary for informal communication between households. This means that it is possible that 27% (56 of 208) of the households did not have access to the correct information. Another reason may be the insufficient capacity of containers in the environmental room. The collection rate for the collected packaging in the environmental room was therefore limited. Observation of this room showed that the packaging containers were often overflowing on the collection days. This usually leads to poor sorting behavior which results in a mess in the room, which could negatively affect the inhabitants' participation in the sorting scheme. It is also not clear how the households perceived the new information in the form of written information, stickers, thank-you letters, and feedback.



Hence, the results obtained from the second and third pick analyses answered the third research question given in Section “Objectives” (*i.e.*, how should the effect of interventions be assessed?).

### 3.2. Recycling Behavior Transition (RBT) Procedure

The aim of this research was to create, test, and evaluate a procedure which can improve recycling behavior. The procedure consisted of four steps: (1) first pick analysis; (2a) a few semi-structured interviews; (2b) a larger number of structured interviews; (3) interventions based on findings from the interviews, and; (4) a pick analysis to assess the effect of interventions. The four steps, which included both quantitative and qualitative methods for data collection, were implemented and tested.

Pick analysis is a quantitative waste characterization method that measures missorted waste in a system. Structured interviews are also considered to be a form of quantitative method, whereas semi-structured interviews are a form of qualitative method; both forms of interview processes were used in this procedure. The combination of quantitative and qualitative methods (*i.e.*, using a mixed method) gives the necessary breadth and depth to understand complex phenomena [30] such as recycling behavior.

As discussed above, the first pick analysis quantifies the prevailing sorting behavior. In fact, this pick analysis identifies “*How*” inhabitants sort their waste without asking them. The output from the characterization of the collected waste is more reliable than using self-reported assessments of the participants in a source separation scheme.

In a study of the accuracy of three surveys of waste attitude/behavior undertaken in Scotland and north-west England, P. Tucker and D. Speirs (2003) [8] concluded that the results of these surveys usually give an over-optimistic picture of recycling behavior. They also concluded that it is difficult to make actions, promotions, and campaigns for improvement of recycling behavior by using results from surveys [8]. In contrast, pick analysis measures the actual waste sorting behavior of inhabitants regardless of what they answer in surveys.

The interventions that should be investigated are identified in Step 2. To do this one needs to understand “*Why*” inhabitants sort in the way that they do (as identified in Step 1), and “*What*” should be done to motivate and enable them to improve it. To do this, semi-structured interviews were designed. A semi-structured interview can provide answers to questions that cannot be checked or measured in other ways. It is difficult to get an absolute answer during an interview, but it can provide clues and indications that guide the subsequent steps. Although the results of the pick analysis give relevant data of the sorting behavior, these data require interpretation via the qualitative interview (*i.e.*, the semi-structured interview). This interpretation is needed to understand the sorting behavior.

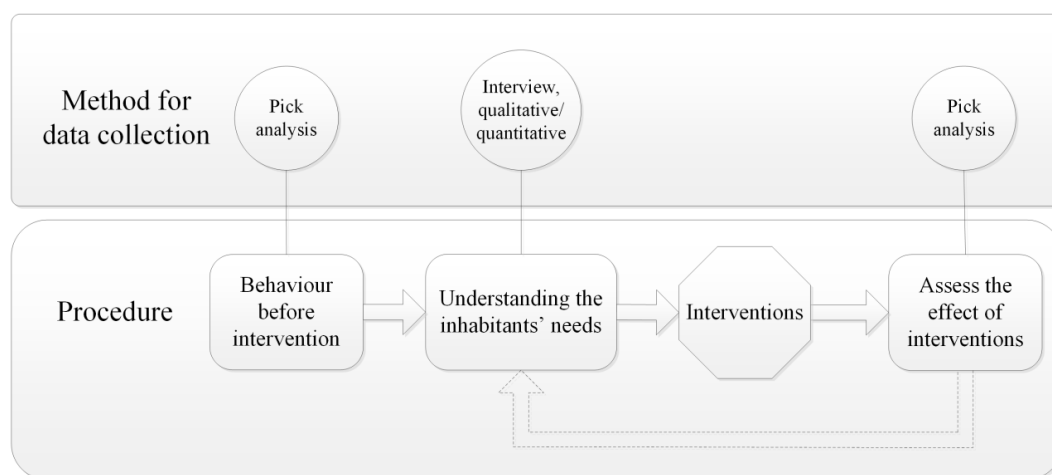
For example, in the study conducted in the pilot area, the results of the first pick analysis showed that packaging and newspapers dominated the missorted material. Hence, the pick analysis revealed that one should focus on improving the sorting of packaging and newspapers waste. There are many possible interventions that could have been studied to achieve this goal, but the interviews identified that improved information and decreasing the distance to recycling stations were the interventions that the households perceived as being the most appropriate. The interviews also give the users, who are influenced by the interventions, a central role when developing the waste management system.

In a study in Madeline Island, Newenhouse and Schmit (2000) [31] found that qualitative approaches can add value to waste characterization studies in order to discover potential solutions to change recycling behavior. They discussed the fact that the interviews engage inhabitants in the process which, according to them, has a positive impact. The results of semi-structured interviews (Step 2a) can identify relevant interventions for improving the system, but it is important to have the opinion of a larger part of the population. The structured short interview (Step 2b) ascertains if the selected interventions are relevant for many of the inhabitants. Through these two steps, (2a) and (2b), interview results will be both qualitative and quantitative. Another reason for including Step 2b in the procedure is to involve as many inhabitants as possible. In the pilot study, the result of the structured short interviews was in agreement with those of the semi-structured interviews. If they had not been

in agreement, then it would have been necessary to re-analyze the semi-structured interviews or to conduct more semi-structured interviews to identify other possible interventions.

Step 4, the second and third pick analyses, assesses the effect of the interventions. These analyses provide data on the actual recycling behavior after the interventions, which can be compared with the first analysis in order to see if the interventions were effective or not.

The RBT procedure is summarized in Figure 8 together with the methods for data collection. The procedure was called recycling behavior transition since a source separation system can be improved by a transition of the behavior of the inhabitants in sorting their waste. The dashed line in Figure 8 shows that the procedure can be repeated to enable continued development of the waste management system. After doing the last step (*i.e.*, the second or third pick analysis), there are two scenarios: (1) The interventions were effective: In this case the result of second pick analysis can be the basis for finding new interventions and further improvement, including a new round of interviews with inhabitants; (2) The interventions were not effective. In this case the factors which prevented the success of the interventions need to be identified (e.g., by a new series of interviews). It is possible to choose another qualitative approach other than semi-structured personal interviews to communicate with inhabitants (e.g., focus group or telephone interviews or combining interviews with observations). An important element with Step 2 is to understand the needs of the inhabitants for effective participation in source separation.



**Figure 8.** The Recycling Behavior Transition (RBT) procedure for continuous improvement of source separation and waste collection systems.

Recycling behavior is a complex phenomenon. The RBT procedure showed that it is possible to improve this behavior with a simple and accurate procedure. There are several advantages with the RBT procedure, and these are listed and commented upon below.

- The combination of quantitative and qualitative methods provides reliable and useful results to implement the appropriate interventions.
- The RBT procedure can be applied in any source separation system in any location, independent of local circumstances. The procedure can be used to identify the relevant intervention in other cultures, socio-economic backgrounds, and other source separation schemes.
- The RBT procedure quantifies the effect of the interventions. Actors responsible for planning waste management may hesitate to apply interventions because they do not know how to identify them and how to measure their effect. This procedure can help them not only to improve their system, but also to control the quality of the system.

- The RBT procedure focuses on user involvement in waste management systems. When the intervention is identified from the needs of the users, there is a higher probability of success.
- The continued improvement of source separation systems results in the collection of recyclable materials in larger quantities and of better quality, and consequently help in the development of a circular economy and sustainable development.

There are also several potential weaknesses of the RBT procedure that need to be recognized and, where possible, removed in future studies.

- The RBT procedure requires careful design in both time and implementation, and one often needs to wait for a specific time period for implementing interventions so that the pick analyses that are performed before and after the interventions can be compared to each other. In addition, since the procedure requires a long time, the effectiveness of the interventions is reduced if many residents move into and out of the neighborhood during the time between successive pick analyses.
- Interviews with the inhabitants to identify proper interventions are good since it identifies interventions that are relevant to the inhabitants and also increases the involvement the inhabitants in the waste management system. However, these interviews may lead to improved sorting behavior (which is good in many perspectives) which means that the effect of the intervention is difficult to isolate.
- Pick analyses, which are an integral part of the RBT procedure, require large sample sizes to be statistically meaningful. This increases the cost of the procedure.

#### 4. Conclusions and Outlook

The waste sorting behavior of households can be quantitatively measured and evaluated by waste sampling and pick analysis (*i.e.*, waste characterization by manual sorting). Thereafter, appropriate interventions for improvement of the sorting can be identified through interviews in two steps: (a) semi-structured interviews (with a few households) where the questions are based on the pick analysis results; and (b) short, structured interviews (with a large population of households) based on the results of the semi-structured interviews. Once the interventions have been implemented, their effect can be evaluated by a new pick analysis. The missorting ratios before and after the interventions can thereby be quantified and compared.

This four step recycling behavior transition procedure enables continued improvement of waste sorting behavior in any household waste collection system that includes waste sorting at the source. The combination of quantitative and qualitative methods allows the RBT procedure to evaluate the actual sorting behavior, to understand the reasons for this behavior, to identify the needs for improvement, to design relevant interventions, and to assess the effect of the interventions. The RBT procedure can be designed and applied in any source separation system irrespective of local factors such as culture and social-economic backgrounds.

Further development of the RBT procedure is needed. Repeated use of the procedure in various types of waste separation systems will identify more strengths and weaknesses of the procedure. The RBT procedure can also be combined with other methods such as life cycle assessment and cost analysis for a wider system analysis of a waste management system.

**Author Contributions:** Kamran Roustas has taken part in planning the study, conducting the experimental work, analyzing the results, and has been the principal writer of the manuscript. Lisa Dahlén and Kim Bolton, supervisors, have taken part in evaluating the results and writing the manuscript.

**Conflicts of Interest:** The authors declare no conflict of interest.

## Abbreviations

The following abbreviations are used in this manuscript:

RBT                                      Recycling Behavior Transition

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