UNIVERSITY OF GOTHENBURG
SCHOOL OF BUSINESS, ECONOMICS AND LAW

Master Degree Project in Logistics and Transportation Management

An investigation into Swedish E-waste collection and recycling system

A case study in Gothenburg

Yiwei Zhang

Peyman Bashiri

Supervisor: Michael Browne
Master Degree Project No.
Graduate School

Abstract

With the fast growth of information communication technologies industry, the amount of electrical and electronic waste also increases quickly. If they are treated in wrong way, some hazardous components of E-waste might pollute environment and threaten human health. However, proper treatment can make E-waste become resource and be used again. In this context, collecting and recycling E-waste become more and more important. Sweden has one of the most efficient E-waste collection system in the world and the pattern of reverse logistics in Sweden has some reference for other countries and areas. Through examining relevant literatures and conducting a case study in Gothenburg, the second biggest city in Sweden, this thesis clarifies the entire reverse logistic process of E-waste and the some approaches of collecting E-waste from residents. Through analyzing the Swedish E-waste collection and recycling reverse logistics system, some insights which might be helpful are proposed and the limitations of this system also be pointed out to provide operators with improved directions. There are lots of countries and areas facing the requirement of collecting and recycling E-waste, and the experience from Swedish practice could give them some inspirations.

Key words: E-waste management, reverse logistics, Sweden, Gothenburg, E-waste collecting and recycling system

Acknowledge

Throughout the process of writing our thesis we would like to dedicate an exceptional appreciation to our supervisor, Michael Browne, Professor in Industrial and Financial Management and logistics, who provided us with valuable visions and Feedbacks within the area of our Research. Without his experience and knowledge this assignment would not have been possible.

We also want to send our gratitude to our interviewees for their engagement and the time they voluntarily dedicated to our work. Without their inputs and expertise this project would not have been imaginable.

Table of Contents

Abbreviations 1
1 Introduction 2
1.1 background 2
1.2 Purpose and research questions 4
1.3 Delimitations 5
2 Literature Review 6
2.1 E-waste 6
2.1.1 The definition and scope of E-waste 6
2.1.2 Necessity of E-waste management 8
2.2 Reverse logistics 10
2.2.1 Reverse logistics and E-waste management 11
2.2.2 Challenges in implementation of reverse logistics 13
2.3 EPR and E-waste management 15
2.4 Legislation of E-waste management 16
2.4.1 Directives and regulation in EU 16
2.4.2 Related implementations in Sweden 17
3 Theoretical Framework 19
3.1 Five stages in reverse logistics 19
3.2 Different types of reverse logistics 20
3.3 Takeback approaches 21
4 Methodology 23
4.1 The choice of research method 23
4.2 Validity and reliability of research 25
5 The E-waste collection system in Sweden 27
5.1 Main actors in the system 27
5.2 Entire process 28
5.3 Collaboration between actors 29
6 Findings 32
6.1 Findings from interviews and field survey 32
6.2 Online survey 37
7 Analysis and discussion 39
7.1 Type of Swedish system 39
7.2 Advantages of Swedish practices 42
7.3 Limitations in the practice 47
8 Conclusion and future direction 51
8.1 Contribution 51
8.2 Limitations 52
8.3 Future directions 52
References 54
APPENDIX A 61
APPENDIX B 65

Abbreviations

EEE	Electric and Electronic Equipment
ICTs	Information Communication Technologies
WEEE	Waste Electrical and Electronic Equipmen
Mt	Million tonnes
PRO	Producer Responsible Organization
EPA	Environmental Protection Agency

1 Introduction

1.1 background

With the development of technology, the use of electronic equipment has become more and more widespread in people's life and indeed become essential part of a daily life. The electric light replaced the position of candles and oil lamp and brought light to people's life. Various types of household appliances, such as refrigerator, vacuum cleaner, and dishwasher, etc reduce the household affairs of people. And more recently, personal computers and mobile phones help people connect to each other and even make the world as a "global village".

Electric and Electronic Equipment (EEE) has become more and more important for people. There has been an enormous upsurge in the volume of EEE produced in recent years, due to changes in consumption habits, and improvements in information communication technologies (ICTs), which have increased demand for the latest consumer goods. Production and consumption of these goods is expected to rise even further in the future, as ICTs continue to develop.

However，what EEE brings are not only convenience but also some potential threats to both people and environment. To be specific, when EEE loses its function or it cannot meet the owner's requirements, it will be abandoned by their owners and become waste, which are also known as Waste Electrical and Electronic Equipment WEEE or E-waste. According to Sinha (2004), E-waste was defined as "*an electrically powered appliance that no longer satisfies the current owner for its original purpose*".

E-waste might result in more serious economic and environmental problems compared with general household waste since it contains many hazardous components like some kinds of heavy metals and toxic substances (Baldé, 2015). If these E-waste are treated in wrong ways, those harmful substances might leak out into air, soil and water. Besides causing environmental pollution directly, those pollutants can also through the biological accumulation get into organism and harm the living organisms as well as humans.

From another perspective, collecting E-waste can be a way to economize on and protect resources since there are many revertible resources existing in E-waste. Not only because of the enormous number of EEE in the market, but because of the decrease of product lifecycle and the increase of product updating speed, the biggest and most pressing problem people face now is how to dispose those abandoned devices, and waste management of EEE continues to be a global challenge.

An important reason for increasing of E-waste is that electronics, telecommunications and

information technology (ETI) has become the fastest growing industry in the global scale (Khan, 2014). With the fast growth of ETI industry, the amount of E-waste is also increasing quickly. Specifically, the global volume of E-waste generation was around 41.8 Million tonnes (Mt) in 2014 and will reach to 49.8 Mt in 2018 (Balde et al., 2014). However, in contrast to its rapid growth, the percentage of recycled E-waste was only 30.6% in 2012 (US EPA, 2015).

To solve these problems, some international organizations, such as European Union and UN-related organizations, have published many guidelines and directive to instruct the behavior of people and companies. In addition, they created specialized "take-back and treatment system" to work on E-waste collection from final customers and related disposal (Baldé, 2015). However, the number of countries that have published official take-back legislation is limited (Balde et al., 2014), and there are still informal E-waste sectors which are disposing E-waste in an irregular way, especially in some developing countries, like China and India (Li and Tee, 2012).

But in some developed countries they do well in E-waste collection, and Sweden is one of them. Sweden started the E-waste system in 2001, and till now, it has put in place a national system and many localized implementations to collect and dispose E-waste (Lee and Sundin, 2012). According to El-Kretsen (2009), every Swedish citizen leaves around 16 kilos of E-waste to collection points every years and it makes Sweden become the leader of E-waste collection in the world.

In Europe, the total amount of E-waste generation was 11.6 Mt and the top three regions with the highest per person E-waste generation are Norway (28.3 kg per inhabitant), Switzerland (26.3kg per inhabitant) and Iceland (26.0 kg per inhabitant) (Balde et al., 2014). In Directive 2012/19/EU, the target for collection rate of E-waste is larger than 85% (EU, 2012). However, in practice of E-waste collection, only in Sweden, Denmark and Bulgaria the collection rates are more than 60% (Balde et al., 2014). Approximately 0.7 million tonnes of E-waste end up in waste bins, and it is 8% of the total E-waste in European Union (Balde et al., 2014).

For instance, in Netherland, the amount of EEE that was put on the market in 2010 is 26.5 kg per inhabitant, or 440 kilo tonnes (kt) in total (Balde et al., 2014). However, the amount of E-waste that was collected and exported is estimated as 2.7 kg per inhabitant and 44 kt in total (Balde et al., 2014). This gap between 440 kt and 44 kt illustrates the shortage of the e-waste management and potential of recovery.

To show the situation in European, four different countries from Eastern, Northern, Southern and Western Europe are selected. And in the Table 1, related data in these four countries are shown to illustrate the current situation in Europe. In Sweden, the collection rate can reach

almost 80%, in contrast, this figure in Italy is only 21.45%. It shows that even in Europe, almost one of the most developed area in the world, the situation is varied and gap between the different countries is large.

Table 1. The volume of E-waste and collection in four European countries in 2012

Country	Total Generation (kt)	Collection (kt)	Percent of collecting (%)
Poland	397	175	44.08
Sweden	215	169	78.60
Italy	1077	231	21.45
Germany	1769	691	39.06

Source: Table 1 based on Balde et al (2014) with additional calculation by authors.

1.2 Purpose and research questions

According to several previous researches (El-Kretsen, 2009; Hanna et al, 2015; Swedish Environmental Protection Agency, 2009) about the E-waste collection and recycling system in Sweden, it shows that the collection pattern is mature and efficient, although there are still some tiny issues in the system. Therefore, the purpose of this research can be expressed from two aspects.

First, due to the collection rates are very different in Europe (see the table 1 in introduction), there still exists improvement space for many countries and areas in the world.
From this perspective, the collection pattern in Sweden could be a good paradigm for them. Therefore, understanding how Sweden manages their system can be meaningful.

Second, also based on previous researches, they mentioned some issues exist in this system such as customers' responses and classification of E-waste (Lee and Sundin, 2012; Hanna et al, 2015; Ylä -Mella et al, 2014). Using the second largest city, Gothenburg, as an example, could reveal some of issues in practices and help to make the system better.

To adapt to the purpose of this research, two research questions has been presented as following:

Research question 1: *How does Sweden use reverse logistics to collect and recycle E-waste from residents?*

Answering this question can provide readers with a complete process of how E-waste flows from residents to disposals. It will not only focus on logistics process but also financial factors and how they cooperate with each other.

Research question 2: *What are the main strengths of the current system and to what extent can limitations or problems be identified ?*

Under this question, the gap between users' demands and reality of the system will be pointed out, as well as some issues exist in the system itself. However, the advantages in this system will also be found out to provide some insights for those who need to build E-waste management systems.

1.3 Delimitations

Several delimitations should be added before start discussing to increase the practicability and reliability of this research.

First of all, there are two main producers of E-waste in Sweden, residents and businesses. However, the focus of this study is on E-waste created by residents. Businesses also contribute to E-waste volumes but this has not been considered in our studies because they are mainly handled in a different waste collection system.

Then, a case study will be conducted in Gothenburg about how they collect E-waste from residents. Although some information from previous studies were used to analyze the whole system in Sweden, the primary data is related to Gothenburg.

2 Literature Review

The purpose of this chapter is to explain and evaluate the available academic literature regarding the scope of the thesis. The two core areas studied are reverse logistics and E-waste Management. Which will help to capture an understanding in these fields. After that we look into both subject areas together to see what are their relationship and boundaries' when they applied together. We also look at Extended Producer Responsibility policy to see its relation with E-waste management and how it guides the activities in the process of E-waste collection and recycling. We additionally look into the regulations of EU and Sweden which are related to Electronic Waste Management. By doing so we try to see if these laws create any boundaries for the operation of the E-waste Management or support the system to become more efficient.

2.1 E-waste

2.1.1 The definition and scope of E-waste

To study the reverse logistics of E-waste, the first thing is to clearly define the E-waste because the components of E-waste is complex. In this part, a brief process that how definition and scope of E-waste changed is discussed in details. The reason why the definition and scope of E-waste are critical is that these goods are typically comprised of a diversity of materials and components, which can be disassembled and redistributed (Ongondo et al, 2010).

E-waste, or WEEE, is a generic term which stands for electric and electronic equipment that has have no value for its owner, and this term was first coined by Widmer et al. (2005). In EU WEEE Directive (EU, 2002), the definition of E-waste was given as "'*waste electrical and electronic equipment' or 'WEEE' means electrical or electronic equipment which is waste within the meaning of Article 1(a) of Directive 75/442/ EEC, including all components, subassemblies and consumables which are part of the product at the time of discarding*".
With the development in science and technology, the scope of E-waste seems to become more and more widely in these years (Widmer et al., 2005). For the practice of logistics management, it is important to note that the categories of goods that are included under this definition of E-waste are more and more varied and diverse. In this case, the importance of E-waste classification is highlighted because different types of E-waste needed to be treated separately.

Goggin and Browne (2000) mentioned a rough classified method of electronic equipment. Four different categories of electronic equipment manufacturing can be identified from a resource recovery viewpoint (Goggin and Browne, 2000), commercial public sector, commercial private sector, domestic large product sector and domestic small product sector.

The commercial public sector is characterized by a small number of customers, like government bodies and large institutions. The customer number of commercial private sector is moderate, and products in this sector are something like telecommunications and IT equipment. The third sector is domestic large product sector. This sector is characterized by many customers and the products of the category is bulky, for instance, refrigerator and air conditioner. The final category includes some small products with high number customers like cell phone and laptop.

EU WEEE Directive (EU, 2002) gave a more-detailed categories of electrical and electronic equipment than before in 2002, which aimed to guide the E-waste management in reality. In this directive, ten categories were distinguished, and Table 1 shows the specific content of each categories.

Then, in 2012, a systematic and compatible classification of E-waste was developed by UNU (Wang, 2012), which encompasses about 900 products that are grouped into 58 categories. It gives a more definite scope of E-waste and a better comparability of performances results.

According to these definitions and classification, different types of E-waste can be identified. In actual management of E-waste, especially in process of production take-back, different categories can be collected separately and be disposed differently in subsequent steps.

Table 2. E-waste categories according to the EU Directive

NO	Category	Label
1	Large household appliances	Large HH
2	Small household appliances	Small HH
3	IT and telecommunications equipment	ICT
4	Consumer equipment	CE
5	Lighting equipment	Lighting
6	Electrical and electronic tools (with the exception of large-scale stationary industrial tools)	E&E tools
7	Toys, leisure and sports equipment	Toys
8	Medical devices (with the exception of all implanted and infected products)	Medical equipment
9	Monitoring and control instruments	M&C
10	Automatic dispensers	Dispensers

Source: From ANNEX IB (EU, 2002), and it still used in new EU directives.

2.1.2 Necessity of E-waste management

According to the introduction, it is easy to reach the conclusion that the E-waste problem is serious in the most of countries in the world. In terms of this issue, there are many studies which are related to the harmfulness of E-waste to remind the public of the importance and necessity of E-waste management. To make the things more clearly, three main reasons for E-waste management were summarized and described as following text.

First, the composition of E-waste is very complex, and some hazardous substances within them have risk of causing contamination and might be harmful to people if they are not treated in appropriate way. This issue was presented in the Provision (7) of Directive 2002/96/EC as the major concern during the waste management phase and recycling of E-waste (EU, 2002). The Table 3 gives the content of several contaminants in E-waste and ecological source of exposure.

Table 3. Several contaminants in E-waste

Contaminant	Component of EEE	Ecological source of exposure	Content of E-waste (mg/kg)
Polychlorinated biphenyls	Condensers, transformers	Released as combustion byproduct, air, dust, soil, and food (fish and seafood)	14
Cadmium (Cd)	Batteries, toners, plastics	Air, dust, soil, water, and food (especially rice and vegetables)	180
Lead (Pb)	Solder, CRTs, batteries	Air, dust, water, and soil	2900
Zinc (Zn)	Cathode ray tubes, and metal coatings (Grant, 2013)	Air, water, and soil	5100
Mercury (Hg)	Fluorescent lamps, batteries, switches	Air, vapour, water, soil, and food (fish)	0.68
Lithium (Li)	Batteries	Air, soil, water, and food (plants)	--

Source: based on Robinson (2009), Grant (2013) and Morf (2007)

Because they have realized the danger of E-waste pollution, to reduce the E-waste pollution of domestic environment, some industrialized countries export their E-waste to the countries with an IWS (Informal Waste Sector) like China and India. IWS can be defined as a type of informal sector who neither have the proper training nor the proper equipment/facility (Li and Tee, 2012). Therefore, it do not have enough capabilities to dispose these e-waste and reduce its damage to environment. As an example, Guiyu, a small town in Guangdong China, has become one of the most polluted towns by E-waste. The health of people who live in there is harmed by the E-waste that is disposed in wrong way, especially for children. There is a significant increasing trend in Blood lead levels for children with the increase of age in Guiyu (Huo, 2007). As a result of the pollution, the mean height of children in Guiyu has been lower significantly than standard height (Zheng, 2008).

Except environmental pollution and public health issues, the second reason for recycling E-waste is due to some materials that can be reused like iron, aluminum, copper, gold, silver, and rare earth metals (Heacock et al., 2016). In fact, more than 60 elements can be found in E-waste and most of them can be recovered in different methods (Balde et al., 2014). Especially the rare earth metal, the applications of rare earth metal is more and more important, but the distribution of it is very limited in the earth. If those metal materials in E-waste can be recovered, the relevant mineral resources can be protected in a certain extent. Figure 1 illustrates the compositions of E-waste.

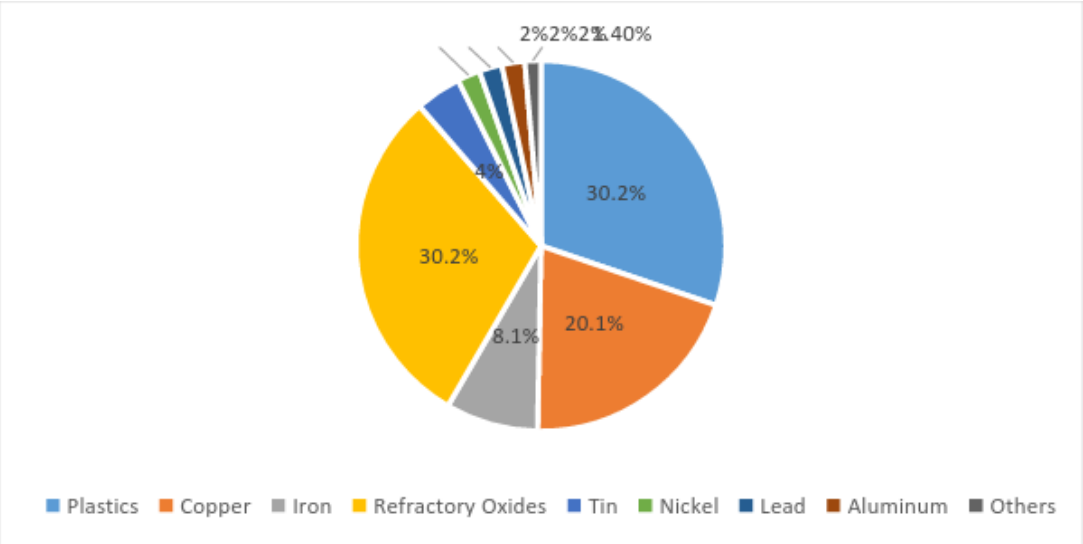

Figure 1. The compositions of E-waste (Sodhi and Reimer, 2001)

Another material that can be recycled in E-waste is plastic, which is a major component of E-waste (Link, 2012). There are two types of plastic that used in electronic and electrical equipment, thermosetting and thermoplastic. Thermosetting plastic is a polymer material that irreversibly cures so that it cannot be remolded. But thermoplastic is a thermos softening plastic and it has great value to be reused (Link, 2012). According to Balde et al. (2014), E-waste contains approximate 8600 Kilotons of Plastics (PP, ABS, PC and PS) that value about 12,300 million Euros. In this aspect, E-waste is the mine in cities.

And the third reason is that there is growing pressure on governments, including the Swedish government, to address the problem of waste and the environmental and health problems that it causes (Kiddee et al, 2013; Ongondo et al, 2010). The issue of electronic waste is often a focal point of intergovernmental negotiations on sustainability and environmental management, for instance (Selin and Van Deever, 2006). Therefore, governments and authorities have to find out a sustainable way to do the E-waste management and cooperate with each other to solve the problem.

2.2 Reverse logistics

Facing the threat which is brought from E-waste problem, in the directive of EU, a responsibility called extended producer responsibility (EPR) was implemented to producers and related companies to instruct and regulate their activities (this will be discussed in the next part). To better undertake this responsibility, the take-back schemes in E-waste area are effective for retailers and manufacturers to reduce their waste output (Cherrett et al., 2010), and reverse logistics plays an important role in process of products take-back. Reverse

logistics provides a means for retailers and manufacturers to identify goods that can be repurposed, resold or recycled, in order to reduce the volume of waste goods that must go to landfill, thereby contributing to the pollution problem.

In this situation, the reverse logistics has gained more and more attention from both academics and practitioners, in part by growing consumer concern for the environment and greater legal constraints on waste management (Fleischmann, et al, 2004).

First, the need for reverse logistics procedures is expressly set out in the key legislative arrangements governing the waste management of electrical and electronic including the Waste Electrical and Electronic Equipment Directive (McLeod and Cherrett, 2014). Second, growing competitiveness, and the need for firms to remain efficient and to minimize costs means that firms are increasingly looking for ways to make efficiency savings (McLeod and Cherrett, 2014). Third, there is increasing pressure from consumers on retailers and manufacturers to ensure that their practices and actions are environmentally responsible and there is evidence that firms – and retailers in particular – are paying more and more attention to customer satisfaction (Vlachos, 2016). Fourth, due to shortened lead times as a consequence of improvements to research and development processes, and to technology more generally, electrical and electronic equipment is becoming obsolete quicker than ever before (McLeod and Cherrett, 2014). As product life cycles shorten, the volume of returns increases. Finally, as pointed out by Cherrett, Maynard, Macleod, and Hickford (2010), the contemporary period is characterised by a throwaway culture, in which it is increasingly seen as acceptable to discard goods in favour of newer versions.

Then, what's the reverse logistics? Reverse logistics is defined by Guide and van Wassenhove (2002) as "*the series of activities required to retrieve a used product from a customer and either dispose of it or reuse it*". That is, reverse supply chain logistics involves the coordination and management of used, waste products. Typically, the parts, raw materials and products used in the supply chain process are physically collected and delivered from the field to disposition, recycling or processing plants as appropriate (Tibben-Lembke, and Rogers, 2002). According to the literature, there has been a huge increase in the use of reverse logistics processes in recent years, particularly among retailers (McLeod and Cherrett, 2014).

2.2.1 Reverse logistics and E-waste management

It is important to note that there are substantive differences between reverse logistics and waste management (Cherrett, et al 2010). Waste management "*is mainly concerned with the efficient and effective collection and processing of waste: that is, products for which there is*

no longer any reuse potential" (Cherrett et al, 2010). In contrast, reverse logistics involves identifying goods that can be repurposed or reused. Examples of these goods are recalled products, items that are deemed to be obsolete, but whose parts may be re-used (such as hi-fi equipment), unsold goods, and products with potential secondary usage.

On the one hand, reverse logistics can be an effective way to help dispose these E-waste in process of waste management and reduce the pollution and waste that are produced in manufacturing. On the other hand, reverse logistics is a critical way to achieve the physically transferring of E-waste from final customers to disposal points, and the quality of reverse logistics plays a decisive role in the whole E-waste management system. Therefore, the importance of reverse logistics does not need to say. Through reverse logistics, waste can be transport from the end of supply chain to the origin, therefore, some materials in waste even the waste itself can be disposed, reused, recycling or remanufactured. In this regard, there are some successful case in the world. For example, the collection and reuse of aluminum cans (Almeida et al, 2010) and pesticide packaging (Veiga, 2013) in Brazil. These measures have worked and helped to reduce pollution and protect environment.

As an important part of supply chain, as previously stated, reverse logistics can make supply chain become a complete circulation. Therefore, a type of sustainable supply chain, Closed Loop Supply Chain (CLSC), gradually entered the researchers' attentions and became a good method to manage the collecting and recycling process of waste (Guide and Van Wassenhove, 2009). According to Guide and Van Wassenhove (2009), the focus of CLSC is taking back old or end-of-life products and creating new value through reusing them. Obviously, it's an effective improvement for E-waste industry and Directive 2002/96/EC (EU, 2002) contains some regulations to close the loop of electrical and electronic equipment.

However, although there are many related academic researches and regulations, the situation in practices for E-waste might be more complicated. E-waste is a special type in all kinds of waste. As it mentioned in introduction, it has high potential to be reused. But being different from other recyclable waste, it needs some special care to protect it from being contaminated and harmful. A main characteristic of E-waste is that unlike an aluminum can or a plastic bag, electronics scraps is usually mainly composed by metal, plastics and refractory oxides, and their proportion is roughly 4:3:3 (Sodhi and Reimer, 2001). For reverse logistics, it means more complicated logistics process. For example, an aluminum can can be transported directly to disposed point. But for E-waste, because metal, plastics and refractory oxides require different handle methods, it might have to be predisposed and then transported to three different disposed points.

Another problem in E-waste reverse logistics is that, although developing reverse logistics can be a great approach to collect E-waste, how to manage this logistics chain and who has

sufficient ability to take this responsibility still be a problem. From perspective of market economy, these activities can be undertaken by business managers, but the distrust of researchers that if business managers are able to bear this responsibility is still not overcome (Migliano et al, 2014).

According to Migliano et al. (2014), Braga Júnior et al[1]. in 2006 argued that as the reverse logistics is a high-cost, non-essential and non-strategic operation, it's difficult for companies to manage this system is an appropriate way. Furthermore, Jayaraman and Luo (2007) pointed out that few retailers and suppliers do not realize that there is a potential market for waste reverse logistics, and they are not used to think from the aspect which has been expelled, such as waste recycling. From these researchers, it is conclusive that waste reverse logistics can be challengeable for all business managers. And the part of challenges will be discussed in section 2.4.

To cope with the problems of responsibility and decrease the distrust to business managers, EPR was introduced into field of E-waste management, and this policy can help government to supervise those companies which are related to E-waste.

2.2.2 Challenges in implementation of reverse logistics

While reverse logistics supply chains are generally viewed to be environmentally worthy, there are many challenges associated with implementing a successful and effective strategy (Aras et al., 2010).

Obviously, the cost of reverse logistics can be a big problem. The distribution of the new products can be consolidated, but the consolidation of reverse logistic can be diverse, for instance, multiple firms and some shared resources. Therefore, the cost of reverse logistics can be 9 times higher than the cost of forward logistics (Kaynak et al, 2014).

Another challenge is coordination problem between upstream and downstream supply chain. It is important to note that the upstream aspect of reverse logistics creates many difficulties that differ from those that emerge in the downstream supply chain process (Tibben-Lembke and Rogers, 2002). Importantly, there are differences in the number of destination and origin points that must be managed. While the downstream supply chain process typically involves the movement of one good from one point of origin to many destinations, the reverse logistics process typically involves the movement of a variety of goods from many points of origin to

[1] The original article is "Junior, S. S. B., da Costa, P. R., & Merlo, E. M. (2006). LOGÍSTICA REVERSA COMO ALTERNATIVA DE GANHO PARA O VAREJO: UM ESTUDO DE CASO EM UM SUPERMERCADO DE MÉDIO PORTE. Anais do XI Simpósio de Administração da Produção, Logística e Operações Internacionais, SIMPOI." Because this articles is in Portuguese, there uses the related quotes from Migliano et al. (2014).

one destination (Tibben-Lembke and Rogers, 2002).

One of another the key differences between the forward logistics supply chain process and the backwards process is that the quality of the goods being returned – as well as the packaging in which the goods are placed – may be poor (Tibben-Lembke and Rogers, 2002). This is the case both with goods that are recovered and returned from private households, small businesses and users, as well as those that are returned from retailers. This is an important point because the quality of the goods returned will impact decisions about how they might be used and disposed of.

In Sweden, there are also specific geographical challenges associated with the reverse logistics chain. Sweden is one of the most sparsely populated regions in Europe (Solvang and Hakam, 2010). The landscape is challenging in parts, and the island make up of the country means that there are specific challenges in coordinating and managing the transportation of reverse logistics supply chains (Solvang and Hakam, 2010). This is particularly difficult given that the process is centralized and involves the collection of many different goods from different locations. The upshot is that the collection and recovery process of waste goods may be more costly in Sweden than it is in other, more densely populated regions of the world (Liu et al, 2006).

McLeod and Cherrett (2014) have argued that in order for a reverse supply chain system to be economically as well as environmentally viable, a number of criteria must be met. Crucially, it is important that the agent or agents that are responsible for coordinating and running the reverse logistics system must ensure that returned goods are allocated to the correct line: waste, recycling, or refurbishment. This is key because there is evidence from some empirical studies that current reverse logistics supply chain processes are not as efficient as they could be, with many goods that could be refurbished or remanufactured being lost to landfill (McLeod and Cherrett, 2014).

In addition, it is important that the goods returned must be processed in a timely manner. This is largely because there may be substantial costs associated with storage (McLeod and Cherrett, 2014). Furthermore, as technologies continue to develop, the risk of key components and materials becoming obsolete rises (Ongondo et al, 2010). This may have an impact on the extent to which these materials and components can be repurposed in new production processes. Firms must also deal with returned products in a way that maximizes their value (Tibben-Lembke and Rogers, 2002). This means that returned goods must be transformed into a state that incurs the minimum cost, but which generates for the firm the highest revenue. In order to meet these objectives, organizations usually need to implement electronic or automated network systems that are linked to the forward supply chain system (Tibben-Lembke and Rogers, 2002).

2.3 EPR and E-waste management

As mentioned before, the full name of EPR is extended producer responsibility. Different from reverse logistics, EPR is a method that trying to solve some problems such E-waste problem from the angle of policy. Exactly, environmental problems like air and water pollution were controlled by the regulations from the aspect of factories, utilities and other installations, and the responsibility of making regulations is undertaken by government traditionally (Lifset, 1993). However, it is not enough for only government to assume social responsibilities. To improve this situation, the notion of extended producer responsibility was presented.

To be specific, extended producer responsibility (EPR) is an environmental policy approach which uses financial incentives to motivate producers to take responsibility for the post-use collection, transportation, and processing (like dismantling and recycling) of their products (Gui et al., 2015). It means that conventional responsibilities are to be broadened. On the basis of the Kibert (2004), it is a policy mechanism that can integrate sustainable development principles into international trade according to Polluter Pays Principle, which is an international environmental law principle.

Due to the features of EPR, it has been the key point for many policies and regulations that aim to solve the problems of end-of-life electric and electronic equipment and recyclable E-waste in these years. OECD (Organization for Economic Co-operation and Development) published a guideline for government to understand what EPR is and how to implement in practice (OECD, 2001). In this guideline, the clear definition and scope of EPR were given. And after this guideline, in the Provision (4) of Directive 2003/108/EC, it mentions that the financial responsibility for the collection, treatment, re-use, recovery and recycling of E-waste should be borne by producers (EU, 2003).

Under the requirement of EPR, the producers should provide a channel or financial support to collect the end-of-life electronic equipment and help to control the environmental problems. And in reality, from the perspective of customer, there are two basic types of take-back directive principles to achieve EPR, customer pays and producer pays (Atasu, 2009). Customer pays principle means end-customer will take the cost of controlling environmental pollution. To the contrary, this cost will be undertaken by producer in the producer pays principle. Based on the statement of Atasu (2009), in the relevant legislation, the former has been chosen by Japanese and Californian governments the European and Washington government have chosen another. Besides take-back principle, some other policy instrument like reuse and recycling targets, setting emission limits and recovery obligation can also help to divert the responsibility from governments to producers (Gupt and Sahay, 2015).

Since EPR has become a guiding ideology in related legislation and regulations, the actual operators of E-waste management should combine it with their activities, and EPR have to be considered in our research.

2.4 Legislation of E-waste management

Legislation is a critical part in E-waste management, and it provides a framework for all of actors involved in E-waste problem, including government and authorities, producer, PRO (Producer responsibility organization), and some companies which might undertake the work of transporting and disposing E-waste. They should work together to achieve the goal that is written in the law and regulation, and all of their activities have to be constricted by legislation. Therefore, legislation is important for E-waste reverse logistics, and it will be discussed in both EU and Sweden level in this part.

2.4.1 Directives and regulation in EU

It is the most important to note that as a full member of the European Union, Sweden is bound by the directives and regulations developed by the EU in relation to waste management, and that these regulations take precedence over national legislation should there be any conflict (Selin et al, 2006). It is therefore first necessary to examine the relevant EU regulations in addition to national legislation.

The key piece of EU regulation is the Waste Electrical and Electronic Equipment Directive (WEEE Directive), which is also known as the Directive 2002/96/EC (Pérez-Belis et al, 2015). This directive was officially adopted into European Law in February 2003 (Ylä-Mella et al, 2014). The WEEE Directive set out targets for the recycling and recovery of electronic goods (including consumer equipment, toys, leisure and sports equipment, household appliances and IT and telecommunications equipment), and these targets have been continually revised and updated in the years since the initial implementation of the law.

However, in 2011, following heavy criticism of the legislation, the European Council and the European Parliament agreed to revise the content of the Directive itself (Ylä-Mella et al, 2014). Consequently, a revised Directive was introduced in January 2012 (Salhofer, Steuer, Ramusch and Beigl, 2016). The core principle guiding the development and design of the regulation was the so-called polluter pays principle, which is described as the extended producer responsibility (EPR) in the Directive (Ylä-Mella et al, 2014). The Directive sets out a key objective of recovering and recycling a minimum of 2 per cent of electronic and electrical waste by 2016, although, to date, there has been little analysis on the extent to

which this goal has been achieved (Salhofer et al, 2016). Furthermore, responsibility for the disposal of WEEE is imposed upon the producers and manufacturers of the goods (Pérez-Belis et al, 2015). Manufacturers must also establish a system to enable the return and/or collection of waste goods from private households and other users which incurs no costs to the consumer.

2.4.2 Related implementations in Sweden

Prior to the adoption of the WEEE Directive, Sweden already had a substantial framework to govern the voluntary recovery, collection and recycling of electronic waste goods (Pérez-Belis et al, 2015). Nevertheless, by April 2005, Sweden has transposed the provisions of the WEEE Directive into its national law (Ylä-Mella et al, 2014).

In addition to the polluter pays principle, a key tenet of the regulation was the notion of subsidiarity. Subsidiarity means that individual Member States have the right to take the appropriate actions and decisions for the implementation of the Directive. Subsidiarity, according to Ylä-Mella et al (2014, p. 2), "protects the member states' capacity to take decisions and actions; however, it also authorizes the intervention of the community when the objectives cannot be achieved sufficiently by the member states "due to the scale and effects of the proposed action". Accordingly, Sweden implemented the WEEE Directive in the form of an ordinance of producer responsibility for electronic and electrical products set out in the Swedish Code of Statutes in 2005 (Ylä-Mella et al, 2014). The ordinance was updated in 2014, in order to ensure compliance with the revised European Directive. This expanded the provisions of the legislation with far reaching implications:

"*The changes to producer responsibility legislation mean that more equipment is covered and the responsibility of producers is expanded. The requirements relating to supervision and checking become considerably more stringent as all producers have to repeatedly describe how they fulfil their responsibility under the Ordinance. In addition, the Swedish EPA has powers to levy environmental penalty charges in the event of inadequate reporting" (WEEE Registration, no date, online).*

According to WEEE Registration, the ordinance sets out eight key provisions that must be adhered to by producers of electrical and electronic goods:

1. All manufacturers of these products (defined under the terms of the WEEE Directive) must report their existence to the Swedish Environmental Protection Agency (EPA) .
2. A system for collection of waste electrical and electronic goods is established.
3. The ordinance makes it clear that end-of-life electrical and electronic equipment must be dealt with in an appropriate manner (Patrício, Kalmykova, Berg, Rosado and Åberg,

2015).

4. Financial guarantees are available for waste equipment coming from a private household (WEEE Registration).
5. Recyclers must be provided with information on how to obtain and make use of waste electrical and electronic goods.
6. Users of electrical and electronic equipment must be provided with sufficient information and details about how and to where their waste equipment can be returned (WEEE Registration).
7. Goods that fall under the auspices of the Ordinance must be labelled as such.
8. Local authorities are required to participate in the system for the collection and recovery of waste electrical and electronic goods (WEEE Registration; Patrício et al, 2016).

Under these provision, any producer who aims to enter Swedish market to sell electrical and electronic goods has to register to Swedish EPA and their goods will entry the process of collecting and recycling when their lifespans are over

In this chapter we discussed the available academic literature regarding the scope of the thesis. The two main fields explained are reverse logistics and E-waste Management. After that we looked into both subjects together to see what are their relationship and boundaries' when they applied together. Then we studied Extended Producer Responsibility policy to see its relation with E-waste management and how it guides the activities in the process of E-waste collection and recycling. At the end, we examined the regulations of EU and Sweden which are related to Electronic Waste Management.

3 Theoretical Framework

To build the theoretical framework of our study, five stages of reverse logistics, four different types of reverse logistics and three approaches of takeback are described in this part to form the structure of analysis and discussion. Through these theoretical framework, the advantages and disadvantages of E-waste reverse logistics in Sweden can be identified and the results will be presented in a more reasonable way.

3.1 Five stages in reverse logistics

To successfully apply reverse logistics to the practice of waste management, how does reverse logistics operate should be a critical question and needed to be cleared. According to Jamshidi (2011), there are at least five stages in the reverse logistics supply chain.

In the first stage, the used product must be physically collected or returned. Collections can take place from a retailer, manufacturer or warehouse, or from private households. Alternatively, and depending upon the volume of goods to be returned, it may be more efficient for the user to return the goods themselves. However, it should be noted that products do not necessarily have to be returned to the original producer or retailer, but may go to a different collection point (De Brito and Dekker, 2003; De Brito et al., 2004).

During the second stage, the waste goods are scrutinized and sorted. For E-waste, the importance of classification is embodied in this stage.

Third, the returned goods are graded depending on aspects such as their components, their materials and their quality. It is at this stage that identification of goods for reuse and those for waste takes place (McLeod and Cherrett, 2014). Goods that still have some value may be reconditioned, new products may be put back into the forward supply chain, while failed or waste products may be sold for scrap or recycling (Jamshidi, 2011). According to Tibben-Lembke and Rogers (2002), there are at least nine possible destinations for waste goods: return to vendor, sell as new, repackage and sell as new, sell via outlet, refurbish or remanufacture, sell to broker, donate, recycle or landfill.

In the fourth stage of the process, the goods that have been identified for repurposing may be remanufactured or reconditioned. Parts are extracted from those products that are obsolete or cannot otherwise be reconditioned. Again, this may not necessarily be the responsibility of the original manufacturer or retailer, and indeed entire industries have emerged that are responsible for repurposing used goods (Tibben-Lembke and Rogers, 2002).

Finally, remanufactured or reconditioned goods are sold, either by the original retailer or in

secondary markets, such as in emerging economies (Jamshidi, 2011).

For the E-waste, these five stages can also be applied in practice. What need to be noticed is that in the second stage of scrutinizing and sorting, E-waste should be tested carefully due to the hazardous component. And because the technologies change quickly in these years, more and more equipment that still can work is discarded. In this stage, these equipment will have chance to return to secondary market and continue to play its role.

3.2 Different types of reverse logistics

In reality, Companies use some different organization forms to insure reverse process can be carried out efficiently and effectively. Blackburn et al. (2004) argued that reverse supply chain is designed with two fundamental structures, efficient and responsive supply chain. Efficient one means deliver with low cost and responsive one is designed for speed of response. Then they discussed that centralized model is efficient and decentralized model is more responsive.

Cherrett et al (2010) did further researches of these two different mechanisms for returns management: the centralized reverse supply chain and the decentralized reverse supply chain. In the centralized reverse supply chain, responsibility for the collection, scrutiny, disposition and distribution of returned goods is the responsibility of a single organisation (Cherrett et al., 2010). In the decentralized reverse supply chain, however, each individual manufacturer or retailer takes control of the return processes. Furthermore, the authors identify four different types of physical network for taking control of returns.

Type A is the integrated outbound and returns network. This is where the firm makes use of its own fleet, or the fleet that is used for forward supply chain logistics in order to backhaul returns from retailers to a regional distribution center, where the sorting and scrutiny processes take place (Cherrett et al., 2010). This is the system that tends to be used by supermarkets and other major retailers, for it is cost efficiency where there are frequent store deliveries and the volume of goods to be returned is high (Cherrett et al., 2010). For instance, this is the approach that is used by the Ford Motor Company (McLeod and Cherrett., 2014). If Ford's customers require new bumpers (due to, for instance, vehicle accidents), Ford has a policy of recycling the plastic used in those bumpers into taillight housing boxes.

Type B is the non-integrated outbound and returns network (Cherrett et al., 2010). Using this approach, the firm typically hires a third-party logistics provider to manage returns. This supplier collects and manages returns on an ad hoc basis. The key benefit of this approach is that the firm is not required to recruit and train specialist personnel to manage the sorting and scrutiny of goods (De Brito and Dekker, 2003; De Brito, Dekker and Flapper, 2004). This is,

in fact, a major advantage for this is “not a trivial undertaking and is a process that could lead to increased waste generation if not tightly managed and coordinated” (Cherrett et al, 2010, p. 244). This system is more appropriate where the volume of goods to be recovered is low, and where the volume cannot be predicted, or varies over time (Cherrett et al, 2010).

Type C is known as third party returns management. This approach also involves the use of a third-party logistics provider to manage returns (Cherrett et al, 2010). However, while the main function of the type B approach is the transportation, storage and sorting of goods off-site, the third party returns management mechanism delegates responsibility for identifying the goods to be returned at the retailer or the manufacturer’s site. The third-party logistics provider takes responsibility for all aspects of the return and recovery process including refurbishment and disposition (Cherrett et al, 2010). Cherrett et al (2010) argue that this approach is likely to be the most efficient and effective. The centralization of the returns and recovery process means that specialists are better able to recognise goods that can be refurbished, which means that recycling can be optimised.

Finally, type D is termed return to suppliers (Cherrett et al, 2010). This is the process whereby goods are returned upstream to the original suppliers, where they may be exchanged in return for credit, which in turn can be used to purchase new components and materials. While this would seem to offer benefits for the retailer or manufacturer in terms of costs, there are additional costs in terms of transportation (Cherrett et al, 2010). Furthermore, in this case, the burden of responsibility for taking care of returns and recovery merely passes from the retailer or manufacturer to the supplier.

Company selects different organization form in different situation, and for E-waste reverse logistics the principle is the same. Analyzing the advantages and disadvantages of these different types can help us better understand how companies operate in reality and how to improve the actual operations.

3.3 Takeback approaches

Takeback approaches are also important for reverse logistics operation, choosing different approaches means different features and focus in the whole process. Spicer and Johnson (2004) analyzed three different take-back approaches which are under the principle of EPR on theoretics. They are OEM (original equipment manufacturers) Takeback, Pooled Takeback and Third-Party Takeback (Spicer and Johnson, 2004). The following Table 4 summarize these three approaches from aspects imputation of responsibility, advantages and disadvantages.

Table 4. Comparison of three different take-back approaches

	OEM Takeback	Pooled Takeback	Third-Party Takeback
Imputation of responsibility	OEM take physical and economic responsibility for product they manufactured.	Consortia of manufacturers (grouped by product category) take physical and economic responsibility.	Private companies represent OEM and take responsibility for products.
Advantages	✓ Information feedback ✓ Operational efficiencies ✓ Potential loop recycling	✧ Convenience of establishing reverse logistics system ✧ Manage their own demanufacturing facilities	➢ Manufacturers can eliminate the financial risk of end-of-life products ➢ Promote innovation in the demanufacturing industry
Disadvantages	✓ Difficulties in returning products ✓ "Orphaned products"	✧ Economic costs ✧ It's hard for producers to get the feedback information.	➢ Transfer information between designer and demanufacturer

Source: Spicer and Johnson (2004)

What needs to be noticed is that different approach is suitable for different situation. Identifying the characteristics of products and context and selecting the most suitable approach is very important for companies. For example, a big company can afford the cost of OEM takeback and can provide sufficient technical support, but a small company might need to rely on the tack-back system which is built by governments or authorities.

4 Methodology

In this section, the methods that are used in this study are presented and discussed. The question of "how to do this research" will be answered from two aspects, first the choice of research method. the second, reveals the method used for collecting information and clarifications about the quality of this study in regards to validity and reliability of research method.

4.1 The choice of research method

The title of this thesis is "An investigation to Swedish E-waste Collection and recycling system", and as it mentioned in introduction, there are two research questions included in this research:

1. *How does Sweden use reverse logistics to collect and recycle E-waste from residents*?
2. *What are the main strengths of the current system and to what extent can limitations or problems be identified*?

To answer these research questions better, after considering several different methods, the method of case study is chosen in this research. Case study is an approach to research that facilitates exploration of a phenomenon within its context using a variety of data sources (Baxter and Jack, 2008). Because case study is using various data to analyze the case, there are many potential data sources can be included into a case study, such as documentation, archival records, interviews, physical artifacts, direct observations, surveys and participant-observation (Baxter and Jack, 2008). According to Yin (2003) a case study design should be considered when:

1. The focus of the study is to answer "how" and "why" questions;
2. You cannot manipulate the behavior of those involved in the study;
3. You want to cover contextual conditions because you believe they are relevant to the phenomenon under study;
4. The boundaries are not clear between the phenomenon and context.

In the first research question, the goal is to find out how organizations or companies do and collaborate with each other now in Sweden. And for the second research question, discovering the main strengths of the current system and to what extent can limitations or problems be identified should be considered. Case study is appropriate in this research since we do not aim at manipulating their behavior but to understand what they are doing now and what the limitations are in the system.

To better understand this system, the study can be continued from two main perspectives,

operators and users of this system. The first perspective is operator of the system, and in our research it includes El-Kretsen, EÅF and local authority and stores.

To be specific, in Sweden, the producer responsibility for E-waste was introduced in 2001. To push this policy, the cooperation called “Elretur” which is between producers and local authorities was initiated. El-Kretsen takes the responsibility to manage the collection and recycling system for E-waste and it has contract with every local authorities to collect E-waste from residents. Then in 2008, the Swedish Association of Recycling Electronic Products started another system called EÅF. EÅF collects E-waste through their member stores from residents (El-Kretsen, 2009).

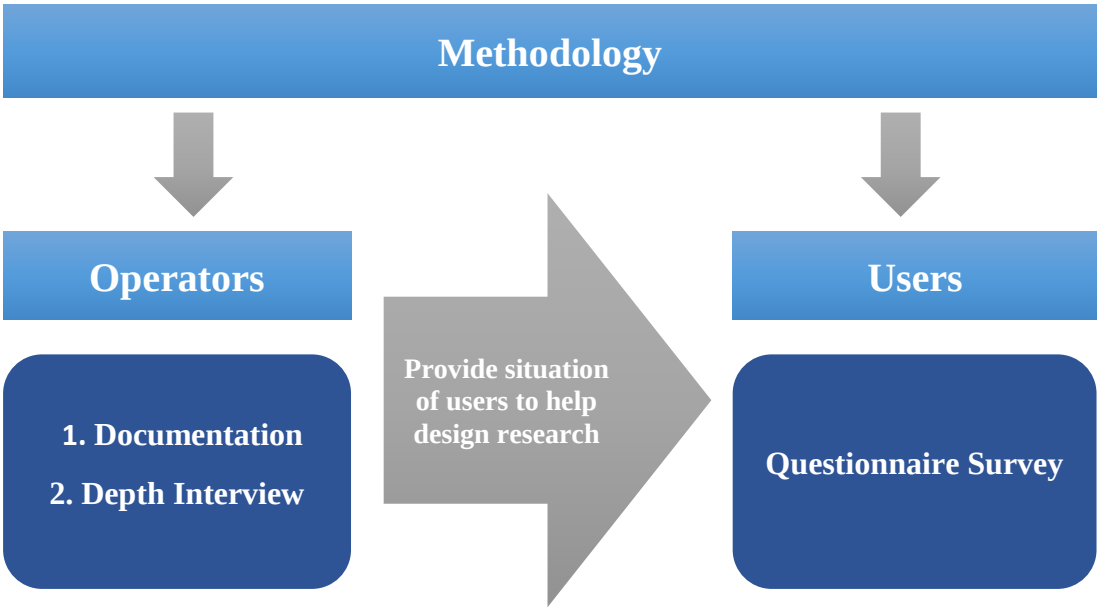

Figure 2. The structure of our research method

Although there are two parallel E-waste collection system in Sweden, Elretur is the only nationwide collecting system and it undertakes 99% amount of collection (Hanna et al. 2015). Therefore, most of our work will be regarding with Elretur. Due to the limit of time we only choose Gothenburg as an example.

The local authority in Gothenburg that manages the collection process is Kretslopp och vatten, and it also collaborates with El-Kretsen. Therefore, we did a depth interview with the process manager of hazardous waste of Kretslopp och Vatten. Kretslopp och Vatten is the waste management authority in Gothenburg and has cooperation with El-Kretsen to collect E-waste from people. The content of interview included what and how they manage this system, and some details about the collection channels in Gothenburg. Because the theoretical framework

has been presented in the section of literature review, one purpose of our interview is to discover the types of the reverse logistics in the system, and combining the theories and practice to analyze the problems. Another interview conducted to member store of El-kretsen which revealed how EPR has been incorporated in their operation of the store.) After the interview with Kretslopp och Vatten , an observation survey was completed at one of recycling parks in Gothenburg to see how the E-waste is collected and sorted in practice.

For another angle of our research, we did a survey to university students and people who live and work in Gothenburg about E-waste management. The questions in this survey are designed according to the results of our interview and the observation survey. The aim of the survey is to find out the gap between user's demand and what operator provide, and some problem will be discovered in this process. As the result, 23 responses are collected totally. 20 of the respondent are university students and 3 of them our people who has been living in Gothenburg for the last three years.

Table 5. Overview of interviews, observation survey, online questionnaire

Research	Perspective	Date	Brief Introduction
Interview with Kretslopp och Vatten	Operator , local authority	2017-04-20	Interviewee: Manager of Process Manager of Hazardous Waste
Online Survey	Users	From 2017-04-22 To: 2017-05-10	Based on interview to Kretslopp och Vatten, including six questions.
Observation Survey to Recycling Park	Operator	2017-04-20	Name: Kretsloppsparken Alelyckan Address: Kommunal, Östra Göteborg
Interview with store	Operator	2017-05-01	Name: Clas Ohlson Address: Nordstan, Göteborg

4.2 Validity and reliability of research

Before talking about validity and reliability of a research, the meaning of validity and reliability should be defined first. According to Kirk and Miller (1986), reliability is "*the extent to which a measurement procedure yields the same answer however and whenever it is carried out*", and validity is "*the extent to which it gives the correct answer*".

Compared with quantitative methods, the method of case study is often labeled as a lack of trustworthiness, and three problems that a case study mainly faces are discussed by Yin (1984):

1. Case study is often a lack of rigour because the researchers of case study might use equivocal evidence or biased views to impact the results of research;
2. Since the number of subjects is small, case study provides very little basis;
3. The content of a cast study might be too long and complex and it is not easy to conduct.

For these three problems, the first two are related to the problem of validity and reliability, therefore they will be analyzed separately in next text.

First, about “a lack of rigour”, we have noticed this problem existing if we only study the operators. Therefore, after finishing the interview, a small survey aimed at the problems that was discovered in interview has been conducted. The evidence from both operators and users are presented to avoid biased views. And besides the interviews, some documentation and previous studies will also be included to help get the results and increase the trustworthiness.

And for the second problem, fortunately, the results from EÅF, El-Kretsen and local authorities can almost represent the situation in Sweden since Elretur and EÅF are the only two E-waste collection system in Sweden. Therefore, the method of case study is really suitable for the conditions in Sweden because it can increase the reliability and validity as much as possible.

Although there are some disadvantages of validity and reliability in case study, it is still a useful explorative method when we face an unfamiliar context and when the context must be taken into consideration if we want to get reasonable results. And in this case, what we need to do is to use various ways to decrease the bias and equivocal evidence and make the findings more dependable.

5 The E-waste collection system in Sweden

The content of this chapter will help to answer the research question one "how does Sweden use reverse logistics to collect and recycle E-waste from residents". All the actors involved in the system and the entire process will be introduced in this chapter.

5.1 Main actors in the system

To maintain the normal operation of E-waste collection system in Sweden, there are Swedish Environmental Protection Agency (Swedish EPA), Swedish Waste Management and Recycling association (Avfall Sverige) and two organizations called producer responsible organization (PRO) working together. In Sweden, since the requirements on take-back system are very high, it's difficult for a new producer to take responsibility individually without cooperation with PROs, Similarly, for a new actor (Hanna et al, 2015). Therefore, the pattern of the relation and cooperation between two organizations in Sweden are relatively fixed.

PRO is an organization which *fulfil the EPR obligations of their members by organizing pick-up of waste from designated public and distributors collection points, ensuring subsequent treatment and recycling, and performing reporting to national governments* (Mayers, 2007). In reality, PRO can be non-profit or commercial. The two PROs in Sweden are El-Kretsen and Swedish Association of Recycling Electronic Products (EÅF). El-Kretsen is a collective representation of its producers and it provides business service for the collecting and recycling E-waste (Lee and Sundin, 2012). The Swedish Association of Recycling Electronic Products registered as PRO in 2008 in Sweden and run the system EÅF to collect and recycle the E-waste.

On the basis of El-Kretsen (2015), they collaborate with Swedish local authorities to manage the E-waste together. There are another PRO Swedish Association of Recycling Electronic Products which is also provide E-waste collection points in some retail stores, however; it is still a very small part in this system. To be specific, El-Kretsen almost undertake total amount of E-waste collection and EÅF only collects 1% of them (Hanna et al, 2015). Before 2015, El-Kretsen had had 1602 producers and the number of EÅF's members is 69 (Hanna et al, 2015).

As an Authority, Swedish EPA undertakes the responsibility of ensuring the implementation of EU directives in Sweden and reporting to EU commission (Lee and Sundin, 2012). For E-waste collection, its responsibility is to make sure the relevant actors in E-waste collection and recycling sector perform in the proper way.

Avfall Sverige is an association which represents 400 members from both public and private waste management and recycling sectors. El-Kretsen cooperates with Avfall Sverige to implement relevant measures in every municipalities to collect E-waste from residents. As an example, in the case study of Gothenburg, the work of collecting E-waste from residents is undertaken by Kretslopp och vatten, which manages municipality collection sites in Gothenburg.

5.2 Entire process

In chapter 5.1, several actors involved in E-waste collection and recycling system were described. And in this chapter, the theory of five stage of reverse logistics will be used to illustrate the process in a clear and systematic way.

First, collections are arranged and it is the first stage in reverse logistics. In accordance with the provisions of the ordinance of producer responsibility, this aspect is coordinated by the two organisations in conjunction with municipal authorities and private transportation companies (Ylä-Mella et al, 2014). Once the goods arrive at the recycling centres, E-waste will move to the second and third stage of reverse logistics. They are scrutinised and sorted into different categories. In Gothenburg recycling park, there are six categories of E-waste (see appendix A):

(1). Miscellaneous E-waste; (2). Fridge and freezer; (3). White goods (except fridge and freezer); (4). Battery; (5). Fluorescent; (6). Light bulbs. Fridge and freezer are picked up separately because they are disposed by different recyclers from other white goods. And fluorescent contains mercury which should be treated specially.

After stage two and three, the E-waste will undergo disassembly. During this process, some components or materials that might require special processing will be removed. In these stage, the specific treatment methods are depended on companies and plants. In recycling sites of El-Kretsen, the E-waste will be registered before being disposed. According to El-Kretsen, these components that should be removed are batteries and other environmentally hazardous components. As an example, the wood and ordinary plastic will be incinerated to generate electricity, and those metal and plastic which can be recovered and used will be disposed to manufacture for new products. Through this process, the raw materials from E-waste will become new products and enter the market, and an “eco loop” is closed.

Ylä-Mella et al (2014) clearly reveal the process of E-waste reverse logistics by a figure, and Figure 3 shows the typical process for the recovery, collection and recycling of electronic waste at both El-Kretsen and EÅF.

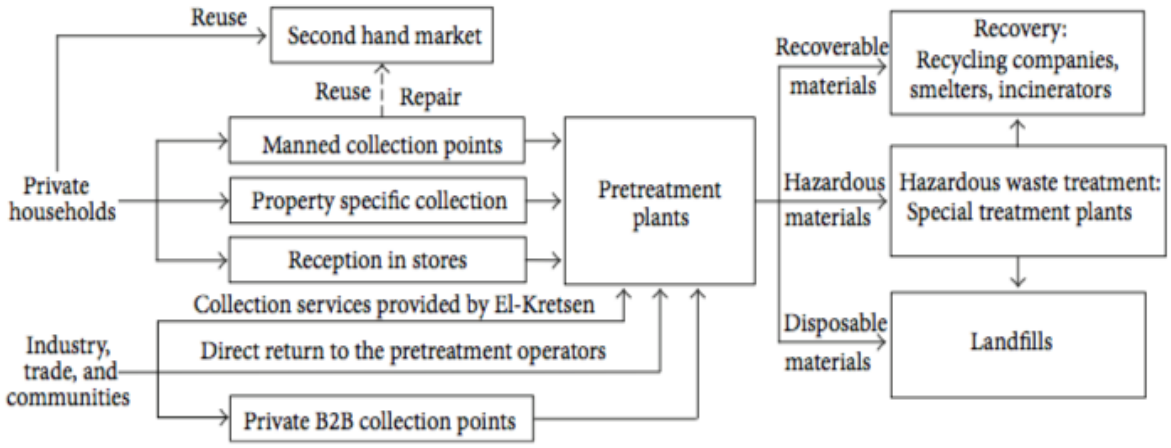

Figure 3. The typical process for the recovery, collection and recycling of waste electronic goods in Sweden (Ylä-Mella et al, 2014)

5.3 Collaboration between actors

To achieve the physical process of E-waste logistics smoothly, the cooperation between different organizations and companies is essential and critical. As mentioned above, there are two PROs, El-Kretsen and Swedish Association of Recycling Electronic Products, which run two parallel systems Elretur and EÅF in Sweden.

Elretur is a nationwide system and covers all areas in Sweden, and it only provides residents with E-waste collection channels. In Elretur, El-Kretsen cooperates with every local authorities and collects E-waste from municipality collection sites which managed by local authorities. On the other hand, To collect the E-waste, besides Elretur, it also runs some projects together with Avfall Sverige to test the adaptability of these projects in some special regions, such as areas with sparse population. As an example, the collector that will be discussed later.

Different from El-Kretsen, EÅF uses its member's retails shop as collection points (Goodship and Stevels, 2012). According to website of Elektronikåtervinning (2017), EÅF offers collection of all types of E-waste and customers can hand in their E-waste for free and without any restriction. But the main problem for EÅF is the range of its collection. Since not all municipalities have their member shop, EÅF has to pay a fee to El-Kretsen to cover those E-waste that belongs to them but collected by El-Kretsen (Goodship and Stevels, 2012).

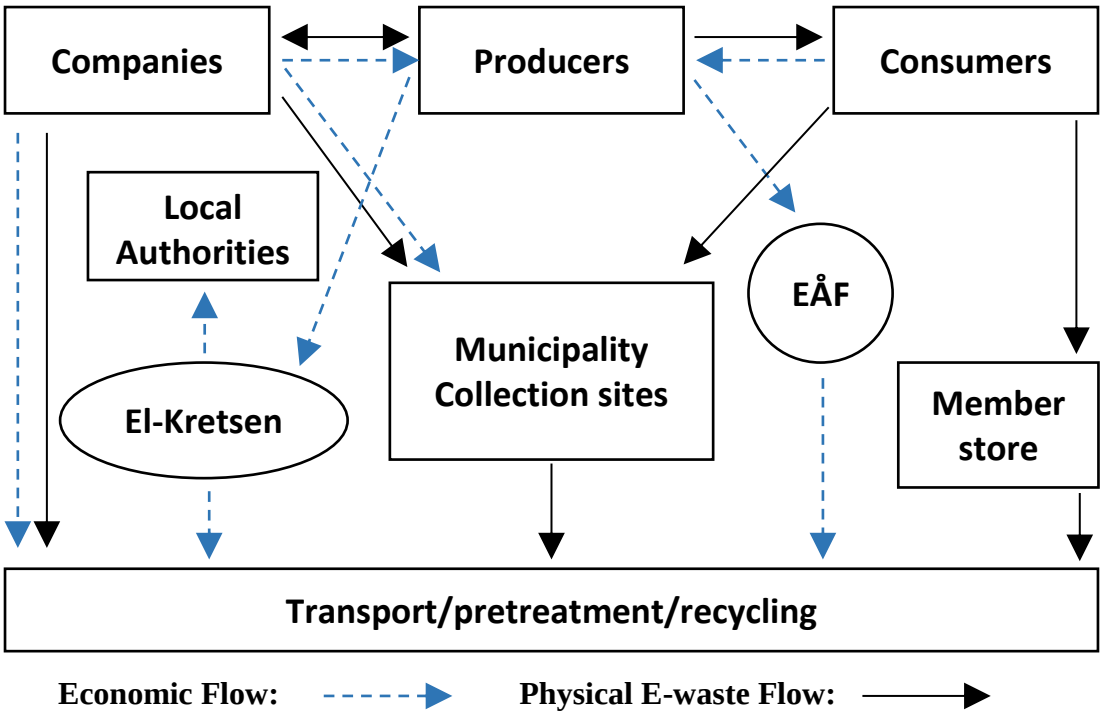

Figure 4. Framework of E-waste system in Sweden

Source: Swedish Environmental Protection Agency (2009)
Notes: "Local Authorities" is added by authors according to interviews

Figure 4 illustrates the framework of E-waste system in Sweden. What should be mentioned is that El-Kretsen contracts with some logistics companies for them to transport E-waste from municipality collection sites to recycling sites, and the pretreatment and recycling parts are also taken on by professional recyclers who have contracts with El-Kretsen. Therefore, El-Kretsen plays a role as an organizer of these series of activities to make sure things go smoothly and the actors involved in these activities follow the CECED (The European Committee of Domestic Equipment Manufacturers) code of conduct. They divided Sweden into different areas according to volume, logistics costs, and location of processing (Ylä-Mella et al, 2014). In these areas, various service providers such as logistics and recyclers do their own work.

In previous studies of this system, local authorities was not included in the framework of E-waste system in Sweden. However, they are very important in operation of the system. They can make many decisions without negotiating with EL-Kretsen regarding the operation of the collection system (Swedish Environmental Protection Agency, 2009). As an instance, according to our interview, for the individual customer sector of E-waste collection in Gothenburg, El-Kretsen is almost entirely dependent on Kretslopp och vatten. Kretslopp och

vatten manages most of the municipality collection sites. They collect E-waste from the public and El-Kretsen picks up the E-waste from Kretslopp och vatten. Although the cost of running the recycling parks and collecting E-waste have been included in the municipal waste management, in these process Kretslopp och vatten still can get paid from El-Kretsen which calculated by kilogram or units they collect to cover the cost such as staff, sorting and informing people. According to Kretslopp och vatten, the pattern of organization in every municipalities for individual customers are similar. Therefore, the local authorities was added into the figure 4 by authors.

6 Findings

To provide insights to the research questions, two interviews, an observation survey and online survey were conducted to carry on with a case study in Gothenburg. And this chapter attempts to display the facts that were found in these researches.

6.1 Findings from interviews and field survey

According to the interviews of Kretslopp och vatten and a store manager, some information in details about how the E-waste recycling process is implemented in Gothenburg was collected. Due to the status of these interviewees, the information is mainly about the process of collecting E-waste from residents rather than the whole process in Swedish system.

Another important reason for analyzing the collection channels emphatically is its complexity. Collecting E-waste from users to disposers is a critical step in the whole process of E-waste reverse logistics. This step is complex and difficult because what the operators need to do is collecting scattered E-waste from many users. It does not like forward logistics that they can just transport shipment from one place to another. There are so many uncertainties which cannot be controlled by operators since the users have the final power of decision if handing in the equipment or not. In this aspect, the operators must collaborate with users to achieve the goal.

After reviewing the relevant materials and doing an interview with a staff of Kretslopp och vatten, in Gothenburg there are some channel as following for people to recycle their E-waste:

1. Local garbage room and environmental station (Miljöstation)

Figure 5. Environmental station (Miljöstation)

In Gothenburg, there are many garbage rooms near apartments for residents to leave their waste. Generally, the household waste will be separated into different types, such as paper, plastics and glasses, and different types of waste have their specific dustbins. According to our interview, Kretslopp och vatten has been trying to implement boxes in garbage room to collect E-waste since two years ago. To achieve this, Kretslopp och vatten needs to have dialogue with different housing companies to convince them to reserve enough room in their garbage rooms. However, the reality is that not all garbage rooms have E-waste boxes and Kretslopp och vatten still have to work hard on this.

Another approach which is similar with garbage room is environmental station, and in Swedish is called Miljöstation. Environmental station is not only for collecting E-waste, but also for some contaminated waste, like chemicals and other hazardous waste. Environmental station looks like a container and it is 10 feet in size. The figure 5 is one of the environmental stations in Gothenburg.

In environmental station, rooms are divided into different categories to collect corresponding type of E-waste. As for E-waste, small E-waste like light bulbs and batteries are putted in different cages and big E-waste can be putted on the ground

directly. Based on the introduction from our interviewee, these environmental stations are located in six different gas stations and several small harbors with some small boats to collect E-waste.

2. Recycling park

Recycling park is an integrated waste recycling center with various types of waste. There are five recycling parks in Gothenburg totally. The park is very big and has a circular lane which connects the entrance and exit for private cars. People can transport their waste themselves to the recycling parks. Recycling park collects various sorts of waste, such as bulky waste, wood, metal, gypsum, garden waste, electronic and hazardous waste. People could also donate the old items they do not like or need to recycling park, and these items will be sold out as second-hand items.

Based on the interview, recycling park is the main channel for Kretslopp och vatten to collect E-waste. People leave E-waste there, then El-Kretsen pick up these E-waste and transport it to plants. It's worth mentioning that El-Kretsen pick different types separately, and the frequency of picking up is depended on the quantity that people leave to recycling parks. The cages and containers for E-waste in recycling parks are provided by El-Kretsen. They have ID tags on them and the bar code on the ID tags can be registered when the E-waste is picked by carriers. This process makes the system controlled and safe.

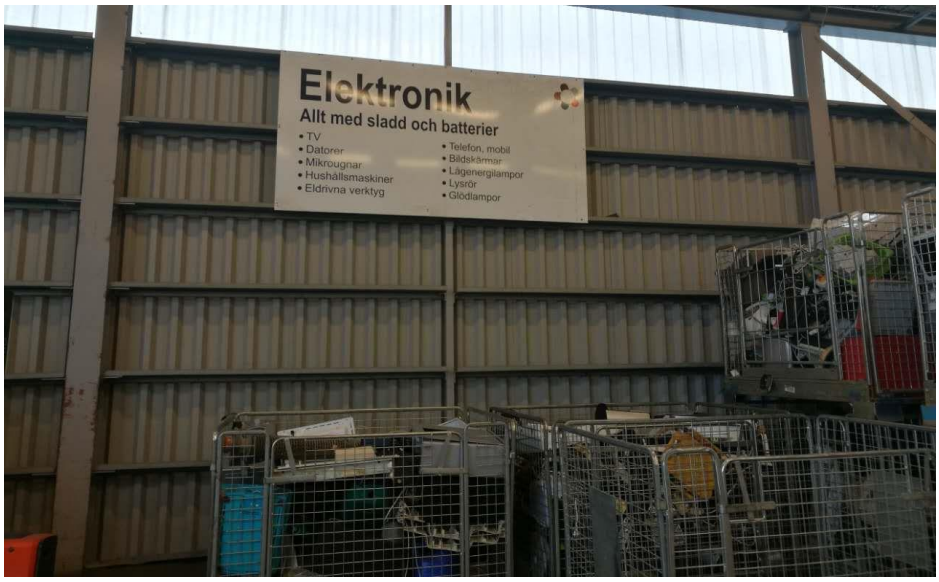

Figure 6. The sign of E-waste area in recycling park

After the interview, we did a field survey about a recycling park near the office of Kretslopp och vatten. Figure 6 is a sign above the E-waste area. It lists the type of E-waste which should be recycled here. The small E-waste in the cages, like computers and

lamps, have been removed batteries and bulbs. Batteries are putted into the red container, and fluorescent bulbs and general bulbs are putted together in yellow container.

Figure 7. The continers with bulbs and barries

In recycling park, fridge and freezer are separated from other white goods, and there is an area specifically for fridge and freezer, like figure 8.

Figure 8. Fridge and freezer in recycling park

3. Collector (Samlare)

Collector is called Samlare in Swedish. It is run together by Avfall Sverige and El-Kretsen with some local authorities. In Gothenburg, the operator is Kretslopp och vatten.

Collector is a special device with several independent spaces that are designed for

different sorts of E-waste. They are often placed in grocery stores in Gothenburg for people to put in light bulbs and some other small E-waste and batteries. According to our interview, the fluorescents are collected separately from ordinary light bulbs before, but they are collected together in new devices. The reason might be the development of technology. Avfall Sverige. (2014) in their report mentioned that the process of collection has been simplified due to the new technology, and customers can put different small E-waste into the same container.

Figure 9. Collector (Samlare) in store

4. Electronic and hazardous waste truck

Figure 10. Electronic and hazardous waste truck and staff

Electronic and hazardous waste truck is the most flexible part in E-waste collection

system in Gothenburg. These trucks provide an approach for those who don't have private cars to get to recycling parks.

There are two trucks going around the town in different neighborhoods to collect waste, and approximately more than half of the waste collected by these trucks is E-waste. These two trucks go out for collecting waste four times a week and they stop in three different places every day. The schedules of the trucks are different in different neighborhoods, and there are 450 stops totally for these trucks.

Another function for those trucks is to help collect large E-waste. For example, if someone want to recycle his refrigerator but he can't transport it to recycling park himself, he can call Kretslopp och vatten for help. Kretslopp och vatten will send their trucks to pick it up. It's a good solution for collecting those bulky E-waste like refrigerator and washing machine.

5. Stores

Kretslopp och vatten administrate the first four collection channels in Gothenburg. However, besides them, some stores can also accept E-waste.

There are two type of stores in Gothenburg, the one is the member store of EÅF, and the other is those stores collaborated with El-Kretsen. Member store is the only channel that is run in the EÅF system, which is managed by the Swedish Association of Recycling Electronic Products. Based on the map of collection points in website of EÅF. In Gothenburg there are four member stores where consumers can hand in their E-waste. For those stores have contracts with El-Kretsen, by interviewing Store Manager of Clas Ohlson we understand that every electronic product that is sold by any shop in Sweden needs to be recycled through the same store that the initial purchase has happened. Electronic stores, such as Clas Ohlson and Elgiganten they have a contract with El-kretsen, give the E-waste they collected regularly to El-Kretsen. They do not do any check or inspection of E-waste and the second-hand market does not exist in these stores.

6.2 Online survey

As mentioned in Methodology part, the issues are planned to be found out through comparing users' requirements with current situation of collection. Therefore, the questions are designed based on the results of interviews and trying to found out the problems.

The following table shows the questionnaire and results.

Table 6. The results from online questionnaire survey

Total Responses: 23 (Age distribution 18~30: 39% 30~40: 61%)	
Question	**result**
Do you know what E-waste is? (single response possible)	Yes: 70%
	No: 30%
Which option do you think is electronic waste? (multiple responses possible)	Light bulb: 50%
	Battery: 77%
	Shoes with light: 41%
Have you ever recycle any electronic waste? (single response possible)	Yes: 87%
	No: 13%
Which options have you ever used for recycling E-waste? (single response possible, 20 responses of this Q)	Local garbage room: 60%
	Grocery store or electronic store: 10%
	Collector (Samllare): 20%
	Recycling park: 40%
	Electronic and hazardous waste truck: 10%
Does there have a special garbage can for electronic waste in your garbage room? (single responses possible)	Yes: 56%
	No: 44%

Note: Responses are selected randomly, and they live in different apartments.

7 Analysis and discussion

In this section, some features and advantages in Sweden system are discussed combining with theoretical framework. In the 7.1, the type of system and takeback approach are discussed. Then, some insights from Swedish practice are presented and argued, and they might provide reference to other countries and areas which are developing their E-waste collection system.

After that, the problems of system will be argued. However, the limitation of the survey should be considered into analysis. The university students in Gothenburg were selected as the target group because they are more convenient to access for us. For example, university students might be more able to accept new things and concepts and maybe they could get the information of E-waste more easily compared with other people.

7.1 Type of Swedish system

After doing some researches, although there are some small problems, the results still show that there has been a mature reverse logistics system in Sweden for public and business to collect E-waste. And since Sweden has have this policy for more than ten years, most people have used to separate the different sorts of waste and leave them in different garbage cans. Combining with the theoretical framework, this section will discuss the characteristics of system in Sweden and pointing out some merits which might be helpful for some other areas.

1. Centralized E-waste collection system in Sweden

Halldórsson and Skjøtt-Larsen (2007) presented that the centralized reverse supply chain means one organization undertakes the responsibility of collection, inspection, disposition and redistribution of returned items, which might come from many different retailers.

Combining with the section of theoretical framework and the definition of centralized reverse supply chain, the system in Sweden is more like a centralized reverse supply chain, and the centralized organization is El-Kretsen. However, it is not an absolute decision, due to flexibility of business activities in practice, when a business model has to adapt to different environment, some parts of this model might should be adjusted. In Sweden, E-Kretsen is a centralized organization in Elretur system, but it doesn't undertake specific work such as disposition and inspection. It plays a role as an organizer and outsources these works to professional companies.

Therefore, analyzing the whole collection and recycling system in Sweden, the type of this physical network can be identified as Type C, third-party returns management. For the producers on the electronic equipment market, the El-Kretsen is the third-party companies

which is responsible for the whole process after the electronic equipment become E-waste. The different is that El-Kretsen is not a profit company. Those producers who want to sell electronic equipment in Sweden have to provide funds as financial guarantees, and El-Kretsen will use these funds to handle the E-waste. It often set aside enough funds for one year operation.

In reverse logistics aspect, due to the transportation of E-waste is not undertaken by El-Kretsen itselves, it plays the role of fourth party logistics which control the business process and employ some transport companies to transport E-waste from municipality collection sites to recycling plants. In every municipalities, the authorities pick up the E-waste from collection sites, and the cost of this process is covered by the authorities themselves. In conclusion, as a centralized management organization, El-Kretsen ensures the whole system work normally and outsourcing the work of transporting and recycling.

In conclusion, the centralized reverse supply chain could be a good choice for the E-waste collection and recycling in Sweden. According to Blackburn et al. (2004), the aim of centralized supply chain is delivering items with low cost, but it often led to long delays compared with decentralized reverse supply chain. El-Kretsen is a non-profit company and represents its producers, therefore it is reasonable for El-Kretsen to choose the low-cost strategy. Another important factor is the cost of training relevant staff. A decentralized reverse supply chain means that the inspection and evaluation of equipment should be decentralized rather than transporting them to a disposing center. In Sweden, it suggests that staffs in authorities and stores which cooperate with El-Kretsen should have enough professional knowledge to do these. But it is uneconomical to retain professionals and there are some other companies with more professional skills of inspection and disposal. Therefore, the centralized pattern could be more economical compared with decentralized reverse supply chain.

At municipal level, it is wise for El-Kretsen to cooperate with authorities and employ different logistics companies in different regions. The first reason is that Sweden is a narrow country whose distance from north to south is 1,574 kilometers (Source: Nations Encyclopedia). Populations are separated and natural environments are various. This geographical characteristic means that for El-Kretsen it’s too costly to build a completed traffic network by itself. But the situation is different for local authorities because they already have had mature systems to collect household waste. The cost will be much lower if El-Kretsen can borrow these existed systems.

2. Takeback approach

Obviously, the takeback approach of E-waste in Sweden is “pooled takeback” which has a consortia as PRO to undertake the responsibility of controlling the whole process. Spicer and

Johnson (2004) argued that pooled takeback approach can perform better in logistics aspect and it is more universal for different situation compared with OEM take-back. Due to the centralized position of El-Kretsen in E-waste collection and recycling system, it naturally becomes the consortia for pooled takeback.

One significant advantage of this approach is that it can enjoy the full economy of scale. The reason is that for the PROs in the specific regions under their management, all E-waste will be transported to their recycling sites and be disposed together. In Sweden, El-Kretsen have 30 recycling sites to dispose (dismantling sorting and shredding) the E-waste which come from nearby areas. Therefore, the centralized disposal will reduce long-run average total cost for disposing an individual E-waste, and maximize the effectiveness of facilities and recyclers in recycling plants.

Besides reducing the cost, centralized disposal can also provide a chance to treat E-waste more professionally. For example, a large company which is able to collect E-waste through its own channels, like Haier, might have various types of EEE (for Haier, it has products such as fridge, air-conditioner, television and kitchen appliance). The method of disposing some of them are different from others. Like fridge and freezer, they are collected and disposed separately from other white goods in Sweden (see chapter 6.2, recycling park). Although a large company can build its own disposal system, the cost still high if things are disposed in the most suitable way. To reduce the cost, Companies might do not provide targeted disposing methods for every types of E-waste. Futhermore in Sweden, due to the small size of population, the quantity of products might be uneconomical for a brand to dispose its E-waste by itself. But the pooled takeback approach can centralize all similar products in a certain area and dispose the products that can be treated in the similar procedures together.

The third advantage is that the problem of “orphan product” can be solved. This problem indeed exists because the lifetimes of some durable goods are long, and they might become orphaned products before they are out of service. For those products that manufacturers had exited market, they cannot be recycled by OEM takeback. But pooled takeback can solve this problem. All the E-waste are collected uniformly by El-Kretsen in Sweden, and the cost can be covered by funds from producers.

However, this approach also has some disadvantages compared with OEM takeback. For OEM takeback, since OEM manages the demanufacturing process themselves, the feedback information can back to producers easily to form a closed loop. It’s helpful for manufacturers to refine their design of products. And also, they know their own products better and can utilize the fullest potential of these E-waste to avoid waste. But for pooled takeback approach, El-Kretsen controls the process of demanufacturing and disposes different type of E-waste almost in the same way. On the one hand, it will be hard for the original manufacturers to get

the feedback and refine their products. On the other hand, some materials of E-waste might be disposed in an inappropriate method so that resulting in waste of resources.

In conclusion, the main features of E-waste reverse logistics in Sweden is centralized and it has a main organizer of activities. For one type of business pattern, it must have both advantages and disadvantages, and Sweden is no exception. Centralization is an efficient and effective way for producers to achieve the EPR, especially for those small and middle companies. They maybe do not have sufficient ability to build completed takeback channels by themselves or it is high-cost for them. In this case, current E-waste collection and recycling system can help them undertake their responsibilities in an economical way. The problem is that for those companies which can recycle their E-waste and want to get feedback information from these old equipment, the situation might be disadvantageous and they have to collect information from some other ways.

7.2 Advantages of Swedish practices

This chapter will discuss the advantages in Swedish E-waste collection and recycling system. The meaning of this chapter is to point out the advantages and provide a good model for other areas which needs E-waste management. There are several positive features in Swedish system and practice and these have been grouped together in five categories and will be discussed below.

1. People's positive view of recycling E-waste

Since the E-waste collection and recycling started in 2001, it has been 15 years for Sweden to improve this system and solve the problems. Also, in these years, the public have had the sense of collecting and recycling E-waste and the results of the survey can show that the most of people know E-waste and have ever recycled E-waste in their past lifes. People's positive view seems like an ordinary thing but it is vital for recycling E-waste. As mentioned before, collection rates highly rely on people's responses, and people's positive view can help to increase collection rate effectively.

In this condition, some new measures related to E-waste are more easily accepted by people and they are willing to do the right things. It provides a forward motivation from their own thoughts and it could be more effective compared with mandatory requirements.from top to dowo Though more knowledge about E-waste should be conveyed to the public, it still has a good environment for PROs and government to implement related measures to collect and recycle E-waste. For other areas, propagandizing the negative impacts of E-waste and the necessity of recycling are critical for promoting the growth of people's positive view.

2. Uniform administration with certain degree of local authorities' independence

Uniform administration and certain degree of local authorities' independence are two features in Swedish E-waste collection and recycling system. For any individual one, it has both advantages and disadvantages. Total uniform administration might not adapt to all municipalities and total local authorities' independence could make troubles in management of PROs. However, when they become a combination, they can overcome each other's drawbacks and make the whole system uniform but having enough adaptability for different conditions.

As it mentioned before, El-Kretsen manages a nationwide collection and recycling system for E-waste. Although there are two PROs in Sweden, El-Kretsen almost undertakes total collection of E-waste. According to Hanna et al. (2015), El-Kretsen has around 1000 collection points, and EÅF only has 126 collection points. Therefore, compared with Norway and Denmark (both of them have more than four PROs in their system), the collaboration become easier for the local authorities.

An obvious characteristic is the efficiency of system. Since there is only one major organization to manage the system, it does not need to spend lots of time on negotiating with another company or organization, and it can make a decision quickly. When a problem occurs, a small number of actors means less waste of time and money.

Another characteristics is that the system is easy to manage for both El-Kretsen and local authorities. Different companies have different management ideas and standards, and conflicts might occur when they have different ideas to the same thing. In this aspect, the cost of management can be reduced by uniform administration.

Then, uniform administration can also help to gain the full economies of scale. This point should be analyzed combining with the situation of Sweden. Sweden is a small market for EEE due to the size of population. Uniform administration means that at least the most of E-waste will be managed in the same system and they can be centralized to any proper disposal site according to cost and convenience without barriers between different managers. It can help to reach the quantity requirement of enjoying the economies of scale in a small market. Therefore, what should be noticed is that for the small country or area, uniform administration might be helpful.

To avoid the limitations come from total uniform administration, according to Swedish Environmental Protection Agency (2009), local authorities can make their own decisions on the basis of their actual conditions in spite of they are operated under the same E-waste

nationwide system. Obviously, this policy give independence to the local authorities on the premise of collecting E-waste from residents as much as possible. The manager of Kretslopp och Vatten also mentioned that different authorities have different situations although they often think in the same way. For example, Gothenburg is a large city and it has five recycling parks, but some small cities might not have recycling parks and they collect E-waste in some other ways rather than recycling park. Which kinds of collection methods they use due to the size of population, geography situation and some other conditions that could influence E-waste collection. And the methods they used to inform the public about E-waste collection and recycling are also different.

Because local authorities know the situation better than PROs, it is an important policy for El-Kretsen since the geographical conditions are diverse and in some northern areas populations are sparser than other large cities like Stockholm and Gothenburg. This management pattern not only is suitable for Sweden, but also provides inspiration to other areas and countries. Therefore, this combination has stronger applicability than standard systems, and it can also be efficient and effective as them.

3. Law and regulations

At European level, the first WEEE Directive (2002/96/EC) in Europe entered into force in February 2003, and it proposed ten categories of E-waste for producers and governments to guide the E-waste collection and recycling. Then, to tackle more and more serious E-waste problem in Europe, a new version of WEEE Directive, 2012/19/EU, became effective on 14th of February in 2014. This Directive covers all aspects of E-waste management's, from the design of electronic equipment to the final disposal of E-waste, and even the information that must be known to users of electronic equipment.

At national level, the new Directive has been implemented into the national legislation in Sweden. It's "Förordningen om producentansvar för elutrustning, 2014:1075" and it entered into force on October 15th in 2014. This national legislation provides some more detailed interpretation to make EU Directive comprehensible and suitable in Sweden.

Due to these two level of legislation, all of activities related to E-waste management have official guidance. For new entrants, they will know what they should do before beginning to sell electronic equipment into Swedish market. For the PROs such as El-Kretsen, they will know how to set the standards of managements and requiring their sub-contractors. For those companies who undertake the specific works like disassembling, the relevant standards in details are presented in these documentation. Undoubtedly, the clear law and regulations make the electronic equipment market become manageable, and confirming the ownership of E-waste become easier. Therefore, for those who want to build a completed E-waste system,

clear and useful law and regulations are the fundament of the whole things.

4. Multiple channels of collection

For reverse logistics process, one of the biggest problems is how to collect the goods from customers. The rate of collection is largely depends on user's intention (Lee and Sundin, 2012). In this case, providing the public with sufficient channels to reduce people's cost of actions is necessary. In this aspects, as a nationwide collection and recycling system, Elretur provides users with various collection channels to recycle E-waste conveniently. Otherwise, people can also hand in their E-waste to the member stores of EÅF. In Gothenburg, the system involves both fixed facilities like recycling parks and flexible facilities such electronic and hazardous waste truck. These multiple channels make it possible for most of people to have access to the E-waste recycling facilities. According to the result of our survey (Figure 12), although local garbage room and recycling park are the main channels, the other approaches still play their roles in process of E-waste collection.

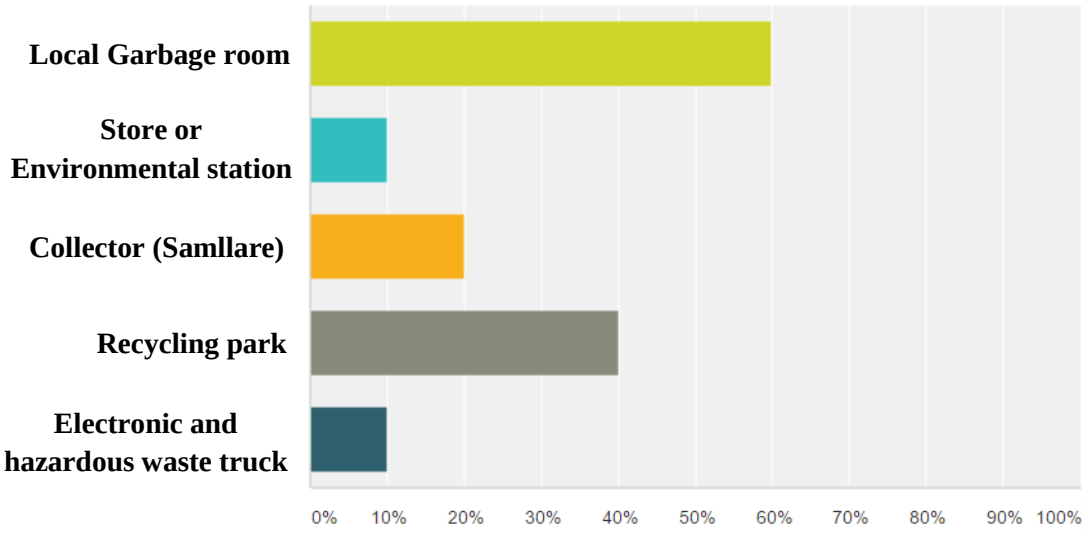

Figure 11. People's preference of different collection approaches

Considering the practices in Gothenburg, these channels work out some tough problems in reality. For some special types of E-waste, for example large household appliances like refrigerator and washing machine, if people are not able to transport them to recycling park by themselves, Kretslopp och vatten can help to collect these E-waste near their home. Besides that, the stores that sell large household appliances also have some relevant services for customers to help them collect these equipment.

For users, multiple channels mean that they can do right things by less cost. People's positive view is the internal reason of recycling E-waste, but convenient facilities could be an external

reason why people choose to do the right thing. In this case, people are more willing to leave the E-waste in correct place and it can help manager reduce much workload which separating the E-waste from general household waste.

In the multiple channels, combining the fixed collection sites with flexible channel can be a good idea, for example, using the electronic and hazardous waste truck. This combination can provide enough mobility while ensuring the stability and reliability of the system. And it can also solve the problem of bulky E-waste as it mentioned above. In regard of cost, unlike general household waste, the frequency of people to produce E-waste is low and the amount is also small if compared with general household waste. Therefore, it's uneconomical for operator to install so many facilities to collect E-waste. In some areas with sparse population, a flexible facility can replace many fixed facilities and it can decrease the fixed cost of facilities.

For other countries or areas, how to arrange the different types of collection channel is also a critical problem. It should combine with the actual factors such as geography, economy and culture, and balance the inputs and outputs. Although flexible trucks seems like a good idea, it might be unnecessary to have them in urban areas with dense population. And for the areas which have many electrical and electronic stores, using these distribution channels as collection channels could also reduce fixed cost.

5. The closed loop in E-waste recycling process

The meaning of collecting and recycling E-waste is not only to prevent the environmental pollution and protect human health, but also to improve the resources utilization and reduce the waste of resource. In this aspect, a closed-loop system in E-waste management is critical. In Sweden, this loop is closed mainly through the re-use of raw materials from E-waste. Sometimes some equipment that is handed in to recycling parks and stores might be put into second-hand market to achieve the recycling. Although some E-waste can be utilized in a more proper way (will discussed in 7.3, second-hand market), the recycling process in Sweden still could be accounted as a completed loop.

However, the problem is that for the whole industry of recycling E-waste, it's risky for companies to do the recycling from an economic standpoint. Specifically, El-Kretsen is a non-profit organization which is established for promoting the development of E-waste management in Sweden and achieving the closed loop is one of its goals. But things are different for profitable companies and it might be difficult for them to close the loop. The first reason is that, for those companies which aim at making profit, the motivation for them to recycle E-waste is insufficient. And then according to Guide et al. (2003), no matter how managers work hard on them, some of these sustainable solutions for reverse logistics will

never be profitable. In this case, relying on companies themselves to undertake the recycling work is unreliable, and government has to take some actions to help to close the loop and let E-waste comes back to market again.

Enacting relevant legislation and regulation is a critical way for government. If there has mandatory regulations for companies, in most cases they will obey these regulations. However, it might have negative impact if the cost for companies is too heavy. Big companies could form an economy of scale to reduce the cost, but for small companies they might not pay the cost of taking back their produces (Spicer and Johnson, 2004). Lawmakers should be cautious to make law and regulations like that to avoid seriously damaging the company's interests.

Therefore, according to the practice in Sweden, establishing a centralized, non-profit organization to control the whole process can be a good solution. But it does not mean only non-profit or one centralized organization can handle it. As it mentioned before, PRO can be profit or nonprofit, and there can be several PROs which have similar business scale in one countries, such as Norway and Denmark (Hanna et al, 2015). The key point is that the business pattern should be suitable for the condition of target area or country.

7.3 Limitations in the practice

Although there is a general consensus in the literature that the regulatory framework that is currently governing waste management in Sweden is one of the best in the world, there still are some gaps between users' requirement and services provided by E-waste collection system. In this section, the results come from both documentations and users in Gothenburg will be discussed.

1. Lack of a formal second-market of E-waste

To form a closed loop in E-waste industry, there are two possible approaches. The first one is what Sweden uses now (using raw materials from E-waste). Though using raw materials could be one of these methods, it is not the optimization and there is another way for operators to achieve closed loop by refurbishing old equipment and putting them on the second-hand market. In five stages of reverse logistics, the fourth and five stages include disassembly and refurbishment the equipment then selling them to customers. They also suggest the possibility to close this loop by this way.

Though refurbishing the old electronic equipment can be an important stage in the process of E-waste recycling, according to Ylä-Mella et al (2014), there is still no centrally managed or formal second-hand market for the returned goods that are collected by the two agencies

responsible for goods recovery. Many individuals do return functioning products (and indeed, many of the 550 of the country's recycling centres identified by Ylä-Mella et al (2014) have special areas where individuals can return such goods). Therefore, there is the potential for these goods to be sold on to new users. However, more often than not, these goods are disassembled, and the components repurposed elsewhere. This may be suboptimal, and indeed, there is evidence to suggest that facilitating the resale of such goods may in fact be more cost effective and have less of a detrimental impact on the environment (MacLeod and Cherrett, 2014). Therefore, when considering the improvement of E-waste reverse logistics, selling the refurbished equipment on second-hand market can also be a more effective way.

Our researches also found some evidences about this problem. In our observation survey, when people leave E-waste to recycling parks, they will be asked if their equipment is still in service. If the answer is yes, they will tell people that they could put their equipment in other spot and these equipment will enter the second-hand market which is very small and only in recycling park. However, for the equipment that is handed in electronic stores, according to the manager, there is no second-hand market.

For the small second-hand market in recycling parks, they use a simple and useful way to check the equipment when the equipment are household appliances such as fridge and lamp. However, there might have some privacy issues when the E-waste are smart phone or computer. Some professional approaches should be taken before put them on the second-hand market. And also for those equipment which is badly damaged but still has potential to be repaired, they need some procedures before entering second-hand market. From perspective of reverse logistics, in the second stage when E-waste is sorted, the relevant procedures to identify the equipment which is potential to be refurbished should be taken.

Specifically, one method is that simple examining approaches can be carried out in stores and recycling park which have staffs there. Another way is that these examinations could also happen after E-waste has been shifted from the local authorities or member stores to PROs. Then PROs (El-Kretsen and EÅF) could bear this responsibility (checking by themselves or outsourcing this procedure) to increase the resource utilization and reduce environmental impact.

2. People's further understanding of E-waste

According to the interview, sometimes people might make some mistakes when they separated different types of E-waste although they are willing to do the right thing about recycling E-waste in Gothenburg. People treated some types of E-waste as general household waste and staff have to collect them out artificially.

In response to this, three questions are related to this in our questionnaire. In all of our responses, 70% responses selected that they know what E-waste is, and 87% responses said they have ever recycled E-waste. This fact means most of university students think they have basic knowledge about E-waste. After that, respondents were asked to select out the E-waste in given options. Since we aimed at exploring if customers can recognize those atypical E-waste, three options were provided and they are light bulb, battery and shoes with light. The result is that around 80% respondents selected battery, half of them selected light bulb and only 40% respondents thought shoes with light should be grouped into E-waste.

However, the three options which were provided are all E-waste. There are 70% respondents believe they know what E-waste is, but only 30% of them selected three options correctly. Though our respondents are well-educated, the results show that they still lack further knowledge of E-waste. In our interview, our interviewee also mentioned one thing they have to do is to inform the public some knowledge about E-waste. Kretslopp och vatten get paid from El-Kretsen and one of their duty is educate people how to do the right thing.

Therefore, the situation is that people have a sense of recycling the E-waste but they still need further information about E-waste to guide them to recycle them properly. For the local authorities such as Kretslopp och vatten, since they undertake the responsibility of informing people how to recycle E-waste correctly, they have responsibilities to take more actions about that.

3. Clearer classification of E-waste

According to Lee and Sundin (2012), El-Kretsen pointed out that the classification used currently is too generic. From practical point of view, different resources need different treatments. It will be more efficient if the products with similar resources can be sorted into the same category. For relevant staffs, this classification could be more instructive.

Another problem about classification is new products. Kretslopp och vatten pointed out that some new products are difficult to be classified, such as children's shoes with light. People often treat them as general household waste but they often have to pick them out from other types of waste. Therefore, these new products should to be defined more clearly to reduce the confusion during the collecting and sorting. For instance, clear labels about "E-waste" on products to remind people they should be sorted into E-waste category.

4. Specific collection dustbin in garbage room

In Sweden, as it mentioned before, there are some garbage room near apartments and communities for people to leave their household waste. In these garbage rooms, the waste can

be separated initially by people themselves.

There is no doubt that it's the most convenient way since people do not need to drive and spent too much time on accessing to them. In our survey, almost all respondents who said there has a garbage can for E-waste in their garbage room selected "local garbage room" in the question "which options have you ever used for recycling E-waste". It shows a high relevance between them and means that people are more willing to leave E-waste in their garbage room if they can. And in the interview, our interviewee also referred to that they are trying to put some boxes in garbage rooms but they have to negotiate with house companies due to the reasons of cost and spaces..

Based on the results of our survey, 55% respondents said there are garbage can for E-waste in their garbage rooms, and the rest chose "No" in this question. It shows that although Kretslopp och vatten has realized this problem, they still have to continue working hard on it.

What should be noticed is that the situation of collection channels in different municipalities are different. In Gothenburg this limitation is identified, but maybe other local authorities do well in this aspect. Therefore it is not certainly to be a problem for Sweden, and this problem need to be investigated in other cities.

5. Financial risk for El-Kretsen

El-Kretsen and EÅF use different methods of financial guarantee. According to website of Elektronikåtervinning (Ny producent page), to achieve the financial guarantee, the members of EÅF use insurances and every product is insured individually. It means that producer only need to guarantee for their own products.

Different from EÅF, El-Kretsen select a collective financing solution. El-Kretsen set aside funds for at least one year to operate the system. In this process, the cost is evaluated from two aspects: cost of historical E-waste is calculated by their current market share, and new products is evaluated by the time they are expected to become E-waste (Hanna et al, 2015). Because El-Kretsen do not recognize the producer of E-waste when they collect them, therefore, in this pattern producers might take the risk that paying for the E-waste which is not produced by them. If this risk is too high for producers to take, they might stay out of the market or choose another PRO. Therefore, there exist financial risk for El-Kretsen and this risk should be considered into its management.

8 Conclusion and future direction

In this section, the results of this thesis will be summarized and some limits will be presented in part 8.1 and 8.2. After these, according to our researches, some potential extension which can be done in future are also provide in 8.3.

8.1 Contribution

In this thesis, we examined a wide range of previous researches about E-waste collection and recycling system in Sweden. Besides reviewing the literature, a case study about the collection system in Gothenburg was also conducted to get more information in practice.

To be specifically about the case study, a deep interview to the local authorities Kretslopp och vatten and a short interview to a store manager were done and we also did a observation survey about a recycling park to know how it works to collect and sort E-waste. To find out the gap between users' requirement and what operators provide, a small survey to University students in Gothenburg was conducted and we collected some information based on the results of interviews and literature review.

According to the result of case study in Gothenburg, the collection system is convenient for users in Gothenburg. Five different channels for residents to hand in their E-waste in Gothenburg were described in details to make the operational process of the system more clearly. Although in different municipalities, collection channels might be a little different, the situation in Gothenburg still could be helpful for those who want to know municipal collection sites in detail.

Then, combining the theoretical framework, Swedish system is identified as a centralized reverse supply chain and uses the pooled takeback approach. The features of Swedish system were discussed and advantages and disadvantages were pointed out. Then, some insights from Swedish system were grouped into five different categories. They could provide inspirations to other countries or areas.

In 7.3, five limitations were identified combining with our own researches and some previous studies (which were mentioned in 7.3). For some limitations, we presented simple directions of improving the situation. However, the specific solutions are difficult to propose because they need more information and investigations about the current system. But these limitations which pointed out in this thesis still can provide PROs with several improvement directions.

8.2 Limitations

Due to the reasons of time and our abilities, there still have some limitations in this thesis, and they are listed as following:

1. The range of our survey about the users of E-waste collection system is too limited. We only focus on the group of University students, but they cannot represent all people in Gothenburg. On the one hand, since they are well-educated, it's more possible for them to have further knowledge about E-waste. On the other hand, they might have less experience of recycling E-waste compared with their parents and other older people. Therefore, the results of this survey might have a gap with the real situation.

2. Without interviewing the managers of El-Kretsen, the first hand materials of El-Kretsen are lacking. All information in details about El-Kretsen is based on previous studies and the website of El-Kretsen. The first problem is that it's difficult to verify the reliability of these information. El-Kretsen might suppress some negative information about their operation and exaggerate the positive aspects. Another problem is that sometimes these second-hand information cannot answer all the question, and the research have to be limited in a certain range due to lacking of materials.

3. Plenty of materials about E-waste in Sweden is in Swedish, especially for the website of EÅF. In this condition, to understand the texts, we used google translate to understand the content of these materials. However, it might bring risks of misunderstanding due to the poor translations. Besides, it's difficult to find out the useful information so that some important texts might be neglected.

8.3 Future directions

During the process of carrying on this research, we found some points which have potential to do some further studies.

1. The pattern of collection and recycling the E-waste in Sweden might have more potential to be applied in some states that government has more control such as China. As we mentioned before, El-Kretsen collects more than 90% E-waste in Sweden. In the country with a powerful government, such a non-profit centralized organization can be established more easily by government. Therefore, current situation in Sweden could provide some guidance and experience.

2. Due to cost and space problem, it has made a slow progress of implementing the

specific garbage bin to collect E-waste in local garbage rooms in Gothenburg. Therefore, some new schemes could be discussed such as setting up one E-waste bin for two or more adjacent apartments. It might involve some logistics problems such as location problem, and can be solved with operations research approaches and relevant software.

3. Lacking a formal second-hand market for the EEEs which are refurbished by those old equipment can be a problem in Sweden. Consistent with that, some researches can be carried out to explore the possibility of establishing a formal second-hand E-waste market. For example, how to combine this market with existing PROs and El-waste collection system in Sweden.

References

Achillas, C., Aidonis, D., Vlachokostas, C., Moussiopoulos, N., Banias, G. and Triantafillou, D., 2012. A multi-objective decision-making model to select waste electrical and electronic equipment transportation media. Resources, Conservation and Recycling, 66, pp.76-84.

Almeida, C.M.V.B., Rodrigues, A.J.M., Bonilla, S.H. and Giannetti, B.F., 2010. Emergy as a tool for Ecodesign: evaluating materials selection for beverage packages in Brazil. Journal of Cleaner Production, 18(1), pp.32-43.

Alumur, S.A., Nickel, S., Saldanha-da-Gama, F. and Verter, V., 2012. Multi-period reverse logistics network design. European Journal of Operational Research, 220(1), pp.67-78.

Aras, N., Boyaci, T. and Verter, V., 2010. Designing the reverse logistics network (pp. 67-98). Auerbach Publications.

Atasu, A., Van Wassenhove, L.N. and Sarvary, M., 2009. Efficient Take‐Back Legislation. Production and Operations Management, 18(3), pp.243-258.

Avfall Sverige. 2017. Avfall Sverige – the Swedish Waste Management Association http://www.avfallsverige.se/in-english/ (Accessed May 1, 2017)

Babu, B.R., Parande, A.K. and Basha, C.A., 2007. Electrical and electronic waste: a global environmental problem. Waste Management & Research, 25(4), pp.307-318.

Balde, C.P., Kuehr, R., Blumenthal, K., Fondeur Gill, S., Kern, M., Micheli, P., Magpantay, E. and Huisman, J., 2015. E-waste statistics-Guidelines on classification, reporting and indicators", United Nations University, IAS-SCYCLE, Bonn (Germany) 2015, 51 pages (ISBN Print: 978-92-808-4553-2)(with CP Balde, K. Blumenthal, S. Fondeur Gill, M. Kern, P. Micheli, E.

Baldé, C.P., Wang, F., Kuehr, R. and Huisman, J., 2014. The global e-waste monitor. UNU-IAS: Bonn, Germany.

Baxter, P. and Jack, S., 2008. Qualitative case study methodology: Study design and implementation for novice researchers. The qualitative report, 13(4), pp.544-559.

Betts, K., 2008. Producing usable materials from e-waste.

Blackburn, J.D., Guide, V.D.R., Souza, G.C. and Van Wassenhove, L.N., 2004. Reverse supply chains for commercial returns. California management review, 46(2), pp.6-22.

Brunner, P.H. and Rechberger, H., 2015. Waste to energy–key element for sustainable waste management. Waste management, 37, pp.3-12.

McKinnon, A., Browne, M., Whiteing, A. and Piecyk, M. eds., 2015. Green logistics: Improving the environmental sustainability of logistics. Kogan Page Publishers.
De Brito, M.P., Dekker, R. and Flapper, S.D.P., 2005. Reverse logistics: a review of case studies. In Distribution Logistics (pp. 243-281). Springer Berlin Heidelberg.

De Brito, M.P. and Dekker, R., 2004. A framework for reverse logistics (pp. 3-27). Springer Berlin Heidelberg.

Directive, E.U., 2002. Directive 2002/96/EC of the European Parliament and of the Council of Jan. 27, 2003 on Waste Electrical and Electronic Equipment. Official Journal of the European Union L, 37.

Directive EU. Directive 2003/108/EC of the European parliament and of the council of 8 December 2003 amending Directive 2002/96/EC on waste electrical and electronic equipment (WEEE)[J]. Official Journal of the European Communities, L, 2003, 345(31):

Directive EC. Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment, WEEE[J]. Official Journal of the European Union L, 2012, 197: 38-71.

El-Kretsen. 2009. Sweden-world leader in electric and electronic waste collection. http://www.avfallsverige.se/fileadmin/uploads/elretur_eng.pdf (Accessed February 25, 2017)

Elektronikåtervinning i Sverige. 2017. Consumer. http://en.elektronikatervinning.com/consumer/ (Accessed May 1, 2017)

Elektronikåtervinning i Sverige. 2017. Ny producent. http://elektronikatervinning.com/producentansvar/ny-producent/ (Accessed May 1, 2017)

Goggin, K. and Browne, J., 2000. Towards a taxonomy of resource recovery from end-of-life products. Computers in Industry, 42(2), pp.177-191.

Goodship, V. and Stevels, A. eds., 2012. Waste electrical and electronic equipment (WEEE) handbook. Elsevier.

Grant, K., Goldizen, F.C., Sly, P.D., Brune, M.N., Neira, M., van den Berg, M. and Norman, R.E., 2013. Health consequences of exposure to e-waste: a systematic review. The Lancet Global Health, 1(6), pp.e350-e361.

Guide Jr, V.D.R. and Van Wassenhove, L.N., 2002. The reverse supply chain. Harvard business review, 80(2), pp.25-26.

Guide Jr, V.D.R. and Van Wassenhove, L.N., 2009. OR FORUM—The evolution of closed-loop supply chain research. Operations research, 57(1), pp.10-18.

Gui, L., Atasu, A., Ergun, Ö. and Toktay, L.B., 2015. Efficient implementation of collective extended producer responsibility legislation. Management Science, 62(4), pp.1098-1123.
Gupt, Y. and Sahay, S., 2015. Review of extended producer responsibility: A case study approach. Waste Management & Research, 33(7), pp.595-611.

Halldórsson, A.R.N.I. and Skjøtt-Larsen, T., 2007. Design of reverse supply chains: centralized or decentralized structure. Managing Supply Chains: Challenges and opportunities, pp.1-26.

Hanna, L., Linea K. I., Hanne, L, R., & Anna, F. 2015. WEEE system setup: a comparison of Sweden, Norway and Denmark. Swedish Environmental Research Institute.

Heacock, M., Kelly, C.B., Asante, K.A., Birnbaum, L.S., Bergman, Å.L., Bruné, M.N., Buka, I., Carpenter, D.O., Chen, A., Huo, X. and Kamel, M., 2016. E-Waste and Harm to Vulnerable Populations: A Growing Global Problem. Environmental health perspectives, 124(5), pp.550-555.

Huo, X., Peng, L., Xu, X., Zheng, L., Qiu, B., Qi, Z., Zhang, B., Han, D. and Piao, Z., 2007. Elevated blood lead levels of children in Guiyu, an electronic waste recycling town in China. Environmental Health Perspectives, pp.1113-1117.

Jamshidi, M. 2011. Reverse logistics. In Farahani, Z. (Ed.) Logistics Operations and Management: Concepts and Models.

Janse, B., Schuur, P. and de Brito, M.P., 2010. A reverse logistics diagnostic tool: the case of the consumer electronics industry. The International Journal of Advanced Manufacturing Technology, 47(5), pp.495-513.

Jayaraman, V. and Luo, Y., 2007. Creating competitive advantages through new value

creation: a reverse logistics perspective. The Academy of Management Perspectives, 21(2), pp.56-73.

Guide, V.D.R., Harrison, T.P. and Van Wassenhove, L.N., 2003. The challenge of closed-loop supply chains. Interfaces, 33(6), pp.3-6.

Kaynak, R., Koçoğlu, İ. and Akgün, A.E., 2014. The role of reverse logistics in the concept of logistics centers. Procedia-Social and Behavioral Sciences, 109, pp.438-442.

Khan, S.S., Lodhi, S.A., Akhtar, F. and Khokar, I., 2014. Challenges of waste of electric and electronic equipment (WEEE): Toward a better management in a global scenario. Management of Environmental Quality: An International Journal, 25(2), pp.166-185.

Kibert, N.C., 2004. Extended producer responsibility: a tool for achieving sustainable development. Journal of Land Use & Environmental Law, 19(2), pp.503-523.

Kiddee, P., Naidu, R. and Wong, M.H., 2013. Electronic waste management approaches: An overview. Waste Management, 33(5), pp.1237-1250.

Lee, H.M. and Sundin, E., 2012, May. The Swedish WEEE system—challenges and recommendations. In Sustainable Systems and Technology (ISSST), 2012 IEEE International Symposium on (pp. 1-6). IEEE.

Lifset, R.J., 1993. Take it back: extended producer responsibility as a form of incentive-based environmental policy. Journal of Resource Management and Technology, 21, pp.163-163.

Link, T., 2012. Empa,"Improving plastic management in Delhi. A report on WEEE plastic recycling," Delhi, India.

Li, R.C. and Tee, T.J.C., 2012. A reverse logistics model for recovery options of e-waste considering the integration of the formal and informal waste sectors. Procedia-Social and Behavioral Sciences, 40, pp.788-816.

Liu, X., Tanaka, M. and Matsui, Y., 2006. Electrical and electronic waste management in China: progress and the barriers to overcome. Waste Management & Research, 24(1), pp.92-101.

Mayers, C.K., 2007. Strategic, financial, and design implications of extended producer responsibility in Europe: a producer case study. Journal of Industrial Ecology, 11(3), pp.113-131.

McLeod, F., & Cherrett, T. 2014. Reverse logistics for sustainable waste management processes. In Information Resources Management Association (Ed.) Sustainable Practices: Concepts, Methodologies, Tools, and Applications (pp. 1505-1518). Hershey, PA: IGI Global.

Migliano, J.E.B., Demajorovic, J. and Xavier, L.H., 2014. Shared responsibility and reverse logistics systems for e-waste in Brazil. JOSCM: Journal of Operations and Supply Chain Management, 7(2), p.91.

Morf, L.S., Tremp, J., Gloor, R., Schuppisser, F., Stengele, M. and Taverna, R., 2007. Metals, non-metals and PCB in electrical and electronic waste–Actual levels in Switzerland. Waste Management, 27(10), pp.1306-1316.

OECD. Publishing, 2001. Extended Producer Responsibility: A Guidance Manual for Governments. Organisation for Economic Co-operation and Development.

Ongondo, F.O., Williams, I.D. and Cherrett, T.J., 2011. How are WEEE doing? A global review of the management of electrical and electronic wastes. Waste management, 31(4), pp.714-730.

Patrício, J., Kalmykova, Y., Berg, P.E., Rosado, L. and Åberg, H., 2015. Primary and secondary battery consumption trends in Sweden 1996–2013: Method development and detailed accounting by battery type. Waste Management, 39, pp.236-245.

Pérez-Belis, V., Bovea, M.D. and Ibáñez-Forés, V., 2015. An in-depth literature review of the waste electrical and electronic equipment context: Trends and evolution. Waste Management & Research, 33(1), pp.3-29.

Robinson, B.H., 2009. E-waste: an assessment of global production and environmental impacts. Science of the total environment, 408(2), pp.183-191.

Salhofer, S., Steuer, B., Ramusch, R. and Beigl, P., 2016. WEEE management in Europe and China–A comparison. Waste Management, 57, pp.27-35.

Selin, H. and VanDeveer, S.D., 2006. Raising global standards: hazardous substances and e-waste management in the European Union. Environment: Science and Policy for Sustainable Development, 48(10), pp.6-18.

Sinha, D., 2004. The management of electronic waste: a comparative study on India and Switzerland. St. Gallen7 University of St. Gallen.

Sodhi, M.S. and Reimer, B., 2001. Models for recycling electronics end-of-life products. OR spectrum, 23(1), pp.97-115.

Solvang, W.D. and Hakam, M.H., 2010. Sustainable logistics networks in sparsely populated areas. Journal of service science and management, 3(01), p.72.

Spicer, A.J. and Johnson, M.R., 2004. Third-party demanufacturing as a solution for extended producer responsibility. Journal of Cleaner Production, 12(1), pp.37-45.

Avfall Sverige. (2014). Swedish waste management 2014. Malmö: Avfall Sverige. http://www.avfallsverige.se/fileadmin/uploads/Rapporter/sah_2014_Eng_141001.pdf (Accessed April 27, 2017)

Swedish Environmental Protection Agency. 2009. WEEE Directive in Sweden: Evaluation with Future Study. http://www.swedishepa.se/ (Accessed May 3, 2017)

Tibben-Lembke, R.S. and Rogers, D.S., 2002. Differences between forward and reverse logistics in a retail environment. Supply Chain Management: An International Journal, 7(5), pp.271-282.

United States Environmental Protection Agency (US EPA), 2015. Advancing Sustainable Materials Management: Facts and Figures 2013.

Veiga, M.M., 2013. Analysis of efficiency of waste reverse logistics for recycling. Waste Management & Research, 31(10_suppl), pp.26-34.

Vlachos, I.P., 2016. Reverse logistics capabilities and firm performance: the mediating role of business strategy. International Journal of Logistics Research and Applications, 19(5), pp.424-442.

Wang, F., Huisman, J., Baldé, K. and Stevels, A., 2012. A systematic and compatible classification of WEEE (pp. 1-6). IEEE.

WEEE Registration. WEEE Registration in Sweden http://www.weeeregistration.com/weee-registration/sweden.html Accessed 6 February 2017 (Accessed February 27, 2017)

Widmer, R., Oswald-Krapf, H., Sinha-Khetriwal, D., Schnellmann, M. and Böni, H., 2005. Global perspectives on e-waste. Environmental impact assessment review, 25(5), pp.436-458.

Yin, R.K., 2013. Case study research: Design and methods. Sage publications.

Ylä-Mella, J., Poikela, K., Lehtinen, U., Tanskanen, P., Román, E., Keiski, R.L. and Pongrácz, E., 2014. Overview of the WEEE Directive and its implementation in the Nordic countries: national realisations and best practices. Journal of Waste Management, 2014.

Zeng, X., Yang, C., Chiang, J.F. and Li, J., 2017. Innovating e-waste management: From macroscopic to microscopic scales. Science of the Total Environment, 575, pp.1-5.

Zheng, G.J., Leung, A.O., Jiao, L.P. and Wong, M.H., 2008. Polychlorinated dibenzo-p-dioxins and dibenzofurans pollution in China: sources, environmental levels and potential human health impacts. Environment International, 34(7), pp.1050-1061.

APPENDIX A

Interview summaries

Date: 20th April, 2017
Place: Kretslopp och Vatten in Gothenburg
Interviewee: Åsa Tärnström (Process manager of hazardous waste)

A brief introduction about the E-waste section in their work:

We are collecting electrical equipment in different waste in recycle parks and that's most of electrical equipment is collected. we have also samlare, which is container that residents could use to recycle their electronic and electrical waste in different parts of the city.

Collection at recycle parks are in collaboration with El-Kretsen. The other kind of collection we have hazardous waste truck and environmental stations we use these to give the opportunity to people of Gothenburg to have different kind of ways to leave their electrical equipment. But the recycling park is the main collector of electrical waste.

Environmental stations are use to collect electrical equipments, chemicals, and other hazardous waste. The size of the environmental stations are 10 feet in size. We are located these stations in 6 different gas station in Gothenburg plus in small harbors where there are small boats.

Samlare which translated to collector are placed in different grocery stores in Gothenburg so that residents can leave their small electronics waste such as toothbrush, light bulbs, chargers and Batteries and etc.

The other option which is available for residents to dispose their electronic and Hazardous waste in Gothenburg is conducted by a truck which is going around the town to different neighborhood's according to their schedule with 450 stops. There are two trucks that stops in three different places every day and they go around four times a week. Half of the waste that is collected by these trucks are electronic waste. Which shows that people are aware of the importance of recycling of these waste in a proper way.These trucks let the people who don't have personal vehicles the chance to dispose their WEEE and Hazardous waste in a proper and efficient way.

We also trying to implement boxes to collect electronic waste for households at their garbage rooms as well since two years ago. Kretslopp och Vatten started to inform and try to have dialogue with different housing companies such as Poseidon to convince them to allocate

some space in the garbage rooms of their apartments to collect electronic waste.

Questions:

Some questions are asked because she sent to us a report about their work.

1. Do you think the current method of WEEE classification is easy to apply?

It is a very interesting question when the law was written we only had like television and refrigerators and other big electronic equipment's, therefore it was easy for us to recognise what is electronic equipments. But nowadays, we have shoes with lights implemented inside them which make them electronic equipments. The led technology let us to use and put electronic devices in almost every product. However, people don't think of these product such as shoes as an electronic product but they are electronic equipment's therefore the classification has to be improved and changed.

2. There are many areas in Sweden which are managed by different municipalities, so when you want to carry out some policies, do they act in the same way or different ways?

I would say that municipality often think in the same way. Because we think it should not depend on where you live electrical waste such as light bulb is the same in every location. Therefore, we have kind of agreement between all municipality and El-kretsen is clear how it will work the system. The system that we have for the collection of the waste in Gothenburg city is quite similar to the rest of municipalities in Sweden.

3. What's does the "WEEE from private households from businesses" mean? We don't really understand about the difference between that and "WEEE from private households from households"?

Kretslopp och Vatten has the responsibility for the household's waste. If you have small business like one or two persons and you want to dispose your electrical waste through our recycling parks are possible. However, if Volvo or bigger firms they have contract themselves with waste companies to manage their waste.

Every store that sales battery and light bulbs for example the have to collect the same amount electrical waste that they have been sold to their customers. And most of these kind of stores have agreement with El-kretsen or Elektronikåtervinningsföreningen which is the other system that collects electronics.

4. The report says some other actors are also involved in the collection of WEEE from

private households from businesses, so what are those actor?

We have to act that are approved by environmental agency in Sweden. That's Elektronikåtervinningsföreningen and they have collaboration with El-Kretsen.

5. What does the "municipal collection points" mean?

We have five different collections points in our municipality and in smaller municipality have only recycling parks.

6. For different type of WEEE, for example, some are too large and heavy to transport by customers themselves like refrigerators, so how to collect such special WEEEs?

Most part of the refrigerators are transported individually by people to recycling parks. However, we can collect them at the households however they needed to put them in the street first and then we can send our trucks to pick it up for them. Many stores that sell refrigerators they also have some strategy for collecting and recycling the product after its life cycle.

7. Who take the responsibility of Gatekeeper (testing the value of E-waste) and decide how to dispose these E-waste (to landfill or incinerate)?

We do not do any treatments. El-Kretsen takes responsibility for that. However, we ask people who bring their electronic waste to recycling parks if their products still working, and if they say yes we tell them that we could put them in different spot in recycling parks so therefore it will be on the second market. We cannot force people to sell their electrical waste to the second market if they don't want because of personal reasons. However, what we could do is to try to inform people to use their devices for longer. And there's no need to change your mobile phone every year. In this way we could improve our resident's behaviour in regards to usage of their products and environmental aspects of their product.

8. Does Kretslopp och Vatten get paid from El-Kretsen?

Yes, we get paid from El-Kretsen per kilograms we collect. The payment includes, for example, the work the staff do with sorting and answering questions from customers.

9. How many times does El-Kretsen pick up the E-waste from recycling park monthly? (This question is asked through e-mail.)

It's hard to say how many times the pick up waste from the recycling parks. Its depends of the

size of the parks and the quantity that people leave to us. And they pick up different things at different times. In the chart below you can see what was collected from Kretsloppsparken (the place we visited) during March.

Miscellaneous E-waste, Fluorescent, Light Bulbs, Battery = units of cages not kilograms.

Recycling parks name	Fraction	Date of pick up	Units
Kretsloppsparken Alelyckan	Miscellaneous E-waste	2017-03-01	15
Kretsloppsparken Alelyckan	Fridge and Freezer	2017-03-06	109
Kretsloppsparken Alelyckan	Miscellaneous E-waste	2017-03-06	13
Kretsloppsparken Alelyckan	White Goods	2017-03-08	53
Kretsloppsparken Alelyckan	Miscellaneous E-waste	2017-03-13	16
Kretsloppsparken Alelyckan	Miscellaneous E-waste	2017-03-17	12
Kretsloppsparken Alelyckan	Battery	2017-03-21	3
Kretsloppsparken Alelyckan	Miscellaneous E-waste	2017-03-21	8
Kretsloppsparken Alelyckan	White Goods	2017-03-22	86
Kretsloppsparken Alelyckan	Fridge and Freezer	2017-03-27	101
Kretsloppsparken Alelyckan	Miscellaneous E-waste	2017-03-27	21
Kretsloppsparken Alelyckan	Fluorescent	2017-03-30	1
Kretsloppsparken Alelyckan	Light Bulbs (fd. GL+LE)	2017-03-30	1

APPENDIX B

Interview with Clas Ohlson

1. Does your store have agreement with El-kretsen or EAF to help them collect old electronic equipment?

We have a contract with El-kretsen. Usually after we collect enough electronic waste we call them and arrange time for collection of them.

2. Which type of electronic equipment does your store collect? (phone, computer or some other things?)

Everything that we sell in our store is recyclable through our stores and El-kretsen do the collection.

3. How many people give their equipment to your store monthly and do you think the system of E-Waste Management is efficient?

The law in Sweden says if you buy some electronic products you should recycle those product thorough proper channels. I think people in Sweden use Electronic Waste System properly. They dispose their E-waste appropriately. Therefore, I think the system is quite efficient.

4. Does your store have any incentive to encourage people recycle their equipment?

Yes.

5. Does your store do any inspection to decide if an equipment can be putted on the second-hand market? What will happen to the E-waste after they are handed in your store?

We don’t have secondhand market for used products. El-kretsen does the collection and we do not know how the after process is working.

6. Do you have any suggestion to El-Kretsen or EAF? Or have you ever run into problem when you do this work?

No I don’t have any suggestions. We have a good relationships with them and we use their services quite extensively and it works really good.