Recycling E-waste
Not a-waste of time

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Preface

This paper has been written to fulfil the succeeding requirements for the module Academic Skills for the premaster IEM at the University of Twente. The research is carried out in the second quartile of the premaster.

We would like to thank the collaborating companies De Beurs and Twente milieu for giving us the opportunity to carry out this project. We also wish to thank our lecturer dr.ir. Sandor Löwik for the proper feedback.

We hope you enjoy your reading.

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Management summary

--Dutch below--
Twente Milieu and De Beurs have concluded to join hands to address the problem of E-waste in the region Twente. Twente Milieu is responsible for the disposal of waste in the main part of Twente. De Beurs is focused on reviving waste and selling it in their thrift shop. The volume of E-waste is growing and both companies are looking for possibilities to get more value out of the E-waste. This would be an opportunity to offer more jobs for social workers and is a good step to reduce the environmental impact of the region Twente.

Students of the study Industrial Engineering Management have researched the possibilities to get more value out of E-waste. At first, the core problem is determined. It was clear that a lack of space is the biggest threshold to get closer to the companies' vision. This problem is not only easily resolved, but several other problems relate to this core problem. The scope of the research is set to the supply chain of E-waste, because solving a problem of space relates to the entire supply chain. To get a closer view on the problem, a literature review is done.

The main outcome of the research was an eight-step model that reflects a supply chain. This model is used to compare the current supply chain with an optimal supply chain, which is based on the vision of the board members of Twente Milieu and De Beurs. The gap between these two chains is reviewed and used as input for designing three concepts. The main points highlighted by this gap were the lack of space, lack of collaboration and need to re-design internal layout. The three concepts differ from where in the supply chain more space will be created; a link before De Beurs, at De Beurs or after De Beurs.

The new design of the supply chain is set up around a central assembling point where De Beurs and Twente Milieu work together. They can combine their flow of E-waste and get an efficient repair and assembling point for all E-waste. At this central assembling point, we can create more employability and social work places. The advantage of a central point is less waste, because at this assembling center there can be more repaired and stored.

Based on the results of our research, we can say that the new supply chain would lead to an improvement of the current situation. The new supply chain would not only mean that the lack of space is past tense, but our solution also has a positive influence on other aspects of the whole process. By investing in the creation of a central assembling point, the problem of the lack of space is immediately resolved. Other advantages are about environmental consciousness, social responsibility, and social employability.

Twente Milieu en De werken samen om de problematiek rondom E-waste in de regio Twente aan te pakken. Twente Milieu is verantwoordelijk voor het verwerken van afval in het overgrote deel van Twente. De Beurs focust zich op het repareren en verkopen van E-waste in hun tweedehandswinkel. Het volume van de E-waste blijft groeien, en beide bedrijven zijn daarom op zoek naar mogelijkheden om meer waarde uit de E-waste te halen. Het is niet alleen een stap in de goede richting met betrekking tot een milieuvriendelijkere samenleving, het is ook een kans om meer banen aan te bieden aan sociale werkers.

Studenten van de opleiding Industrial Engineering and Management hebben onderzoek gedaan naar de mogelijkheden om meer waarde uit E-waste te halen. Als eerste stap is de kern van het probleem bepaald. Het werd snel duidelijk dat ruimtegebrek de grootste drempel was die De Beurs tegenhield om verder te verbeteren met betrekking tot het verwerken van E-waste. Door dit kernprobleem zijn meerdere problemen ontstaan die, met het oplossen van het ruimtegebrek, gelijktijdig worden opgelost. In het onderzoeksgebied beschrijven we wat deze randproblemen inhouden. De oplossing zal bestaan uit het creëren van meer ruimte, waardoor het onderzoeksgebied is gericht op het verbeteren van de supply chain van de E-waste in Twente.

De belangrijkste uitkomst van het onderzoek is gebaseerd op een model dat in acht stappen de supply chain beoordeelt. Aan de hand van dit model is de huidige supply chain vergeleken met de optimale supply chain. Deze optimale supply chain is ontwikkeld op basis van de visie van zowel Twente Milieu als De Beurs. Het ‘gat’ tussen de huidige en optimale situatie is gebruikt als input om drie verschillende concepten te creëren voor een verbeterde supply chain. De belangrijkste factoren die zijn benadrukt in de verbeterde supply chain zijn het ruimtegebrek, gebrek aan samenwerking en het creëren van meer sociale werkgelegenheid. Het verschil tussen de drie concepten is waar in de supply chain meer ruimte wordt gecreëerd: in een schakel voor De Beurs, bij De Beurs en in een schakel na De Beurs.

Het nieuwe design van de supply chain is opgezet rond een centraal verzamelpunt waar De Beurs en Twente Milieu kunnen samenwerken. Op deze manier kunnen zij hun flow van E-waste combineren en zo een efficiëntere reparatie- en verzamelpunt verkrijgen voor al het E-waste. Op dit centraal verzamelpunt kunnen ze meer werkgelegenheid en sociale werkplaatsen creëren. Omdat er meer gerepareerd en opgeslagen kan worden op dit centrale verzamelpunt, zal zo meer afval hergebruikt worden.

Kijkend naar ons onderzoek, kunnen we concluderen dat de nieuwe supply chain leidt een verbetering van de huidige situatie. De nieuwe supply chain betekent niet alleen dat het gebrek aan ruimte verleden tijd is, maar ook dat onze oplossing een positieve invloed heeft op andere aspecten van het proces. Door te investeren in een centraal verzamelpunt zijn problemen opgelost zoals het gebrek aan ruimte en het gebrek aan samenwerking. Andere voordelen zijn een hogere milieuvriendelijkheid, meer sociale verantwoordelijkheid en meer sociale werkgelegenheid.

Structure

This report starts with a short introduction about electronic waste and the collaborating companies (De Beurs and Twente Milieu). Subsequently, the problem around electronic waste and the collaborating companies is identified and the core problem is pointed out after a problem cluster has been made. Finally, the scope of the research is described.

The following chapter consists of the solution planning, starting with the problem solving approach. We describe in this chapter also the research questions, following by the methodology and the deliverables. We end this chapter with the part where we describe how we collected data.

The next chapters are respectively about what a supply chain is, the current supply chain, the supply chain optimization. The sixth chapter describes the new supply chains and the best solution on the basis of previous chapters. In chapter seven we describe how to implement the new supply chain on the basis of theory. We end this report with the conclusion, discussion, recommendations and reflection respectively.

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1. Introduction

In a rapidly developing technical world, more and more devices become a part of our daily lifestyles and we are always yearning for more. A flatter screen TV, a more energy efficient refrigerator, a faster mobile telephone: lots of technical inventions in combination with a growing economy enable us to renew our devices whenever there is an improved product on the market. So many advantages, but what about the old devices we no longer use? You can not just put it in the trash, since it contains hazardous components that may have a negative influence on the environment and human health (Nnorom & Osibanjo, 2008).

When you do not use a device anymore, it becomes electronic waste, from now on written as E-waste. Devices becoming E-waste does not mean they become useless. Many of these products can be reused, refurbished or recycled (Calrecycle, 2016). That is the reason why inhabitants of The Netherlands have the opportunity to hand in E-waste. Collection points where you can hand in E-waste can be for example the Mediamarkt, a store that sells the electronic products, or a collection service where you can hand it in yourself. A well-known collection service in the region Twente is Twente Milieu. Twente Milieu is located in Almelo, Borne, Enschede, Hengelo, Hof van Twente, Losser and Oldenzaal (Twente Milieu, 2016). When the E-waste is still working, people can bring their waste likewise to a thrift store. In Twente there are several thrift stores, a well-known store is De Beurs. De Beurs is located in Oldenzaal, Denekamp, Tubbergen and Losser (Kringloopbedrijf De Beurs, 2014).

This report is written in behalf of University of Twente, De Beurs and Twente Milieu. Collaboration between these three organizations originated after the question of De Beurs and Twente Milieu about how to get more value out of the electronic waste of households in Twente. This question is rather broad, so to specify this, we choose the following question as a starting position of this report:

'*Given a supply of products and available production area, what would be the most efficient layout and logistics at De Beurs?*'

1.1. Problem introduction

In the current situation (figure 1), inhabitants of Twente bring their E-waste to De Beurs or Twente Milieu by themselves or make an appointment to let De Beurs pick up the E-waste from home. Some employees of De Beurs check whether the devices are still working. If so, they can be sold in the thrift shop. If not, there must be decided whether they can be easily repaired so De Beurs can earn money on it. These repairs take place at De Beurs itself. If repairing is not cost effective, the device will be picked up by Omrin. Omrin is a collector and processor of waste, that is located in the north of The Netherlands (Omrin, 2016). The E-waste, which is placed in the shop, is most of the times sold within two days. From this it can be concluded that devices like washing machines and microwaves are popular among customers. At Twente Milieu E-waste is not recycled, but only divided in small or large electronics. This E-waste goes directly to Omrin.

At the moment, on average only one percent of all devices is being repaired and sold at De Beurs. In the ideal situation, more devices should be repaired, so that more devices will be recycled. By doing this, the environment and employability, which are the two focal points of De Beurs, are taken into account. But the problem is a lack of capacity: there is no more space at De Beurs and there is too little knowledge about the process of recycling E-waste. These constraints contribute to the disability of De Beurs to change. In the current situation, too much E-waste ends up at Omrin. This research report is intended to examine how De Beurs can recycle more E-waste.

According to the managing director, the internal layout at De Beurs is fine, so our focus will be on the supply chain of the E-waste. A supply chain is a network of companies and its suppliers to deliver a specific product to the market. The supply chain represents the steps the product or service must take until it is property of the customer (Investopedia, 2017). De Beurs and Twente Milieu are both part of the supply chain of E-waste in the region Twente.

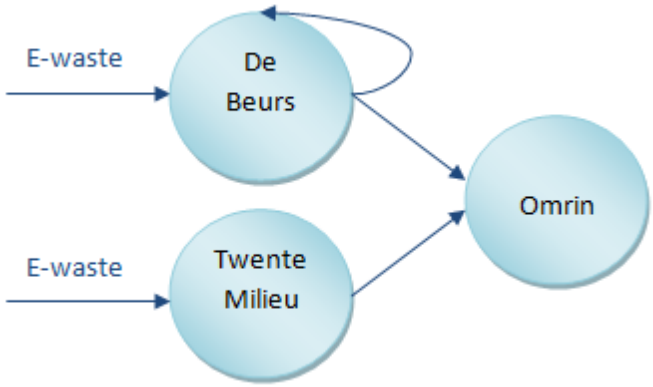


Figure 1: *Current situation of the supply chain of E-waste around De Beurs and Twente Milieu.*

1.2. Problem cluster

According to the managing director, De Beurs should gain more value out of E-waste. In the current situation, De Beurs can't repair all the incoming E-waste and thereby too much E-waste goes directly to Omrin. Since there is a lack of employees with the right knowledge, not all products are tested. This is because the employees are social workers who in general do not have the right education. On the other hand, there are too few employees to repair more devices since the lack of space at De Beurs. This lack of space causes that there are not enough parts in stock to do more repairs.

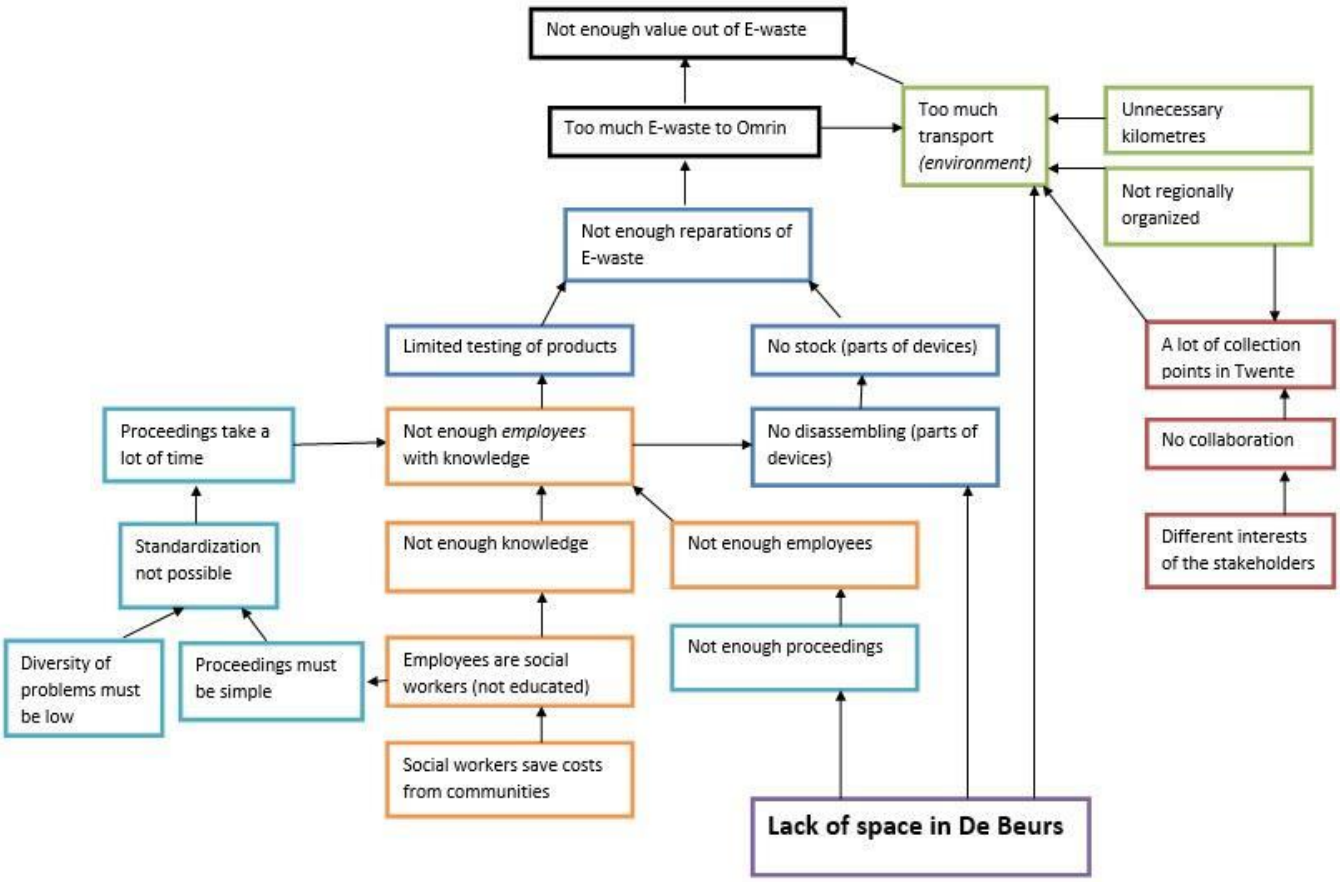


***Figure 2**: The problem cluster*

All relevant problems are clustered in several subjects (figure 2). The black problems are the main problems. It shows that too much E-waste goes to Omrin and De Beurs retrieves not enough value out of E-waste. The green ones are about transport. There are a lot of unnecessary kilometres to Omrin since more E-waste could stay in Twente. The red ones are about the lack of collaboration. The E-waste could be recycled much more efficient if the organizations collaborate more. There are few arrangements between De Beurs, Twente Milieu en Omrin. The dark blue problems are about what is (not) done at De Beurs and the light blue problems about proceedings which must be carried out to repair the devices. The orange boxes are about the employees and their knowledge. The problem cluster also consists of the two focal points of De Beurs, which are the environment (green boxes) and the social employability (orange boxes) respectively. The purple problem is chosen as the core problem of our research: the problem of a lack of space at De Beurs.

1.3. Core problem

De Beurs should gain more value out of E-waste and thereby create more social employability and taking better account of the environment. The problem of the space constraint describes a gap between the norm and reality. In the ideal situation, more value is retrieved out of the E-waste. In this case, the definition of value is more social employability and taking into account of the environment. More value out of the E-waste means that less E-waste goes to Omrin and more devices are repaired and sold in the thrift shop. The reality shows different: at the moment, only one percent of all incoming E-waste at De Beurs is repaired and sold in the thrift shop. One of the reasons for this low percentage of resold devices is a lack of space at De Beurs. In this research, the lack of space is chosen to be the core problem of the current situation at De Beurs. This problem is stated as a major issue for expanding and when solving this problem, one can solve several other causal problems (Heerkens, 2010).

1.4. Scope of the research

As told in section 1.3, the lack of physical space at De Beurs is the core problem. To create more space, several things can be done. The main choice is whether we look at the improvement of internal or external lay-out. In other words, is the layout inside the facility of De Beurs up for a change or does the supply chain of De Beurs has to be redesigned. In this research we are looking at the supply chain of De Beurs. We do this because not only extra space is helpful, but in this case a collaboration with Twente Milieu is easily created. Also the internal layout of De Beurs is already fine, according to the managing director of De Beurs. In the remaining of this research we will look at the internal layout of De Beurs as a black box. The definition of supply chain during this project is the logistic chain of E-waste in the region of De Beurs and Twente milieu. For every link in the chain the activities that take place at a certain location will be described.

By creating more space, the supply chain will change since the space must be made somewhere. For this reason we need to redesign the supply chain. The part of the supply chain which belongs to this research is starting at the households, where electronical devices become E-waste. The E-waste collecting points that are taken into account during this research are the collecting points which are (semi-)property of the government. So, commercial companies who collect E-waste don't belong to the scope of this research. In this case the supply chain ends at the moment the E-waste is transported to Omrin, because from then on, De Beurs and Twente Milieu are no longer involved. This is shown in figure 3.

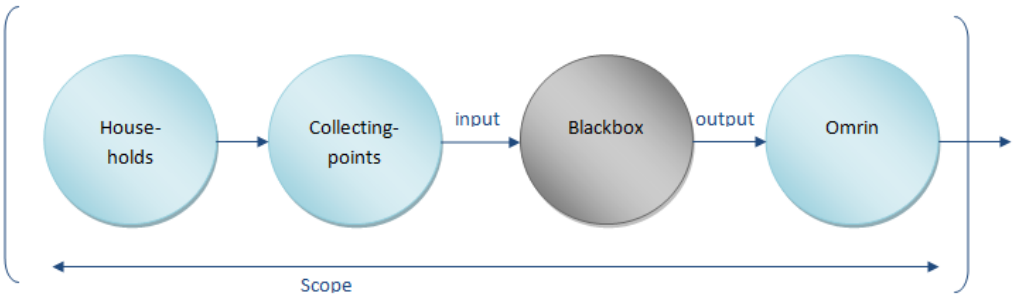


***Figure 3**: Scope of this research*

Furthermore, the lack of knowledge of the employees and the exact way activities should be carried out are no part of this research, because this information is too detailed given the available information and time.

2. Solution Planning

2.1. Problem solving approach

To solve the core problem, a problem solving approach is needed. A problem solving approach describes step by step how to get to a solution. The steps of the approach are corresponding with step 3-7 of the MPSM model (Heerkens, 2010), but more detailed for the problem at hand. As written in the scope of the research, the supply chain has to be improved. To do so, we derived a main question from the core problem. The main question is as follows:

What does a new supply chain of E-waste around De Beurs and Twente Milieu looks like, when more physical space is realized?

In order to give an answer to this main question, we need to follow several steps. From every step, we can formulate a sub research question. The steps for answering the research question are also described, this contains the research methodology.

Supply chain

First we determine the key constructs, and as follows the theory by the key constructs. This is a knowledge problem and can be solved by using scientific articles as background information. To find the right information we formulated the following research question: *1) What is a supply chain?* To answer this question, we will look for a definition, explanations and examples of supply chains. With this information we can get a clear image of a supply chain, and answer the question.

The current supply chain and stakeholders

The current supply chain around Twente Milieu and De Beurs is used as a basis for improvement. The current supply chain can be defined with information from both companies. This results in two research questions: 2) *What is the current supply chain?* 3) *What are the roles of the stakeholders?* With the information retrieved from the visits by Twente Milieu and De Beurs we can describe the current situation of the supply chain. It is interesting to analyse these stakeholders and their influence, to know what their roles are and what interest they have in an improved supply chain. The roles of the stakeholders are important to get a new supply chain that improves the current situation.

The optimal situation

The optimal situation can be described with use of the wishes and demand from Twente Milieu and De Beurs. What is their vision on improvement of the current supply chain? The following research question will be answered to describe the optimal situation: *4) Norm: What is the optimal situation?* We need specific information from De Beurs, Twente Milieu and the stakeholders to answer this question. Because every company has its own interests, it is important to create a situation in which we can satisfy all of the stakeholders.

The gap between norm and reality

To solve the problem statement, the gap between norm and reality needs to be defined. To make the gap between norm and reality smaller, the following steps should be taken:

- Literature review to find solutions used in practice
- Creating several concepts for an improved supply chain
- Proving the created concepts
- Creating a new optimal supply chain
- Reflecting the new supply chain with Twente Milieu and De Beurs
- Writing an implementation plan for the new supply chain.
- Reflecting the plan with Twente Milieu and De Beurs
- Writing a conclusion and recommendations

Out of these steps the following research questions are created.

5. *What are possible solutions for filling this gap between the current- and optimal situation?*
6. *What is the best possible improvement for the supply chain?*
7. *What does the redesigned supply chain look like?*
8. *How can this supply chain be implemented?*

To answer the fifth research question, we apply theory we found about filling gaps between norm and reality. The sixth question follows out of the previous questions and information. The seventh question is about the redesigned supply chain; here we will show what the new optimal supply chain looks like. To answer the last question, we will look for theories in the area of change management and how these theories are implemented in practice. With this information we can formulate an implementation plan for the new supply chain.

2.1.1. Methodology

The method of our research is both descriptive and qualitative. It is descriptive because most information we use is literature. Therefore, in this research we are looking for causal effects in E-waste. The research is qualitative because we created especially open questions and we work with a lot of information that is descriptive. We also do not possess many data with numbers.

Reliability is a discutable factor in qualitative research, because there is nothing to measure. That is why the term dependency is often used as a measure of reliability (IJzendoorn, 1986). Input from our research, that is all the information we have received from Twente Milieu and De Beurs in combination with information retrieved from the internet, is the data we try to connect to literature as much as possible. By doing this, we minimize the chance that the data we use is subjective. This results in a research that is predominantly dependent because of its objectivity based on literature (IJzendoorn, 1986). Because we assume that not all data we are going to collect can be connected to literature, we can not completely guarantee the reliability. Another factor of dependency is the completeness and accuracy of the documents used. Since we saw and checked the current situation at De Beurs and Twente Milieu by ourselves during the company visits, we believe that the information we retrieved is complete and accurate.

Validity is the extent to which a test measures what we actually wish to measure (Cooper & Schindler, 2011). To make sure the research is valid, we did a literature review. In a literature review, you obtain a clear overview of relevant articles on the basis of specific search strings. Based on their relevance and modernity, we assure we only use literature that fits our methodology so we only give answers to the questions stated, and consequently, we exclude side issues.

2.2. Deliverables

The solution for the core problem will be a redesigned supply chain. To display the new supply chain clearly, we will make a schematic representation of the supply-chain of E-waste. The supply chain is the process that describes the flow of E-waste products through De Beurs and Twente Milieu. There are some different sets of symbols, which are used for mapping a process. For this report, we will use the process mapping symbols derived from scientific management, because these are common and easy to read. In this process map the activities during the process of E-waste, locations of these activities and logistics are shown. The map will be explained and argued further on in the report. The report will also contain an implementation plan for the changes to make.

2.3. Data collection

We use several options to gain enough knowledge and data about the current and optimal situation of the supply chain of De Beurs and Twente Milieu. To do so, we conducted an interview with board members of De Beurs and Twente Milieu to create a general awareness of the current situation and their vision on improvements. This gave us a basic understanding of what to do to improve the supply chain. The lack of knowledge about some parts of the problem at hand is filled with a literature research.

We use a two-step approach, as stated by Löwik (2013). The first step to start a literature review is to identify keywords and search strings. To do so, first we need to find key constructs of the research question. In other words, we need to know what we must look for when we are searching for literature. To find those key constructs, we first have to think about the goal of the research. In this research, we look at the supply chain from De Beurs and Twente Milieu. We want to improve the current supply chain in such a way that all demands and wishes of the stakeholders are met. Filling a gap between two situations is in this case about optimizing the current situation.

From this goal, we can relate the key constructs of the research questions at hand. With the key constructs, we can find the right information to answer the questions. The key constructs and their corresponding keywords are used in the search strings.

E-waste
Definition: Electronic waste, the core material that we work with. The entire problem statement evolves around this product. The goal is to get more value out of the E-waste.
Keywords: Waste; Electronic waste.

Reversed supply chain
Definition: The supply chain of recycling products. Most often this is a closed loop supply chain. The goal is to get more value out of the waste, or in other words improve the reversed supply chain.
Keywords: Recycling; Reuse; Remanufacturing; Closed loop supply chain; Design; E-waste.

Supply Chain optimization
Definition: A network of companies and its suppliers to deliver a specific product to the market. The supply chain represents the steps the product or service must take until it is property of the customer. The goal is to improve the supply chain in a way that all wishes and demands from the stakeholders are met.
Keywords: Supply chain; Design; Re-design; Improve; Optimize; Growth.

For the review, we are using Scopus as search engine to find relating articles. Scopus alone gives well relating articles and therefor another search engine is not needed. After using the search strings, 436 articles were found for further study. To assure the reliability and validity of the articles, we set multiple limits to the type of document, source type, language, subject area, citations and year of publishing the article. More information about the search strings and articles can be found in appendix III.

The research will provide a list of variables which can be used to make the constructs measurable. This operationalization helps us to determine what criteria are needed to choose between the different new supply chain concepts. More about these criteria can be found in section 6.2.

3. Supply chain

3.1. Supply chain management

As told in chapter 1.1, a supply chain is a network of companies and its suppliers to deliver a specific product to the market (Investopedia, 2017). The supply chain represents the steps the product or service has to take until it is property of the customer. According to Slack, Chambers & Johnston (2013), supply chain management is the management of the interconnection of organizations that relate to each other through upstream and downstream linkages between the processes that produce value to the ultimate consumer. In this research this value is in the form of electronical products. A supply chain can be considered as a pipeline where these products flow through several operations. Each operation must satisfy their customer needs, but also making sure that eventually the end-customer is also satisfied. Meeting the requirements of end-customers, requires the chain to achieve appropriate levels of five operations performance objectives. These objectives are: quality, speed, dependability, flexibility and cost. For example, it is important to the customers that they are served fast, that prices are fair, that the product is of good quality and that the product is delivered on time (Slack, Chambers, & Johnston, 2013). Keeping the end-customer in mind is also of great importance in a recycling supply chain. In this case, the end-customers are the households who buy the recycled electronical devices and organizations who get the E-waste after De Beurs. However, households are also the suppliers of the E-waste that eventually will be remanufactured to recycled electronical devices. According to Gonul Kochan et al. (2016), previous studies showed that recycling intentions of these households are influenced by the willingness to recycle, convenience of available recycling facilities, attitudes towards recycling and social norms.

3.2. Sustainable Supply Chain Management

For many years, there has been the premise that an efficient supply chain would minimize monetary risks and increases profits. However, environmental and corporate social responsibility have been brought up after changes in the business environment, like a constant access to information and better education. To achieve the goal of sustainability, a more environmental- and social friendly supply chain, concepts of a sustainable Supply Chain Management are made. Two of these concepts are the reverse logistics and the closed-loop supply chains (Beh, Ghobadian, He, Gallear, & O'Regan, 2015). Reverse logistics is a way to recapturing value or get more value out of waste through recycling, remanufacturing or other forms of recovery. It is the process where used products are being brought back to a firm for reuse, remanufacturing, recycling or disposal. This will lead to less environmental degradation. Main drivers for reverse logistics systems are external (government regulations and customer demands) and internal (Rahman & Subramanian, 2012). There are different causes of product returns, such as manufacturing returns, commercial returns, product recalls, warranty returns, service returns, end-of-use returns and end-of-life returns (Beh, Ghobadian, He, Gallear, & O'Regan, 2015). In case of De Beurs, these ‘returns’ are only end-of-use returns or end-of-life returns because De Beurs is a second-life-retailer. A reverse logistics network may occur in one of two contexts: a closed-loop or a open-loop system. E-waste has a closed-loop supply chain because sources (manufacturers of electronic devices) and sinks (households) coincide so that flows cycle in the system (Rahman & Subramanian, 2012). An example of a forward and reverse supply chain is shown in figure 4.

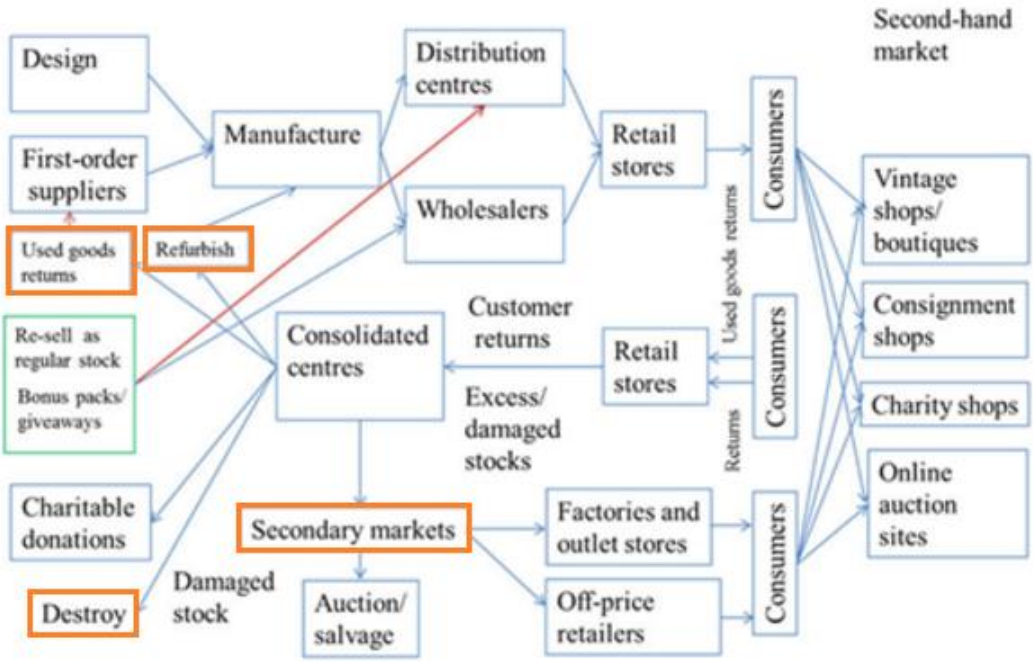


Figure 4: *Typical retail forward and reverse supply chains (Beh, Ghobadian, He, Gallear, & O'Regan, 2015).*

The reverse closed-loop supply chain of e-waste starts with the collection of the electronical waste. A consolidation centre would decide whether the returned goods could be used for (for example) refurbishment, to be destroyed or to be appropriately disposed of. Every reverse logistics system should include the functions of gatekeeping, collection, sortation and disposition (Beh, Ghobadian, He, Gallear, & O'Regan, 2015). After the collection, testing and remanufacturing are two important steps in the chain. Questions that can be made with testing and remanufacturing are: Once core has been collected, which items should be remanufactured? and When to remanufacture them? (Neto & Walther, 2014).

Examples of more practices in a reverse supply chain are reuse; repair; refurbish; recycle; remanufacture; resell; and dispose (Rahman & Subramanian, 2012). If you take a look at figure 4, some of these practices are already mentioned:

- Refurbish: is clearly stated;
- Recycling: means that materials are being processed and used for other goods and;
- Remanufacturing: means that new products are made of (parts of) old products. Recycling and remanufacturing, both can be represented by the square 'Used goods returns';
- Resell: happens on the 'secondary markets';
- Dispose: is also stated with 'destroy'.

Only 'reuse' and 'repair' are missing in the figure. If 'reuse' and 'repair' also were illustrated, reuse should be mentioned between the secondary markets and the consumer. Repair should be illustrated between the consolidated centres and the secondary market.

Rahman and Subramanian (2012) have identified eight factors that many academics view as essential for designing and implementing recycling operations in reverse supply chains. These factors are 1. Legislation 2. Volume and quantity 3. Customer demand 4. Environmental concerns 5. Resource 6. Integration and coordination 7. Incentive and 8. Strategic cost/benefit. Legislation is one of the drivers for success and a motivator for low cost innovative sustainable practices. Customer demand makes firms more socially responsible and to include environmental management practices into their supply chains. Strategic costs in implementing the supply chain would yield benefits to the firm. Environmental concern would lead the firm

to gain competitive advantages. Pricing based on quality amplifies the volume of returns. Incentives would enhance return rates. Appropriate allocation and effective utilization of available resources would yield assets to the firm. Integration and coordination of the supply chain and the information support system would increase the speed of recovery and profitability of the firm.

3.3. Logistical challenges

According to Neto & Walther (2014), there are more challenges for not-for-profit organizations, to overcome as for for-profit organizations. Non-for-profit organizations have been set up to address the issue of electronic waste, while providing much needed training and jobs. Consumers are engaged and support their efforts by, for instance, volunteering for the non-for-profit organizations. For these organizations, it is challenging to obtain quality core. Not-for-profit organizations rely on donations, volunteers, and the government. Concerning testing and remanufacturing, dissimilarities lie on the workforce employed and the operational capacity for remanufacturing may fluctuate over time. Some not-for-profit organizations (as De Beurs) have as main objective training of the workforce and the provision of temporary jobs to the long-term unemployed. It is a goal in itself to employ socially disadvantaged individuals for potential work. A disadvantage of volunteers is that they don't always have the appropriate level of knowledge and do not work in pre-determined schedules. This all makes the supply chain even more difficult. (Neto & Walther, 2014).

Another logistical challenge are the double-ended fluctuations, both in demand and supply. E-waste recycling faces problems when dealing with fluctuations and uncertainties in the supply chain. Supply and demand differ both in terms of price and quantity. If the price of output materials firstly rise and then fall, not only is the purchase cost increased, but also the selling price is decreased, which results in a significant inventory stocking risk. This fluctuation is hard to stabilize. According to Chen, Sheu, and Lirn, (2012) robust control theory ensures better predictions in forecasting. An example of a robust control theory is the Modified Model Predictive Control (MPC), this model contains an algorithm which is designated to be operated under inaccurate modelling conditions such as an E-waste recycling supply chain. These logistical challenges show the difficulties of a reverse supply chain for not-for-profit organizations.

3.4. Conclusion

One can conclude from this chapter that the supply chain of E-waste at De Beurs is a reverse supply chain. This sustainable concept is a consequence of a more environmental and corporate social responsibility caused after changes in the business environment. In this reverse supply chain, end-of-use or end-of-life electronic products are being brought back to De Beurs for reuse, remanufacturing, recycling or disposal. It is a closed-loop supply chain. The eight factors from Rahman & Subramanian (2012) are essential for designing recycling operations in this reverse supply chain.

These eight factors are used in our report as important constructs to design our new supply chain. The factors say something about the supply chain at De Beurs. To make the constructs measurable, the variables of the constructs are determined and explained down below. The eight factors are used to determine the current (3.2) and optimal situation (3.3). After that the gap between norm and reality is highlighted and the factors are used as criteria for several concepts that close the gap between the current and optimal situation.

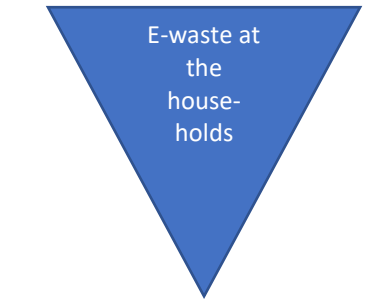
1. **Legislation:** It is important whether the situation corresponds with the current applicable legislation. Either the work of De Beurs and Twente Milieu is not legal, legal or the company thinks ahead about upcoming new rules.
2. **Volume and quantity:** Volume and quantity are measurable with exact numbers. Our research is not based on hard numbers, but we can say something about whether De Beurs can do more or less when volume and quantity changes.
3. **Customer demand:** Customer demand is measurable with exact numbers. Our research is not based on hard numbers, but we can say something about social responsibility, environmental management and demand for recycled E-waste.
4. **Environmental concerns:** Environmental concerns can be measured in terms of impact on the environment.
5. **Resource:** The main resources for De Beurs are their social workers, provided e-waste and the available work space.
6. **Integration and coordination:** A company's strategy is important for integration and coordination. At De Beurs, the focus lies mainly on improving aspects like cooperation and integration of new work activities.
7. **Incentive:** The most important incentives for recycling E-waste are the location of disposal points, costs for disposing E-waste and customers need a good reason to bring E-waste to De Beurs instead of throwing it away.
8. **Strategic cost/benefit:** On a strategic level investments have to be made to grow. Expected output of the investment and strategic advantages are important aspects to measure the impact of a strategic investment.

The articles named above are based on a literature review which you can find in appendix III.

4. Current supply chain

4.1. Process of E-waste at De Beurs

During this project, we will use the process mapping symbols derived from scientific management, see appendix I. Below is the process of E-waste at De Beurs described from the households to Omrin.

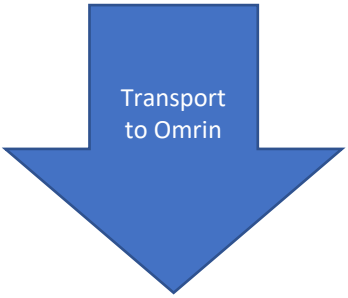


E-waste at the households: At the households the electronical devices become electronical waste. From the moment the consumer decides not to try to repair the device when it is, it becomes e-waste.

Transport to E-waste collecting point: The consumers bring their E-waste to E-waste collecting points. The E-waste collecting points in the region of De Beurs and Twente Milieu, which is the region Twente, are elaborated in appendix II. E-waste collecting points in region De Beurs and Twente Milieu.

The employees of De Beurs check whether the devices are still working or really broken: In case of still working, the devices can be placed in the thrift shop. For the broken devices the employees have to decide whether it is cost efficient to try to repair the devices or to leave it as E-waste. After repairing the E-waste, it will be places in the thrift-shop. The e-waste which will not be repaired continuous this chain.

The E-waste will be stored in a container at De Beurs: The big devices (like washing machines) are separated from the smaller devices (like mobile telephones).



Transport to Omrin once a week: On Monday Omrin will take the (mostly) full container of E-waste at De Beurs away and takes it to their location in Friesland.

The process of E-waste at De Beurs as described above can be compared with the process of E-waste at Twente Milieu. This chain is less comprehensive, because Twente Milieu only collects the E-waste. They do not check or sell the E-waste. The supply chain of E-waste at De Beurs and Twente Milieu is therefore quite similar. The main difference is that De Beurs is a supplier of itself. The E-waste can be repaired and placed in the thrift shop. The supply chain of e-waste at De Beurs and Twente Milieu is shown in figure 5. For an extensive overview of the E-waste collecting points in the region De Beurs and Twente Milieu, see appendix II.

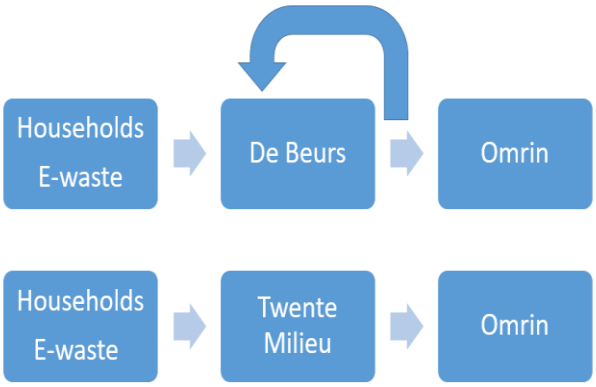


Figure 5*: Supply-chain E-waste*

5. Supply chain optimization

5.1. Optimal supply chain

To create an optimal situation, we must look at every stakeholder's interest. The power and interest of every stakeholder is shown in the stakeholder analysis. Stakeholders are the people and groups who have a legitimate interest in the operation's activities. They can be internal (think of the staff) or external (for example the University of Twente). Stakeholders who are involved in this project, together with their interests in the project and vice versa, are described in appendix IV. De Beurs and Twente Milieu are partly governmental property, so the interests of the government also apply to De Beurs and Twente Milieu. This power-interest diagram is useful for managing the stakeholders. In an optimal situation, we get every stakeholder satisfied. We have seen the position of every stakeholder in the power interest grid in figure 2 in appendix IV. In this chapter, we will look at the demands and wishes of every stakeholder. In the ideal situation, we satisfy all wishes and demands, but this will not always be possible in reality. We try to satisfy the demands and wishes as much as possible in the optimal situation.

Management De Beurs
During the visit at De Beurs we found the following wishes and demands:

- Creating more space for E-waste
    - Storage
    - Repairs
- Employability
    - Creating more social work places
    - Keeping work simple
    - More work in source instead of outsourcing to Omrin
- Environment
    - Less transport between Omrin (north of the Netherlands) and Twente
    - More re-use of E-waste

Management Twente Milieu
During the visit at Twente milieu we found the following wishes and demands:

- Gaining more value out of E-waste
    - Sorting
    - Disassembling
    - Selling part to other companies
- Employability
    - Creating more social work places
    - Keeping work simple
    - More work intern instead of outsourcing to Omrin
- Environment
    - Less transport between Omrin (north of the Netherlands) and Twente

Omrin
In the current situation, Omrin is the next step in the supply chain of e-waste after De Beurs and Twente Milieu. We expect with a new supply chain, that Omrin only gets the E-waste which is useless for De Beurs and Twente Milieu. The wishes and demands for Omrin.

- Stay a big role/step in the supply chain of E-waste.

Government (regional)
With the government we mean the communities of Twente. They have the following wishes and demands.

- Creating more employability;
- Creating more social work places;
- Less people in the Social Assistance.

Government (national)
The government makes laws and guidelines, and it is important that a new supply chain cope with it. Examples.

- Reduce CO2 emissions;
- Less unemployed inhabitants, so less payments

Staff and social workers
The staff and social workers are the people who will execute the work.

- Easy work;
- Nice work sphere;
- Clear workplace.

Customers De Beurs
The customers of De Beurs are people who buy stuff second-hand. Mostly this are people that cannot spend much. They have the following wishes and demands.

- Cheap electronica;
- Good working electronica.

Households Twente
The households of Twente are the suppliers of E-waste. The following is important for them.

- To get rid of E-waste easily;
- A clear overview of collecting points;
- Information about how to cope with E-waste.

Most of the wishes and demands are easy to fulfil in the new supply chain, although there are some contradictions. For example, De Beurs and Twente Milieu want less transport to Omrin so they can do some steps of the recycle process by themselves. Omrin wants all of the E-waste and does the steps itself. We cannot fulfil both wishes. Because De Beurs and Twente Milieu are more important for this situation, we will fulfil the wish of them and not of Omrin.

5.2. Reviewing the situations

After reviewing the current and optimal situation, the gap between these two situations can be determined. To do so, we reflected the situations with the use of the eight factors of Rahman & Subramanian (2012) as mentioned before in section 3.2. The complete reflection and the gaps that are found can be found in appendix V. The most important gaps are further elaborated and (if needed) reviewed with practical solutions from literature. After reviewing the most important gaps, we can look at possible concepts for resolving the issues mentioned below.
The gaps that are found are based on the comparison of the current and optimal situation. Every factor highlighted a certain aspect that should be addressed. In several situations these aspects where about physical space, in a few about collaboration and one factor highlighted the issue of internal layout design.

5.2.1. Most important gaps between norm and reality

Lack of physical space
The biggest gap between norm and reality is the lack of physical space. With this being our core problem (section 1.3), it will be the main thing to think about with the realization of a new supply chain. The upside of this problem is that is easily solved when an investment is made. Possibilities for creating more physical space are creating new space or reducing current inventory.

Collaboration
The second biggest gap between norm and reality is the lack of collaboration. Jacobs & Subramanian (2012) did a mathematical research to the profitable returns of electronic product

recovery (EPR). They state that the sharing of responsibility for product recovery can improve total supply chain profit. They also refer to the fact that responsibility sharing improves social welfare. This information gives us the prove that it can be profitable for Twente Milieu and De Beurs to cooperate in the field of EPR. Improved collaboration therefore is one of the ways to gain supply chain optimization. This statement is back-up by Govindan & Popiuc (2014), who look at a revenue sharing contract between three stakeholders. They conclude that cooperation improves performance measures of participants and increases total supply chain profit. This information tells us that collaboration between Twente Milieu and De Beurs is an important and profitable move to a more sustainable supply chain. In our case, we can link the two companies together in one supply chain.

Another, more out-of-the-box idea of collaboration is referred to by Souza (2013). He refers to a hybrid inventory control system. Many models in the literature consider this hybrid system, where demand can be met by remanufacturing a returned item or by manufacturing (procuring) a new item from a supplier (Figure 6). These two options have different lead times and costs. Hybrid systems are particularly appropriate for managing inventory of spare parts, or in products such as Xerox copiers, where some parts can be obtained from remanufacturing used products. This model could be a solution to our problem statement. This gives Twente Milieu and De Beurs the opportunity to show recycled E-waste can be as good as new products. The downside is that this type of model requires collaboration with a manufacturing company and they will demand perfect remanufacturing.

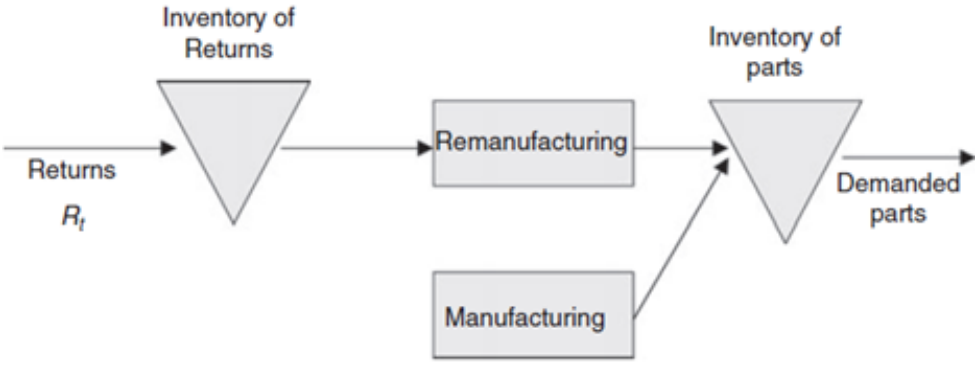


Figure 6*: Hybrid inventory control system layout.*

Internal layout design

As referred to by Dindarian et al. (2012), Improving product design to facilitate reuse and remanufacturing is part of design for remanufacturing, or DfRem (Shu and Flowers, 1999). Interest in DfRem has grown substantially in recent years, but badly needed is more case study type research on products other than the ones commonly investigated, which provides guidance in how to alter the layout to facilitate remanufacturing of three different products. The difficulty of implementing such changes in practice is also discussed, original equipment manufacturers (OEMs) of consumer goods, for example, being commonly less inclined than OEMs that manufacture capital goods to adopt what Sundin and Bras (2005) refer as functional sales (e.g., Rolls-Royce's Total Care system). In our research, we do not address the problem of internal layout design, although it is one of the gaps between the current and optimal situations. This is a point for a follow-up research which can be included easily into a solution to the lack of space problem.

6. The new supply chain

To create a solution and an optimal new supply chain, we have to combine the information of the previous chapters. We have seen a few logistical challenges, bottlenecks and the interest of the stakeholders. To come to an optimal solution, we have first thought about possibilities, and created multiple concepts. Out of these concepts we will find the best solution based on the eight criteria of Rahman & Subramanian (2012).

6.1. Concepts

There are three possibilities for creating more space somewhere in the supply chain, so De Beurs can gain more value out of E-waste. The concepts are derived from the variables, which we defined in the current and ideal situation. The three concepts follow logically from the gap between these two situations in combination with focusing on the core problem, that is, a lack of space at De Beurs. The first concept is about creating more space by adding a step in the supply chain before the E-waste will go to De Beurs. The second concept is about literally creating more space at De Beurs itself. The last concept is about creating more space by adding a step in the supply chain after E-waste has been at De Beurs.

Concept I

By adding a new step in the supply chain, more space can be created for De Beurs. At this moment De Beurs has for some activities not enough space. These activities can be taken over (partly) by the new link in the supply chain, see figure 7.

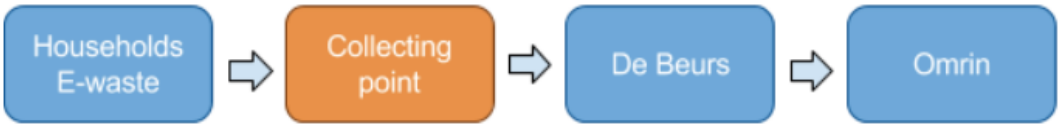


Figure 7: *Supply chain concept 1*

The first activity for E-waste when it arrives at De Beurs is checking whether the electronical devices are still working or not. After this check, the social workers judge whether a broken device can be repaired easily and cost effective. In order to create more space at de Beurs, these activities (collecting, checking and sorting) can be performed at an external location in Oldenzaal. In this case De Beurs will only receive the E-waste which should be repaired and the E-waste which can be placed in the thrift shop directly.

De Beurs will have more space and time because of outsourcing the collecting, checking and sorting of E-waste. The space at De Beurs created by this solution will be partly outside (because of taken out the container with broken E-waste which is being picked up by Omrin once a week). To have enough space to repair more E-waste it can be necessary to use this space outside, to build a building which can be used for repairing the E-waste (or an other activity of De Beurs which is carried out in the current building at the moment.

The broken devices at the collecting point, which can not be repaired, will be placed in a container and picked up by Omrin. Just like in the current situation at De Beurs, but at the new E-waste collecting location.

Concept II

In the second concept (figure 8), we are looking for improvements at the same location as where De Beurs is located at this moment. Since the managing director of De Beurs stated that there is no space left in the current building, an investment is needed for the construction of an extension of the building. From the company visit at De Beurs, we know that there is insufficient space for a new warehouse at the terrain of De Beurs.

In this concept, we refer to Souza (2013), who invented a hybrid inventory control system. Many models in the literature consider this hybrid systems, where demand can be met by remanufacturing a returned item by manufacturing (procuring) a new item from a supplier. These two options have different lead times and costs. Hybrid systems are particularly appropriate for managing inventory of spare parts, or in products such as Xerox copiers, where some parts can be obtained from remanufacturing used products. This would also be the case at De Beurs, when we decide to create more space at the same place as De Beurs is located. This would lead to the following supply chain:

Figure 8: *Supply chain concept 2*

Broken devices will be repaired at De Beurs. After repairing they can easily be placed in the thrift shop on the same location. We consider this concept, because it gives Twente Milieu and De Beurs the opportunity to show recycled E-waste can be as good as new products. The downside is that this type of model requires collaboration with a manufacturing company and they will demand perfect remanufacturing. Also, at this point we can not assure that the extension of De Beurs gives enough space for completely solving the core problem (that is, a lack of space).

Concept III

The last possibility for creating more space is by adding a new step in the supply chain after E-waste has been at De Beurs, see figure 9. Some activities will be carried out at this new link in the supply chain, which are currently still carried out at De Beurs.

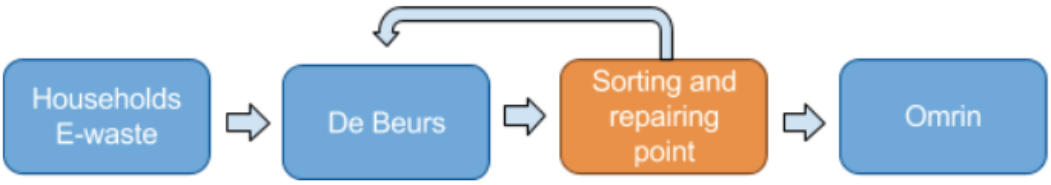


Figure 9: *Supply chain concept 3*

The first check will take place at De Beurs, where the devices which are still working or can be repaired very easily can be placed in the thrift shop. After that all the broken devices will be brought to a central sorting and repairing point. To make this point cost effective, this can be a collaboration between De Beurs, other E-waste collecting points and Twente Milieu. At this new sorting and repairing point the devices will be judged first whether they can be repaired or not. If not, they will be placed in a container, which will be picked up by Omrin. The repairable devices will be repaired. When this will be done in collaboration with some other organizations, scale economies will arise. For example broken E-waste can be disassembled and good parts will be placed in a stockroom. These parts can be used for repairing other devices. Also the municipality will benefit from this repairing center, because of social employability and the sustainable image of the municipality.

6.2. The best solution

Out of the constructs described in the conclusion of chapter 3, we can make up some variables. With these variables, the concepts of paragraph 6.1 can be evaluated. This will be a quantitative evaluation, because this research is far from extensive enough to say something qualitative and still reliable about the variables. Figure 10 shows the links between the constructs and the variables, because these are interrelated. Some more relations could be made, but the most important relations for this project are shown in the figure. Here you can see which variable is derived from which construct.

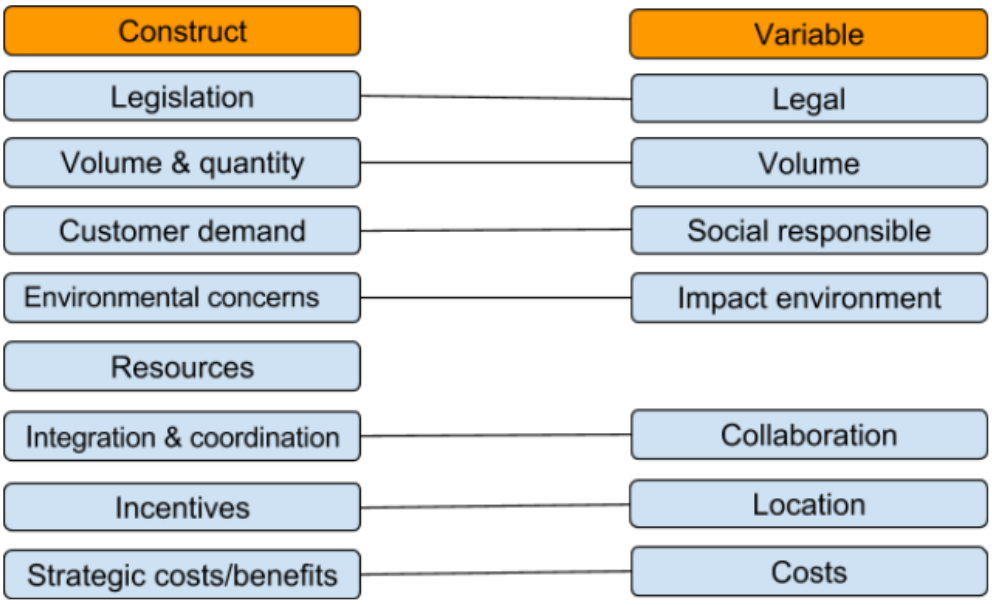


Figure 10: *Supply chain concept 3*

From the construct recourses is no variable derived. One of the recourses for De Beurs are the social workers, which are already concluded in the variable social responsibility. The other main recourses are the provided E-waste and the available work space, which are already concluded in the variables volume. If we would add another variable for recourses, there would be too much overlay.

Below are the variables explained by the main questions of these variables. The concepts will be compared based on these questions.

- Legal: Is the new supply chain only legal or ahead of upcoming new rules?
- Volume: How much E-waste can be processed?
- Social responsible: How many social employees can work in the new supply chain?
- Impact environment: How big is the impact on the environment? This can be in the neighbourhood of the new link in the chain, but also the increase or decrease of transport caused by the new supply chain.
- Collaboration: How much scale economies or other benefits are gained by collaboration with other organizations?
- Costs: How high is the investment?
- Location: How many positive or negative effects will De Beurs encounter by the (eventually) new location of the new link in the supply chain?

After the wishes and demands of the stakeholders in paragraph 5.2 are described, a weighing factor is assigned to the variables. By doing that, we have kept in mind that the key-stakeholders of this project (the redesigned supply chain) are De Beurs and Twente Milieu.

The rating of the concepts on the different variables is done in comparison of each other. Above all the weighted scores, we defined with what rate the weighted score affects the outcome in a scale from one to three. For example, if the new supply chain is legal (weighting one) is less important for an improved situation at De Beurs than the impact on the environment (weighting three). Also it differs per variable if a higher rating means "more" or "less". For example, it is advantageous to have "low" costs but "high" collaboration. You should interpret a high rating as most favourable of the three concepts and a low rating as less favourable. In table 1 the rating per concept for the different variables is shown. In appendix VI you will find the table again, including the explanation of these ratings.

Table 1: *Trade-off Matrix.*

	Legal	Volume	Social responsible	Impact environment	Collaboration	Costs	Location	Total
Weighting	*1*	*2*	*3*	*3*	*2*	*2*	*1*	
Concept 1	**1**	**2**	**2**	**2**	**2**	**3**	**0**	
Weighted score	1	4	6	6	4	4	0	**25**
Concept 2	**1**	**1**	**1**	**3**	**1**	**2**	**0**	
Weighted score	1	2	3	9	2	4	0	**21**
Concept 3	**1**	**3**	**3**	**2**	**3**	**1**	**0**	
Weighted score	1	6	9	6	6	2	0	**30**

The trade-off matrix shows that concept 3 has the highest weighted score is therefore the best solution for the problem of De Beurs. This concept is further elaborated in the next paragraph.

6.3. The redesigned supply chain

In the improved supply chain De Beurs collaborates with other organizations. A new repairing centre will be set up. A possible location for this repairing centre is the ground of Twente Milieu that lies fallow, shown in figure 11.

Figure 11: *Grounds of Twente Milieu*

De Beurs and Twente Milieu will work together closely. They can combine their inflow of E-waste and the inflow of other E-waste collecting points and get an efficient repair and assembling point for all E-waste. At this central assembling point, we can create more employability and social work places. There will be less waste, because at this point there can be more repaired and stored. The more E-waste will be repaired, the less goes to Omrin, which results in less transport to Friesland. The new supply chain will have the structure shown in figure 12.

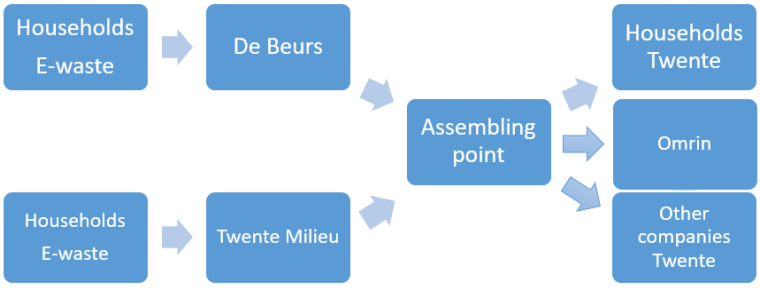


Figure 12: *New supply chain*

The process where the E-waste in the region of De Beurs and Twente Milieu will go through is described in figure 13. The process mapping symbols, described in appendix I, are used.

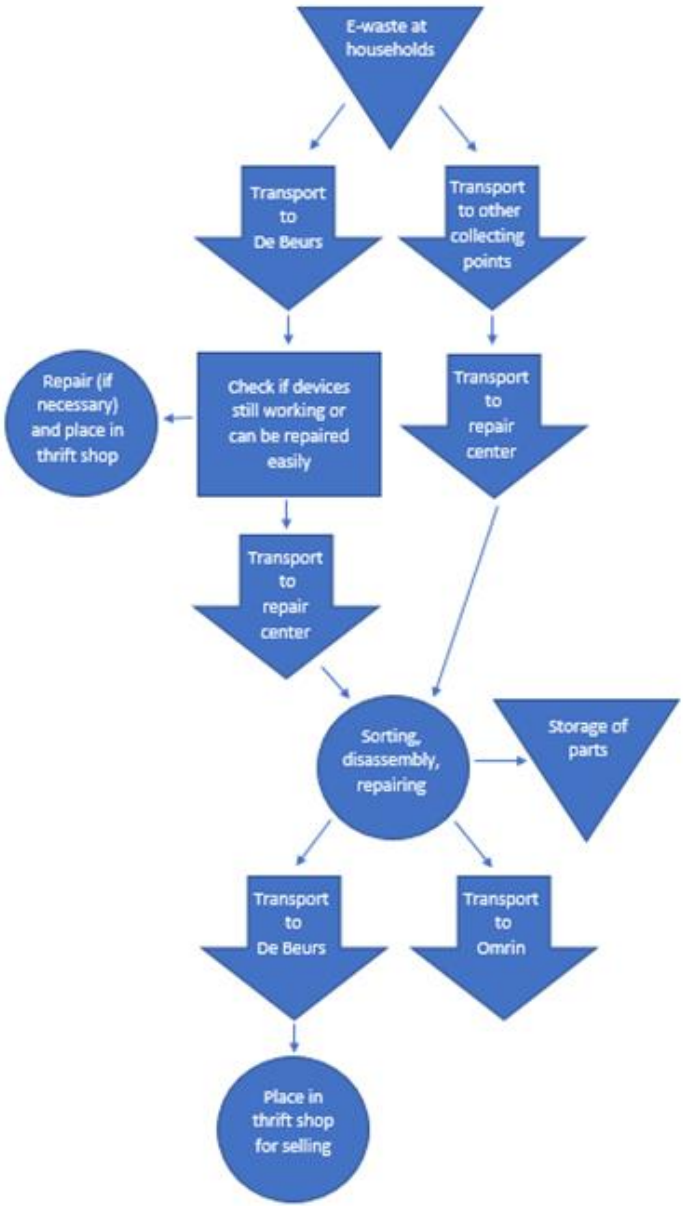


Figure 13: *New process of E-waste*

7. Solution implementation

7.1. Implementation as a form of organizational change

Implementing a new supply chain is a form of planned organizational change. Research shows that in times of change, the supply chain can be unbalanced due to a disruption in the supply, production and distribution systems. Consequently, organizations can face enormous financial losses as well as loss of customer goodwill. Therefore, it is essential to extend the concept of disruption recovery to develop an appropriate model for a supply chain system for minimizing the effect of a sudden disruption (Paul et al., 2016). To manage this change implementation successfully, it is thus important to follow a well-developed change management model (Raineri, 2011). Research has shown that during organizational change processes, firms use more frequently practices related to the change preparation stage, in comparison to practices related to the change implementation stage (Crawford & Nahmias, 2010). But the implementation of the change is just as important as the preparation of the change, since the effects of disrupting the supply chain would be minimized when the implementation stage is well managed by means of change management theories.

Based on leadership competencies, Bass (1990) adopted the task- oriented and person-oriented behaviours model. Effectiveness at task-oriented behaviours joins on the ability to clarify task requirements and structure tasks around an organization's mission and objectives. Effectiveness at person-oriented behaviours, on the other hand, relies on the ability to show consideration for others as well as to take into account one's own and others' emotions (Bass, 1990). Managers might be effective at both task- and person-oriented leadership behaviours, or they might be effective at only one or the other.

When implementing a change in the organization, it is essential to follow a structured and well developed plan that is based on research in order to minimize disruption and confusion among the employees and other possible concerning stakeholders, and consequently, to maximize the effect of the implementation. One of those theories comes from Battilana et al. (2010), who state that the following steps should be taken when implementing a new supply chain in the organization: *communicating* the need for change, *mobilizing* others to support the change, and *evaluate* the change implementation. *Communication* refers to activities leaders undertake to share their vision of the need for change with their followers. *Mobilizing* refers to actions leaders undertake to gain co-workers' support for and acceptance of the enactment of new work routines. *Evaluating* refers to measure leaders' implementation efforts and institutionalize changes. Although these three sets of activities do not cover the complexity of the change implementation process, they have been identified on organizational change as key categories (Battilana et al., 2010).

7.2. Implementation of the new supply chain

In this case, the managing director of De Beurs needs to share the new vision of the supply chain with the concerning stakeholders. That is the social workers and the staff in the first place, since they are most affected by the new supply chain. It can occur that a social worker needs to go to a new location in Hengelo, or that the daily work at De Beurs in Oldenzaal changes significantly since the arrival of a new step in the supply chain. Thus, communicating about the change with the staff and social workers has the highest priority.

After the managing director of De Beurs has shared the new vision, he needs to show such behaviour that he gains support from his staff and the social workers for the new work routines. As mentioned above, it can occur that personnel have to go to a new location or get different tasks. It's up to the managing director of De Beurs to engage in conversation with his staff in such as way that they share the same opinion with respect to the new supply chain to ensure the success of the implementation. Finally, when the new supply chain is realized and became part

of the daily work at De Beurs and Twente Milieu, de managing director needs to be able to measure and institutionalize the change. It is important to measure the change in order to exactly know if the situation is improved (Battilana et al., 2010). When this is the case, it is necessary to institutionalize the change to prevent misunderstandings and confusion. The new supply chain becomes part of the organization and every department, from the thrift shop to the administration, is adapted to the implementation.

Moreover, Battilana et al., (2010) has shown that leaders who are more effective at task-oriented behaviours are more likely to focus on both the *mobilizing* and *evaluating* activities associated with planned organizational change implementation. In addition, leaders who are more effective at person-oriented behaviours are more likely to focus on the *communicating* activities. This results leads to the conclusion that leadership competencies consist of both task- and person-oriented behaviour to maximize the effect of the implementation. With showing a combination of these two behaviours as manager of De Beurs, all of the three steps for planned organizational change are fulfilled.

8. Conclusion, discussion and recommendations

8.1. Conclusion

Based on the results of our research, we can say that the new supply chain would lead to an improvement in comparison with the current situation. The new supply chain would not only mean that the lack of space is past tense, but our solution has also a positive influence on other aspects of the whole process. By investing in the creation of a central assembling point, the problem of the lack of space is immediately resolved. Other advantages are about environmental consciousness, social responsibility, and social employability.

With the creation of a central assembling point, De Beurs and Twente Milieu can combine their inflow of E-waste and get an efficient repair point for all E-waste. The advantage of a central point is less waste, because there can be more repaired and stored since there is greater input and the capacity of the warehouse is big enough to store all the E-waste. Also, spare parts of devices can easily be stored in the new warehouse, that can be used for the reparation of another device. This results in the fact that more and more devices can be sold in the thrift shop and less devices go to Omrin, which leads to less transport to Friesland. This means an improvement for the environment since less E-waste is being transported. As mentioned earlier, the few devices that are placed in the thrift shop, are sold quickly. Thus, our solution also means an improvement in social responsibility since we create more opportunities for inhabitants to buy a relatively cheap device in the thrift shop. Finally, an improvement is made with respect to the social employability. At this central assembling point we can create more social workplaces than there is available now.

8.2. Discussion

Since an investment is needed for our solution, the question arises if the improvements provide enough to earn back the investment within a specific period. We haven't investigated that part, so for now we assume that the new central point just can be built and we exclude the question about who is going to pay for it. We are aware of the effect that this is a limitation of our research since this would be a fundamental aspect of our implementation plan. However, within the available time and our knowledge about this issue, we were not able to investigate this part.

Another limitation of this report is the sensitivity of the weighted scores of the three constructs. The total end scores (25, 21 and 31) are close to each other. This means that if a construct scores differently at a variable with a high weight, this construct suddenly can move from its end position because the total scores differ. For example, if construct three scores 1 at social responsibility in table 1, the weighted score becomes 3 and the end score becomes 24. This means that construct one (score of 25) is the best construct to choose.

8.3. Recommendations

As stated in the conclusion, we expect the new supply chain to be an improvement in comparison to the current supply chain. The new supply chain would not only mean that the lack of space is past tense, but our solution also has a positive influence on other aspects of the whole process. By investing in the creation of a central assembling point, the problem of the lack of space is immediately resolved. Other advantages are about environmental consciousness, social responsibility, and social employability. Taken this into account, we advise De Beurs and Twente Milieu to invest in (or find investors for) the construction of a new warehouse which functions as a central assembling point. As in every research, not every aspect of the problem statement is fully reviewed. We will describe some points of improvement below.

In addition to this research it would be very interesting to do more research on the internal layout of the new assembling center. It is likely that the current layout at De Beurs is not the most efficient layout. Together with the new space, a re-design of the internal layout will provide an even higher value of the E-waste. Another interesting field of research would be the collaboration between more companies than only Twente Milieu and De Beurs. The complete supply chain is bigger than the supply chain we looked at in this research. Therefore, more improvements can be made, when the end-of-line companies and the shops that sell the products are involved in the research.

9. Reflection

From the beginning, it immediately appealed to us that the project was about a real-life business case. We had to physically visit the companies as a basis and this was simultaneous the input for our research. This made it much more ‘tangible’ and ‘real’. Although we were assigned to a specific direction for our research, in the first couple of weeks we found the case still rather unclear. Especially around the first assignment, we kept searching for the right approach: What is the biggest problem at De Beurs and Twente Milieu that is ongoing? What possible research questions arise and which research questions are feasible to dissolve within the limited period? And, subsequently, which methodology is appropriate for solving the main question? Our grade for the first assignment shows that we had no grip on the research yet. We did not have a good approach to tackle the problem. Luckily, after the feedback session of assignment one and a lot of group meetings, we developed an appropriate approach for tackling our chosen core problem based on relevant research questions and useful literature. After the design was favoured in assignment two, the third assignment just consisted of the elaboration of our plan. During the collaboration, we found out everyone’s strengthens and weaknesses. With this as starting point, we nearly always managed to make a fair division of tasks after every group meeting. We also hold on to the agreements we made most of the time, what made it possible for us to demonstrate you this research with - in our opinion - an innovative and realistic outcome for improvement of De Beurs and Twente Milieu in a relative short period.

Literature

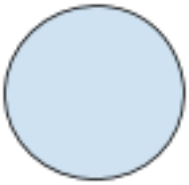
- Bass, B. M. (1990). Bass and Stogdill's handbook of leadership. New York: Free Press.
- Battilana, J., Gilmartin, M., Sengul, M., Pache, A-C., & Alexander, J.A. (2010). Leadership Competencies for Implementing Planned Organizational Change. *The Leadership Quarterly, 21,* 422-438.
- Beh, L.-S., Ghobadian, A., He, Q., Gallear, D., & O'Regan, N. (2015). Second-life retailing: a reverse supply chain perspective. *Supply Chain Management: An International Journal*, 259-272.
- Chen, Y., Sheu, J.-B., & Lirn, T.-C. (2012). Fault tolerance modeling for an e-waste recycling supply chain. *Transportation Research Part E*, 897-906.
- Crawford, L., & Nahmias, A.H. (2010). Competencies for Managing Change. *International Journal of Project Management, 28*, 405-412.
- Cui, J., Forssberg, E. (2003). Mechanical recycling of waste electric and electronic equipment: a review. *Journal of Hazardous Materials, 99 (3),* 243-263.
- Dindarian, A., Gibson, A.A.P., Quariguasi-Frota-Neto, J. (2012). Electronic product returns and potential reuse opportunities: A Microwave Case Study in the United Kingdom, *Journal of Cleaner Production, 32*, 22-31.
- Gemeente Borne. (2017). *Afval*. Retrieved from https://www.borne.nl/digitaal-inzien/producten/productlijst/afval
- Gemeente Dinkelland. (2017). *Afvalbrengpunt*. Retrieved from https://www.dinkelland.nl/afvalbrengpunt
- Gemeente Enschede. (2017). *Milieupas en afvalbrengpunten*. Retrieved from https://www.enschede.nl/afval-milieu-duurzaamheid/afval/milieupas-en-afvalbrengpunten
- Gemeente Haaksbergen. (2017). *Afvalkalender.* Retrieved from https://www.haaksbergen.nl/Afvalkalender.html
- Gemeente Hengelo. (2017). *Milieupark*. Retrieved from http://www.hengelo.nl/Welkom-in-Hengelo/GPDC/GPDC-Producten-catalogus-1/_Burger-en-Bedrijven/Milieupark.html
- Gemeente Hof van Twente. (2017). *Milieupark Bruins en Kwast*. Retrieved from https://www.hofvantwente.nl/afval/milieupark-bruins-en-kwast.html
- Gemeente Losser. (2017). *Afvalbrengpunt.* Retrieved from https://www.losser.nl/Inwoners/Afval_milieu_duurzaamheid/Afval/Afvalbrengpunt
- Gemeente Oldenzaal. (2017). *Afvalbrengpunt.* Retrieved from https://www.oldenzaal.nl/afvalbrengpunt
- Gonul Kochan, C., Pourreza, S., Tran, H., & Prybytok, V. (2016). Determinants and logistics of e-waste recycling. *The international journal of logistics management*, 52-70.
- Govindan, K., Popiuc, M.N. (2014). Reverse supply chain coordination by revenue sharing contract: A Case for the Personal Computers Industry. *European Journal of Operational Research, 233 (2),* 326-336.
- Heerkens, H. (2010). *A methodological checklist for the high-tech marketing project.* Retrieved from https://blackboard.utwente.nl/bbcswebdav/pid-976900-dt-content-rid-2182668_2/courses/2016-201500014-1A/Methodological%20checklist%20by%20H.Heerkens.pdf
- Investopedia. (2017). *Supply Chain*. Retrieved from http://www.investopedia.com/terms/s/supplychain.asp
- IJzendoorn, van M. H., Miedema, S. (1986). *De kwaliteit van kwalitatief onderzoek.* Vakgroep wijsgerige en empirische pedagogiek, Rijksuniversiteit Leiden.
- Jacobs, B.W., Subramanian, R. (2012). Sharing responsibility for product recovery across the supply chain, *Production and Operations Management, 21 (1),* 85-100.
- Kringloopbedrijf De Beurs. (2014). Retrieved from http://kringloopbedrijfdebeurs.nl/

- Löwik, S. 2013. Micro-foundations of absorptive capacity. A study on knowledge processes for innovation in SMEs. *Dissertation, School of Management and Governance, University of Twente, Enschede, The Netherlands.*
- Nnorom, I., & Osibanjo, O. (2008). Overview of electronic waste management practices and legislations and their poor applications in the developing countries. *Recources, Conservation and Recycling*, 843-858.
- Neto, J., & Walther, G. (2014). Not-for-profit supply chains for product take-back: practices, unique logistical challenges and directions for new research. *International Journal of Logistics Research and Applications*, 522-536.
- Omrin. (2016). *Over Omrin*. Retrieved from http://www.omrin.nl/over-omrin/
- Paul, S. K., Sarker, R., & Essam, D. (2016). A Quantitative Model for Disruption Mitigation in a Supply Chain. *European Journal of Operational Research, 257,* 881-895.
- Rahman, S., & Subramanian, N. (2012). Factors for implementing end-of-life computer recycling operations in reverse supply chains. *International Journal of Production Economics*, 239-248.
- Raineri, A.B. (2011). Change management practices: Impact on perceived change results. *Journal of Business Research, 64,* 266-272.
- Shu, L., Flowers, W., (1999). Application of a design for remanufacture framework for the selection of product life-cycle and joining methods. *Robotics and Computer Integrated Manufacturing 15*, 179e190.
- Slack, N., Brandon-Jones, A., & Johnston, R. (2013). *Operations Management.* Edinburgh: Pearson.
- Souza, G.C. (2013). Closed-Loop Supply chains: A critical review, and future research*, *Decision Sciences, 44 (1)*, 7-38.
- Staatscourant. (2014). *Regeling van de Staatssecretaris van Infrastructuur en Milieu.* Retrieved from http://www.weee.nl/sites/all/files/media/nieuwe_regeling_afgedankte_elektrische_en_elektronische_apparatuur_14-2-2014.pdf
- Sundin, E., Bras, B., (2005). Making functional sales environmentally and economically beneficial through product remanufacturing. *Journal of Cleaner Production 13 (9)*, 913-925.
- Twente Milieu. (2016). *Wie zijn wij?* Retrieved from https://www.twentemilieu.nl/over-twente-milieu/wie-zijn-wij
- Weee Nederland. (2015). *De WEEE-wetgeving in een minuut.* Retrieved from http://www.weee.nl/nl/kennisbank/weee-wetgeving

Appendix I - Process mapping symbols

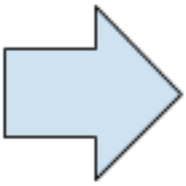
Process mapping is the activity of describing a process schematically and in terms of how the activities of the process relate to each other. There are many techniques for process mapping. All these techniques identify the different types of activities and show the flow of materials, people or information through the process. The main difference between them is the way these activities are typed. The symbols used and their meaning differ from technique to technique, but there are some that are commonly used. The process mapping symbols derived from scientific management is one of them (Slack et al., 2013).

The process mapping symbols derived from scientific management, which are used during this project, are explained below.

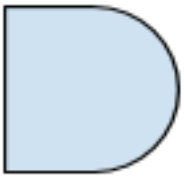


Operations (an activity that directly adds value)

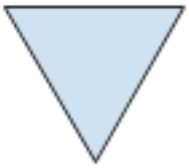
Inspection (a check of some sort)



Transport (a movement of something)



Delay (a wait, e.g. for materials)



Storage (deliberate storage, as opposed to a delay)

Appendix II - E-waste collecting points in region De Beurs and Twente Milieu

As described in the "scope of this project" the E-waste collecting points that are taken into account this research are the collecting points which are (semi-)property of the government (so no commercial companies). We will only enumerate the E-waste collecting points in the vicinity of the locations of Twente Milieu and De Beurs, so Hengelo and Oldenzaal. This are the E-waste collecting points in the municipalities of Hengelo and Oldenzaal and the directly adjacent municipalities to Hengelo and Oldenzaal: Dinkelland, Losser, Enschede, Haaksbergen, Hof van Twente, Borne. See figure 1.

***Figure 1**: Municipalities nearby Hengelo and Oldenzaal.*

The E-waste collecting points are listed per municipality:

- Dinkelland: This municipality has signed an agreement with De Beurs. The E-waste and other reusable are picked up free at the households after making an appointment (Gemeente Dinkelland, 2017).
- Losser: Losser has one waste collecting point at the Ravenhorsterweg where among other things E-waste can be brought for free. Also, De Beurs in Oldenzaal is mentioned on the webpage about waste collecting points of the municipality of Losser (Gemeente Losser, 2017).
- Oldenzaal: The households of Oldenzaal can bring their waste to Twente Milieu or De Beurs, as mentioned on the site of the municipality of Oldenzaal. Twente Milieu and De Beurs are located near each other in Oldenzaal (Gemeente Oldenzaal, 2017).
- Borne: The municipality of Borne mentions on their website that E-waste can be brought to the shop where it comes from as required by the law and it can be brought to a repairer. Borne also has a recycling company where the E-waste can be brought. Bigger devices can be picked up by the company after making an appointment (Gemeente Borne 2017).
- Hengelo: Hengelo has an "environmental park" where e-waste can be brought. The municipality also mentions on their website that goods that are still usable can be brought to a thrift shop, but they do not call specific thrift shops (Gemeente Hengelo, 2017).
- Enschede: The municipality of Enschede has 3 waste collecting points; one in the East, one in South and one in West Enschede. For information about these collecting points is redirected to the website of Twente Milieu. However, on their website can not be found specific information about collecting E-waste (Gemeente Enschede, 2017).

- Haaksbergen: In Haaksbergen is the waste collection point of the firm Langezaal. Waste is separated here and E-waste can be brought freely. On their website is also mentioned that E-waste can be brought to the shop where it comes from and if the devices still work to a flea market (Gemeente Haaksbergen, 2017)
- Hof van Twente: E-waste can be brought freely to Milieupark 'Bruins en Kwast', located in Goor. There is no further specific information about handing in E-waste on the website of the municipality of Hof van Twente (Gemeente Hof van Twente, 2017).

Appendix III - Literature review

***Table 1**: Search strings*

Search strings	Date of search	Scope	Date range	
Search protocol for Scopus				
"Supply chain"				
AND "e-waste"	21-12-2016	Title, abstract and keywords	2012-present	47
AND "design" AND "waste"	21-12-2016	Title, abstract and keywords	2012-present	344
AND "e-waste" AND "improve"	15-12-2016	All	2012-present	45
			Total	**436**
			Removing double articles	-1
			Selection based on inclusion criteria review 1	-373
			Selection based on inclusion criteria review 2	-15
			Selection based on exclusion criteria review 1	0
			Selection based on exclusion criteria review 2	-22
			Articles excluded after reading	-16
			Articles included after reading	0
			Total selected for review	**9**

Inclusion- and exclusion criteria

Table 2: *Inclusion criteria review 1*

Nr.	Criteria	Reason for exclusion
1	Document type: Article	The focus of this literature review is on published articles with recommended research.
2	Subject area: Business, Management and Accounting	Articles in the subject area Business, Management and Accounting are the most interesting for this project
3	Language	To understand the article, English is chosen as language.
4	Keyword: reverse logistics	To specify the articles on the subject reverse logistics this keyword is used (This keyword is only used for, in the end, 1 article).

Table 3: *Inclusion/exclusion criteria review 2*

Nr.	Criteria	Reason for exclusion
1	Citations < 11	To assure reliability and validity, the number of citations is set to more than 10.
Nr.	**Criteria**	**Reason for inclusion**
1	Type of literature set to article and journal	The focus of this literature review is on published articles with recommended research.
2	Language, English only	To understand the article, English is chosen as language.
3	Subject area set to business, decision sciences, environmental sciences, and social sciences	To make sure the articles are about the same area of expertise as the research problem these subject areas are chosen.

Conceptmatrix

Table 4: *List of literature used for literature review*

Nr.	Journal	Authors (year)	Title	Methodology	Operationalization	Key findings
1	The Internal Journal of Logistics Management	Kochan, CG; Pourreza, S; Tran, H; Prybutok, VR (2016)	Determinants and logistics of E-waste recycling	Survey of 327 university students. A structural equation modeling technique is used.	End-customer	Recycling intentions of households are influenced by 3 factors.
					Reverse logistics	Explanation of the beginning of reverse logistics strategy; Demographic influences of the recycling behavior of the residents and the amount of returned products.
2	International Journal of Production Economics	Rahman, S; Subramanian, N (2012)	Factors for implementing end-of-life computer recycling operations in reverse supply chains.	This paper proposes a framework for end-of-life (EOL) computer recycling operations. It identifies critical factors for implementing EOL computer recycling operations and investigates the causal relationship among the factors influencing computer recycling operations in reverse supply chains using the cognition mapping process DEMATEL.	Reverse logistics	Explanation of the Reverse supply chain; Explanation of a closed-loop or open-loop system; Main drivers of reverse logistics: two external factors and customer demands and the internal factor.
					Design of reverse logistics	Explains eight factors for design of a reverse supply chain.
3	Supply Chain Management: An International Journal	Beh, LS; Ghobadian, A; He, O; Gallear, D; Nicholas, OR (2015)	Second-life retailing: a reverse supply chain perspective	This paper is based on an extensive literature review, semi-structured interviews with managers of two second-life retailers in Malaysia and observations of a number of stores	End-customer	The behavior of firms with regard to the environment and corporate responsibility plays an increasing role in determining consumer choice.

					Not-for-profit supply chains	Factors which contributed to environmental and corporate social responsibility; SSCM is a rapidly evolving field incorporating the ecological and social dimensions of businesses as well as economic sustainability.
					Reverse logistics	Reverse logistics aims at improving the exploitation of used products through recycling, remanufacturing or other forms of recovery; The closed-loop supply chain incorporates the returns process, enabling the vendors to capture additional value by exploiting alternative markets for returns or overruns.
					Design of reverse logistics	Every reverse logistics system should include the functions of gatekeeping, collection, sortation and disposition.
4	International Journal of Logistics Research and Applications	Quariguasi Frota Neto, J; Walther, G (2014)	Not-for-profit supply chains for product take-back: practices, unique logistics and directions for new research	Data collection is achieved by seven semi-structured interviews and a literature study.	Not-for-profit supply chains	Social and environmental objectives; Training of the workforce and the provision of temporary jobs to the long-term unemployed are chief goals; Examples of other organizations who are involved; Optimally pricing remanufactured products; Inverted-U-shaped demand curve; Solutions that maximize the overall profit using mathematical modelling as a tool.
					Design of reverse logistics	After collecting of waste, testing and remanufacturing follows
					Logistical challenges	Obtaining quality core is challenging; Main dissimilarities lie on the workforce employed; Operational capacity for remanufacturing may fluctuate over time; Remanufacturing is done by volunteers, they do not work in pre-determined schedules; Employing socially disadvantaged individuals is a goal in itself.

5	Transportation Research Part E	Chen, YJ; Sheu, JB; Lirn, TC (2012)	Fault tolerance modeling for an E-waste recycling supply chain	The inventory management problem is investigated for a double-ended fluctuation for the e-waste recycling supply chain. A E-waste fulfillment model is made and tested on different configurations.	Logistical challenges	Dynamical fluctuations in the cascade supply chain; E-waste chain experiences more difficulties in terms of fluctuations and uncertainties; Double-ended fluctuation in demand and supply; Even harder to stabilize than an ordinary supply chain; Robust control theory ensures better predictions in time-series forecasting.
6	European Journal of Operational Research	Govindan K., Popiuc M.N. (2014)	Reverse supply chain coordination by revenue sharing contract: A case for the personal computers industry	Analytical model to observe the implications of coordination by contracts on the two-echelon and three-echelon reverse supply chain and on the profit of the supply chain members	Implementing revenue sharing contracts for more collaboration.	A revenue sharing contract, which encourages cooperation improves performance measures of participants and increases total supply chain profit.
7	Decision Sciences	Souza G.C. (2013)	Closed-Loop Supply Chains: A Critical Review, and Future Research*	Focus on management of closed loop supply chains (CLSC). Based on other articles, meant as a tutorial on CLSC's.	Multi-dimensional: Strategic, tactical, and operational issues. Focus on strategic issues.	Many models in the literature consider a hybrid system, where demand can be met by remanufacturing a returned item or by manufacturing (procuring) a new item from a supplier.
8	Journal of Cleaner Production	Dindarian A., Gibson A.A.P., Quariguasi-Frota-Neto J. (2012)	Electronic product returns and potential reuse opportunities: A microwave case study in the United Kingdom	82 users of microwave ovens who want to discard the product are interviewed about their opinion	Investigation of quality and costs of remanufacturing.	Large numbers of e-waste are disposed although the e-waste is good enough for reuse or remanufacturing. Quality and costs for remanufacturing are investigated to show the possibilities on reverse supply management.

9	Production and Operations Management	Jacobs B.W., Subramanian R. (2012)	Sharing responsibility for product recovery across the supply chain	Developing and analyzing models of both an integrated and decentralized two-echelon supply chain.	Electronic product recovery, the mandated recovery element.	The sharing of responsibility for product recovery can improve total supply chain profit. Responsibility sharing also improves social welfare.

Appendix IV - Stakeholder Analysis

It may be helpful for this project to understand the (sometimes conflicting) objectives of its stakeholders and set its objectives accordingly (Slack, Brandon-Jones, & Johnston, 2013). Stakeholders are the people and groups who have a legitimate interest in the operation's activities. They can be internal (think of the staff) or external (for example the University of Twente). Stakeholders who are involved in this project are listed in table 2 together with their interests in the project and vice versa. De Beurs and Twente Milieu are partly governmental property, so the interests of the government also apply to De Beurs and Twente Milieu.

Table 5: *Stakeholders' performance objectives*

Stakeholder	***What stakeholders want from the project***	***What this project wants from stakeholders***
Management De Beurs	Future innovation Return of investment Employment social workers Space/capacity for E-waste Recycling of E-waste Minimum impact on environment	Information about E-waste Honesty Responsiveness Appropriate investment
Management Twente Milieu	Future innovation Return of investment More value out of E-waste	Information about E-waste Honesty Responsiveness Appropriate investment
University of Twente	Academic skills of the project group Good level of research	Assistance in problem solving Feedback
Omrin	Being informed	-
Government (regional)	Contribution to regional economy Create jobs for social workers More recycling	Representation of local concerns Support for organization's plans
Government (national)	Conformance to legal requirements More recycling	Appropriate infrastructure Information about legal requirements
Staff and social workers	Create jobs for social workers Safe work environment Career development Good working conditions Simple proceedings	Support for organization's plans Best efforts
Customers De Beurs	Products to buy Fair price	-
Suppliers (households Twente)	Nearby collection points for E-waste	-
WeCycle	Being informed	-

Besides both boards from De Beurs and Twente Milieu, the *University of Twente is* another important stakeholder. The University can influence the project by giving feedback, and thereby, direction to this report. *Omrin* is the collector and processor of waste, they are located in Friesland and collects the E-waste from both De Beurs and Twente Milieu. A regulator with great influence is the *government* (regional in Twente and national). Their objective is to keep the disassembling of E-waste regional and to create jobs for social workers. The regional government of Twente consist of seven communities (Almelo, Borne, Enschede, Hengelo, Hof van Twente, Losser and Oldenzaal). The inhabitants of these communities are the ones who input the E-waste, they are the suppliers. Therefore, they are an important stakeholder in this case. When it is difficult for people to properly dispose their E-waste, they will find other solutions which are even worse than throwing the waste away. An important aspect will be to make it as easy as possible for the communities to dispose their E-waste. *Staff and social workers* are of great importance to this project. It is important to create jobs for the social workers, so they can learn some skills for their return to the labour market. At the same time, the proceedings have to be simple for them. *Customers* are the people who are in need of electronic devices.

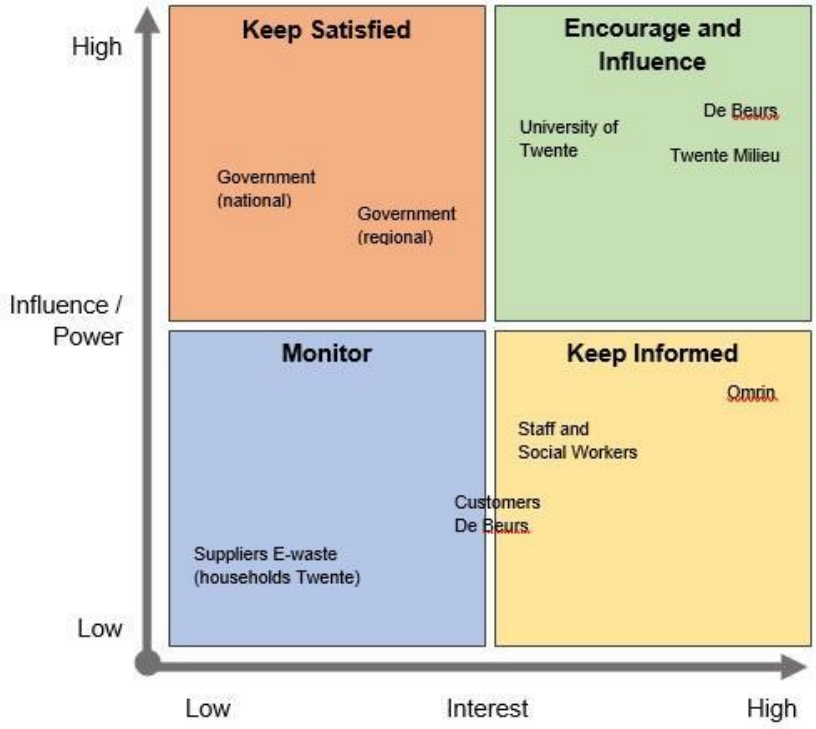


Figure 2*: The Power-Interest Matrix (Mendelow, 1991).*

As you can see, the stakeholders in figure 2 are categorized by interest and influence in four squares. When stakeholders are in the upper left square, then they main objective is to keep them satisfied. The most important stakeholders are arranged in the upper right square, they have a strong influence and are much involved in the project (not only from their side but both ways). Stakeholders in the lower right square are interested and involved in the project, but don't have much power. They will be informed when the solution is being implemented. Stakeholders in the lower left square are being included in this study.

Appendix V - The eight factors of Rahman and Subramanian

Table 6: *The eight factors of Rahman and Subramanian*

Nr.	Factor	Operationalization of the eight factors.	Current Situation	Optimal Situation	Gap between norm and reality
1	**Legislation**	It is important whether the situation corresponds with the current applicable legislation. Either the work of De Beurs and Twente Milieu is not legal, legal or the company thinks ahead about upcoming new rules.	The European WEEE legislation is the abbreviation for Waste Electrical and Electronic Equipment. This law says that producers or importers of electrical and / or electronic devices are legally obliged to register and to arrange for the collection, recycling and environmentally friendly disposal of E-waste (Weee Nederland, 2015).	In an optimal situation, we keep us abide by the law and guidelines of WEEE. Also, we have to keep to the guidelines of the government. It is not needed to think ahead about upcoming rules.	There is no gap between the norm and reality. De Beurs and Twente Milieu are already partly owned by the government and therefore do everything by the law.
2	**Volume and quantity**	Volume and quantity are measurable with exact numbers. Our research is not based on hard numbers, but we can say something about whether De Beurs can do more or less when volume and quantity changes.	In the current situation the volume of the e-waste delivered at De Beurs is more than they can process well. The E-waste placed in the thrift shop is sold within a short period of time. There is enough E-waste brought to De Beurs but because of a lack of space (to check and repair the E-waste) they cannot place the quantity they want in the thrift shop.	In the optimal situation, De Beurs wants to create a bigger turnover. Therefore, the volume and quantity of repaired E-waste in the thrift shop of De Beurs will need to increase to a maximum of the provided E-waste.	There is a gap between norm and reality. The gap is created by a lack of turnover. To decrease the gap, De Beurs must invest in physical space and new employees. There is enough E-waste, but it is not used well.
3	**Customer demand**	Customer demand is measurable with exact numbers. Our research is not based on hard numbers, but we can say something about social responsibility, environmental management and demand for recycled E-waste.	De Beurs is a social responsible organization. They already meet the customer demand for social responsibility and environmental management. The customers demand for refurbished e-waste is not met yet by De Beurs, because the E-waste placed in the thrift shop is been sold relatively very fast.	There are more customers with demand for recycled E-waste than we can supply in the current situation. In an optimal situation, the supply of recycled E-waste is equal to the customers demand.	There is a gap between norm and reality. The recycled E-waste is sold too quickly and De Beurs is not able to sell more products at the moment. To reach customer demand, the turnover must increase. This is another reason to invest in physical space and new employees.
4	**Environmental concerns**	Environmental concerns can be measured in terms of impact on the environment.	To gain competitive advantages from environmental concern is not easy in the branch of De Beurs, because customers already expect thrift shops to be environmentally responsible. Therefore, De Beurs is already on a high level of Environmental concerns.	To distinguish from other companies in the branch of recycling E-waste, De Beurs should invest in a better cooperation with partners to reduce the environmental impact of the chain.	There is a gap between norm and reality. If De Beurs and Twente Milieu (and if possible more companies) cooperate, the value of E-waste will go up and the impact on the environment will go down.

5	**Resource**	The main resources for De Beurs are their social workers, provided e-waste and the available work space.	Important assets for De Beurs concerning E-waste are the social workers, the provided E-waste by the households and the work space at De Beurs. At this moment the social workers can do the job, but it is hard to get social workers with the right knowledge and skills for repairing E-waste.	The optimal situation of using the resources is to put the social workers, provided E-waste and workspace together in an efficient and effective system. This system looks for an consistent flow of products with a small inventory (except for the thrift shop)	There is a gap between norm and reality. To decrease the gap, The social workers must be trained and more physical workspace and work stations must be created. In this way, the flow of products will no longer be too big.
6	**Integration and coordination**	A company's strategy is important for integration and coordination. At De Beurs, the focus lies mainly on improving aspects like cooperation and integration of new work activities.	Well coordinated cooperation in the supply chain can lead to competitive advantages. Tough competition in the branche of De Beurs is out of the question, but it is important to cooperate with partners to improve. In the current situation, this is not done properly	In the optimal situation we get an effective and efficient supply chain, with good integration and collaboration between stages of the supply chain.	There is a gap between norm and reality. Collaboration between De beurs and Twente Milieu can be the first step to improvement of the supply chain. If repairing E-waste is also included more in the process, the integration is at a proper level for De Beurs.
7	**Incentive**	The most important incentives for recycling E-waste are the location of disposal points, costs for disposing E-waste and customers need a good reason to bring E-waste to De Beurs instead of throwing it away.	Most often, E-waste is brought to the nearest collection point. For the inhabitants of Oldenzaal, this is De Beurs.	In an optimal situation, the households have to do little to no effort to bring their E-waste to a collection point. Therefore, all the collection points of waste must be collaborating with De Beurs or another recycling company.	There is a gap between norm and reality. Not all collection points bring their E-waste to a recycling center. Also Twente Milieu doesn't do this. Therefor, the first step is to connect Twente Milieu and De Beurs for a better flow of E-waste.
8	**Strategic cost/benefit**	On a strategic level investments have to be made to grow. Expected output of the investment and strategic advantages are important aspects to measure the impact of a strategic investment.	This has to do with the cooperation in the supply chain of E-waste. To improve on the long term, investments can be needed. In the current situation there are no big investments done in the supply chain where De Beurs benefits from.	This has to do with the cooperation in the supply chain of E-waste. In the optimal situation, every company in the supply chain of E-waste makes sure the E-waste is recycled. In this way the value of E-waste is the highest.	There is a gap between norm and reality. Companies that are involved in the supply chain of E-waste do something about recycling, but all they can do. Collaboration with thrift shops is the best step.

Appendix VI - Explanation trade-off matrix

***Table 7**: Trade-off matrix*

	Legal	Volume	Social responsible	Impact environment	Collaboration	Costs	Location	Total
Weighting	*1*	*2*	*3*	*3*	*2*	*2*	*1*	
Concept 1	**1**	**2**	**2**	**2**	**2**	**3**	**0**	
Weighted score	1	4	6	6	4	4	0	**25**
Concept 2	**1**	**1**	**1**	**3**	**1**	**2**	**0**	
Weighted score	1	2	3	9	2	4	0	**21**
Concept 3	**1**	**3**	**3**	**2**	**3**	**1**	**0**	
Weighted score	1	6	9	6	6	2	0	**30**

Every concept is legal and we cannot say already if it is ahead of upcoming new rules, so we assigned the same score to every concept for this variable.

The volume of E-waste which can be processed in concept 3 is probably the most of the three concepts, because in concept 2 there will be a whole new repairing center. Concept 2 has the lowest score. The increase of volume is limited in concept 2, because of the limited space at De Beurs.

With implementing concept 3 De Beurs will probably create the most social workplaces compared to the other concepts. That is why concept 3 has the highest rating for the variable social responsibility. The workplaces created by concept 1 are less and the workplaces by concept 2 are a little less again, because of the limited possibility to grow.

We expect concept 3 to have the less impact on the environment, because the transport will not increase. For concept 2 and 3 will the transport probably increase a little bit, but this will be compensated by the amount of recycled E-waste, which of course is better for the environment and will reduce the transport of E-waste to Omrin.

The rating of the variable collaboration is the highest for concept 3, moderate for concept 1 and the lowest for concept 2. In concept 3 many other companies will be involved. This can be Twente Milieu, other E-waste collecting points, municipalities and so on. In concepts 1 can also be collaborated with other companies, but on a much smaller scale. In concept 2 the collaboration is very little if anything.

The costs of the three concepts are a roughly estimated. We expect concept 3 to be the most expensive one, while a whole new repairing center has to be set up. Concept 2 will be a bit more cheaper, while the rebuilding takes place on land which is already property of De Beurs. We expect concept 1 to be the less expensive, while in the new building only the activities collecting, sorting and checking take place. This building does not need much facilities and can eventually be an already existing building which will be rented.

The pros and cons of the location of the 3 concepts can not be weighted against each other, because the locations of concepts 1 and 3 are not known yet, especially the location of concept 3 is still very vague.