DECISION MODEL FOR AXIS PRODUCT REPAIR

Faculty of Engineering
Department of Industrial Management & Logistics
Division of Engineering Logistics

Authors
Johan Hansson
Gustav Jiremark

Supervisors
Jan Olhager, Faculty of Engineering, Lund University
Patrik Qvarfordh, Reverse Supply Chain Manager, Axis Communications

Examiner
Louise Bildsten, Faculty of Engineering, Lund University

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Abstract

Axis Communications was founded in 1984 and since then, the growth has been remarkable. Today, Axis is famous for their high-quality network cameras used for surveillance all over the world. Even though Axis's products are designed to last for a long time and are tested to the extreme, some products do break down. When this happens, Axis want to turn this into a positive experience for the customer. Axis Reverse Supply Chain department is responsible to ensure that a customer is serviced within five days. To their help, they have service partners located in all parts of the world that receives the broken units. The partners either repair, scrap, or send the broken unit to the manufacturer for repair. Axis ensure that the service partners have spare parts, equipment, and replacement units in stock. It is perceived that the reverse supply chain hasn't followed the growth of the company. Therefore, the Reverse Supply Chain department need guidance regarding their decision making for how broken units received at service partners should be distributed. Another area of interest is how they handle their warranties when a product is no longer produced.

The problem was approached by building an understanding and foundation of Axis and the subject reverse supply chain. This understanding was established from multiple informal interviews with Axis employees and by conducting a thorough literature study. In addition, three reference companies were interviewed to acquire inspiration and knowledge. Lastly, eleven case products were thoroughly studied and categorized with regards to their value and return volume. With this foundation, an analysis concerning the flow, costs, and the strategies used by the reference companies were conducted to find the optimal solution for Axis.

The analysis identified investment and operational cost elements related to handling warranty cases and a comparison between the reference companies were carried out. Furthermore, Axis's return flow was thoroughly evaluated and costs related to handling the case products were compiled. Additionally, an algorithm that predicts the return volume for a certain product was evaluated and validated.

The final recommendation to Axis is to scrap and replace cameras that are below a value of $120, however, this requires Axis to find contractual agreements with current or new partners to recycle and scrap their cameras for free. For cameras with a value above $120, it is recommended to direct resources to their service partners in terms of training, manuals and a well managed spare parts inventory. This to avoid sending cameras for repair to the manufacturer which is associated with long lead-times. For products that are no longer produced, it is recommended that Axis apply the evaluated algorithm to compute the number of expected returns. Thus, Axis can stock an adequate but not excessive amount of critical components and units to handle their product returns.

List of Abbreviations

Axis	Axis Communications AB, page 2
BOM	Bill of materials, page 6
CLC	Configuration logistic center, page 7
COGS	Cost of goods sold, page 6
DOA	Dead on arrival, page 38
DSM	Decision support models, page 34
EMS	Electronic Manufacturing Services, page 5
EOL	End of life, page 5
IQC	Incoming Quality Control, page 38
LTB	Last time buy, page 6
PCA	Printed circuit assembly, page 54
PHL	Product handling list, page 40
PRR	Predicted return rate, page 44
RMA	Return merchandise authorization, page 4
RSC	Reverse supply chain, page 1
RTV	Return to vendor, page 44

TSE Technical Services Engineer, page 38

Nomenclature

COGS At Axis this is equal to the manufacturing cost of a specific product, page 6

EOL A product enters the EOL state when the sales stop, page 5

RMA-pool Pool of repaired and new units that are sent out as replacements units, page 38

Contents

Chapter 1

Introduction

This chapter describes the background of this master thesis and provides a brief introduction of the company which this thesis is carried out together with. Furthermore, the problem is described, the purpose is stated, and the research questions are presented. Lastly, focus and delimitations are presented and to which group this report aims to address.

1.1 Background

During the twentieth century, plenty of companies have optimized and fine-tuned their forward supply chains, through cutting cost, decreasing delivery times, and improving the customer experience. Lately a new term has arisen within logistics; the reverse supply chain (RSC). The RSC is explained by the actions and steps to retrieve goods from the customer to either repair, refurbish, re-manufacture, recycle, or for disposal. Customers are expecting fast and high-quality service, which allows the RSC to become a competitive advantage. There are also increased regulations and customer pressure on companies to be able to take care of their produced products. An example is the case with tire manufacturing in Europe from 2003, where tire manufacturers have to recycle one tire for every tire sold. There are also cases where companies have seen economic profit from refurbishing and re-selling used equipment (Guide Jr & Van Wassenhove, 2002).

The RSC as a subject has lately got a lot of attention which is something that can be seen in Figure 1.1. The graph shows the number of times the sentence ”reverse supply chain” has been mentioned in publications on Google Scholar.

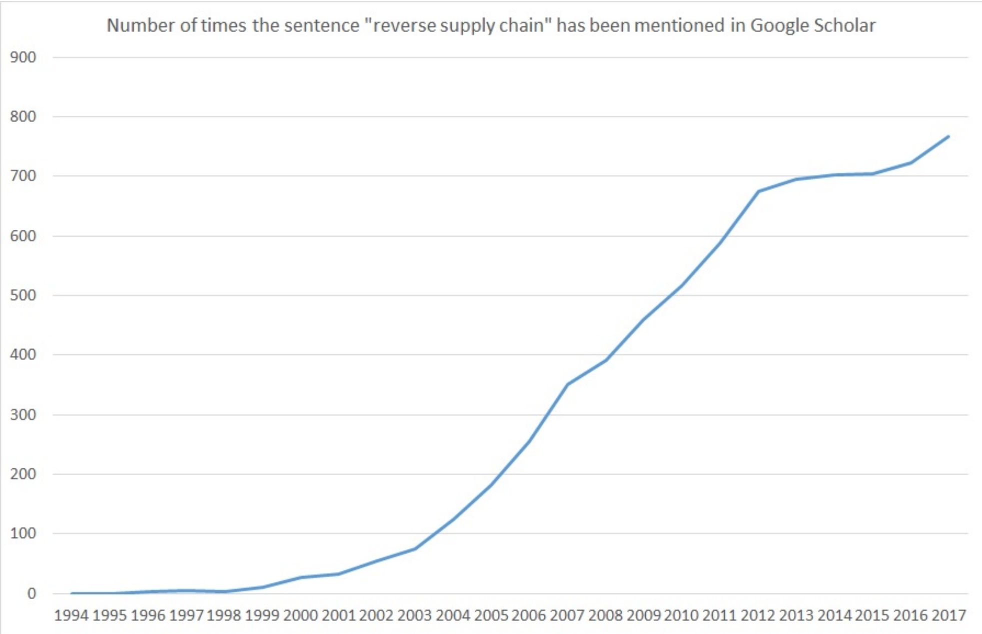

Figure 1.1: Trend for reverse supply chain (Google, 2018)

1.2 Company description

1.2.1 The history of Axis

Initially, Martin Gren, Keith Bloodworth, and Mikael Karlsson founded Axis 1984 with the objective to compete on the market for printer servers. Their first product was a protocol converter. While other companies had a head start, Axis had their innovative aptitude and loyalty towards partnerships which made them number two on the market following IBM. Following some further re-directions such as the storage and thin-server business, Axis launched their first network camera in 1996. This became the first step into the network camera market where Axis now is a global market leader. Since then, Axis has with its innovative capacity released numerous of different camera models and miscellaneous accessories, some of them presented in Figure 1.2. From 2007, Axis growth has been rapid but steady, with an increase in turnover of 10-20 % per year (Allabolag, 2018). The reasons for this can be discussed, but Axis argues that their business model and nonstop eager to release new and innovative products are important factors.

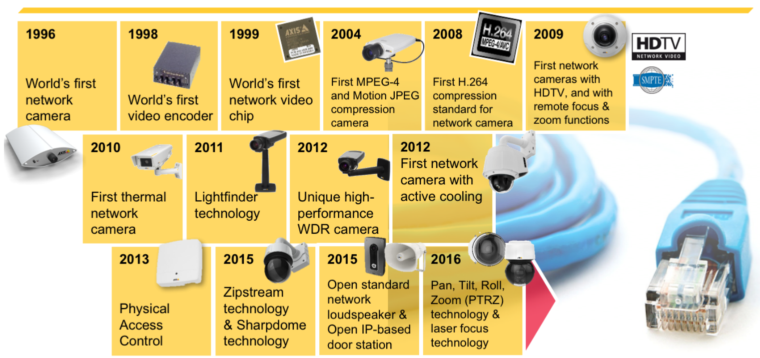

Figure 1.2: A selection of Axis innovations (Source: Axis (2018))

February 2015, Axis was acquired by Japanese Canon Inc., however, Axis is considered as an independent unit, and their innovative capacity and business model has not been altered (Axis, 2018).

Canon is a Fortune 500 company originating in Japan, the turnover in 2016 was SEK 263 billion. Canons business is divided into three areas, where Axis is in the segment called Industry and Others BU. Canons product portfolio of different products is vast, Axis might be considered a large company in Sweden, but is only a fragment of Canons organization (Canon, 2018).

1.2.2 Axis today

Axis is operating globally and has customers all over the world, Figure 1.3 indicates their worldwide presence. Aside from network cameras, Axis sells video encoders, radars, sound systems, access systems, system devices and video management software. In 2016, Axis had 2400 employees and had a turnover of $8,7 billion. In comparison, 2013 the corresponding figures were 1500 employees and $5,5 billion (Axis, 2016, 2013).

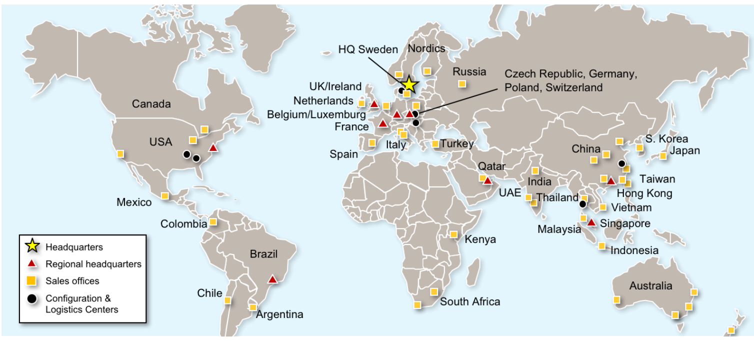

Figure 1.3: Axis global presence (Source: Axis (2018))

This rapid growth is to some extent enabled by their business model, simplified and presented in Figure 1.4. In addition to the sales offices, Axis has more than 90.000 partners, of which roughly 90 % are re-sellers and system integrators. The partners have a network of potential customers and allows the advantage of scalability, which also is one of Axis visions: maximize growth through a scalable and flexible supply chain.

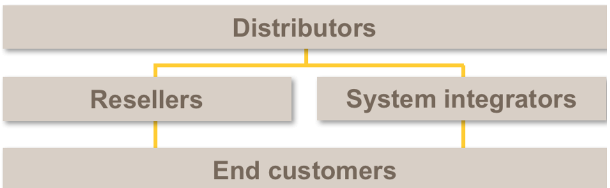

Figure 1.4: Axis business model (Source: Axis (2018))

Today Axis has return merchandise authorization (RMA) partners situated in all parts of the world. They receive all the broken units that are sent in from customers. The RMA-partners performs diagnoses and reparations on products when necessary. Axis has three types of RMA-partners. In some cases the Axis office within the countries is acting as a RMA-partner. The second type is supply controlled RMA-partner. At these partners Axis owns the stock but the site is operated by a third party. The third type of partners are supply non-controlled RMA-partner, at these facilities the RMA-partner runs the operations and owns the stock (Axis, 2018).

1.3 Problem description

At Axis, quality is of great importance. Every single product is tested to the extreme – against water, humidity, vandalism, vibrations, harsh temperatures and more. However, sometimes Axis's products do break, and when that happens, Axis needs to turn this into a positive experience. Axis service organization will then help the customer over phone or web. If it is needed to look into the broken unit, Axis use one of their certified global partners for a quick replacement of the unit, 95 % of all cases must be solved within five days. Upon arrival of the damaged unit, there are some alternatives: scrap, repair at RMA-partner or send back to the electonic manufacturing services (EMS), i.e., contract manufacturer, for repair. Regarding the customer, they either receive the same unit repaired, a refurbished unit, a new unit, or an upgraded unit. To take the correct actions, there are several aspects to consider, both from a technical and a financial perspective.

Currently, a decision is based on experience and personal beliefs. This means that the process is somewhat unclear and it is hard to follow up and evaluate. The process is also inconsistent meaning it differs between people and experience. All products in the RSC can be divided into three following categories:

- New products, these are products that are new to the market, thus there are limited sales data available. It is neither any knowledge on what kind of errors that the cameras usually are returned with. Therefore, it is hard to estimate which spare parts and what quantity that has to be located at the RMA-partners. During the initial phase, the first returns are collected to the headquarter in Sweden to investigate the reason for product failure. This also means that a product failure in this phase is handled by servicing the customer with a brand-new corresponding unit. There is also a continuous improvement process on the products, which lead to different versions of the same product and increases the complexity of the service process.

- Mature products are products that have been sold for a long time and are going to be sold for a foreseeable future. Axis has sales data and knows what kind of errors that occur. A process for retrieving and handling malfunctions for the product is also in place.

- End of life (EOL) products are products that are removed from the product catalog, i.e., they are not sold anymore. There are roughly two to five products per month that enter this phase. However, Axis still has to be able to service these products during the warranty time which is per standard three years with the option to extend to five years. When a product is considered as an EOL product, Axis receives a bill of materials (BOM) for repair from the EMS, containing what spare-parts that has been required to repair a certain product. These components are divided into generic components (e.g. screws) and Last time buy (LTB) components. Whereas generic components are not considered critical, LTB-components are. Thus, LTB-components needs to be purchased and stocked. In addition, the RSC department adds brand-new units to stock which is useful when a product is not repairable.

The RMA-process is defined as the process from when it is decided that a product has to be repaired at either RMA or the EMS, depending on what type of failure. Axis has a fixed lower limit for products to consider repairing them, products with a cost of goods sold (COGS) value below a specific figure are replaced with a new product. When the COGS-value exceeds the given limit, the RMA-process varies between units, depending on product complexity, component availability, etc.

1.4 Research purpose, questions, and objective

The purpose is to develop a decision model for how Axis should handle product repairs.

The research questions are:

RQ1: *What are the cost elements related to handling a RMA-case?*

RQ2: *What strategies are other companies using for similar repair cases?*

RQ3: *How should Axis decision model be constructed to handle their product repairs?*

The objective of the master thesis is to create a decision model that simplifies the decision making and enables Axis to make accurate and consistent decisions based on facts rather than feeling. To achieve this, extensive mapping of Axis's RSC will be carried out, and inspiration from reference companies with similar products will be pursued.

1.5 Focus and delimitations

This thesis has a limited time frame which creates a need for delimitations. The delimitations originate from discussions with the supervisors at Axis and Lund University. The focus of this report is to create a concrete and usable decision model.

The return flow is complex with barriers such as customs, trade regulations and disputes between countries affecting the supply chain. Therefore, it was decided to exclude certain countries. This report will focus on returns to RMA03 and RMA04 which are handling the vast majority of returns. Further, the product catalog is vast, containing over hundred products, a limited amount of them will be studied. Firstly, since it is Axis core business, the study will only include cameras. This entails exclusion of other products such as radars, audio systems, etc. Secondly, only a limited amount of cameras will be studied. However, the cameras selected are believed to represent both the product catalog and the failures occurring fairly.

The study will only investigate the return flow from end customer regarding non-functional products, returning when Axis is obligated to offer service to the customer. Therefore, other types of returns will be excluded. As examples, a return from a configuration logistic center (CLC) to an EMS due to necessary adjustments before reaching further in the supply chain will be excluded. Alternatively, a distributor that, in line with the contract, returns a certain quantity of products purchased due to lack of sales, called stock rotation. These are two examples of returns that not will be studied.

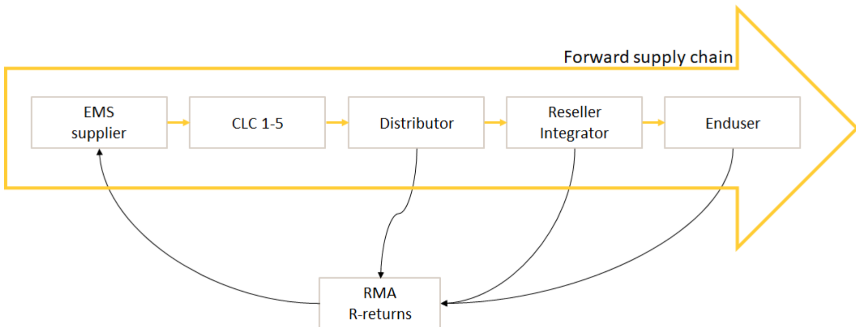

Figure 1.5: The forward and reverse supply chain (Adapted from: Axis (2018))

To clarify this, the concerned flow is illustrated in Figure 1.5, which in some way may be conflicting with the earlier statement ”investigate the return flow from end customer”. However, in some cases, the end customer first ship the product to the distributor or re-seller whereupon the product gets shipped to an RMA-partner.

1.6 Target group

This thesis target group is people with knowledge and interest in logistics, supply chain management and RSC. The main target is the RSC department at Axis Communications.

1.7 Report structure

The first chapter to follow the introduction is Chapter 2 - *Methodology.* In this chapter, different research methods and approaches are described. Pros and cons are discussed, and then an appropriate method is decided. This is followed by a section about different aspects regarding research data collection. Finally, there is a section about credibility and research design.

In Chapter 3 - *Literature Review*, the theory for the master thesis collected from books and articles is presented. It starts with a comprehensive description of the concept of RSC. This is followed by a short introduction to warranties. Later, the costs related to a RSC, and decision support models are presented. The costs associated with the RSC is the most significant part of the section and aims at describing both costs and processes in a RSC.

In Chapter 4 - *Empirical Study*, all information collected from Axis is presented. The chapter starts with introducing the studied return flow followed by how EOL is managed. Lastly, data concerning the flow and costs for the studied products are presented.

In Chapter 5 - *Reference Companies*, all information collected from the reference companies are presented. The chapter is divided into three sections, one for each company. In the paragraphs, every company is briefly introduced, followed by six subsections describing the reference companies approach of handling returns.

In Chapter 6 - *Analysis*, information from the literature review, the empirical study and the reference companies are analyzed to find answers to research questions one and two. From the start, these two questions were believed to be enough to create a solid recommendation to Axis. This was, however, not the case. Additional information was therefore analyzed in Chapter 6, sections 6.3 - 6.5. The final research question is answered in Chapter 7.

In Chapter 7 - *Recommendation*, a recommendation to Axis is presented, answering research question three together with some additional recommendations.

In Chapter 8 - *Conclusion*, the final conclusion is presented and all of the research questions are answered. Lastly, the contribution to theory is stated and future research topics are presented.

Chapter 2

Methodology

This chapter intends to highlight the different options possible within methodology and explain why the selected path is appropriate. The structure of the chapter is illustrated with the research onion presented in the first section. The derived method often correlates to the type of study being executed which also is the case in this thesis.

2.1 Layers of Method

The methodology consists of different layers, like an onion. Combined, the layers are illustrating the structure of this chapter, and each part will be presented further. The different layers and their relations can be seen in Figure 2.1. The method is adapted from the research onion presented by Hair (2007). The illustrated approach has however been modified and adapted to be suitable for a master thesis, the original approach is argued to be more suitable for a PhD dissertation (Barcik, 2016).

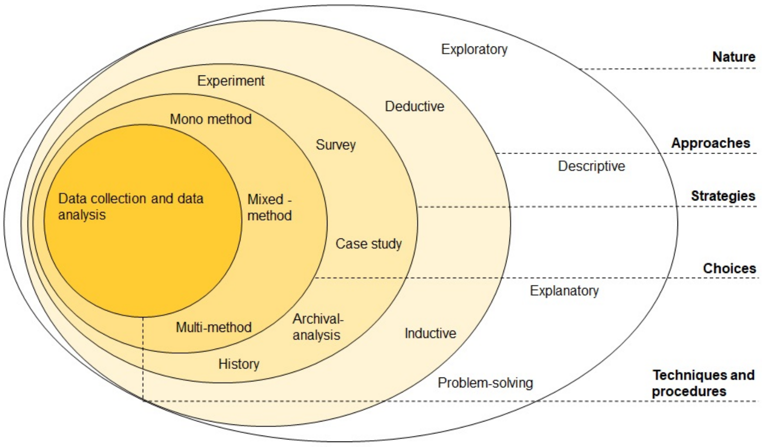

Figure 2.1: The method layers (Adapted from: Hair (2007))

2.2 Nature of research

The knowledge within an area sets the limitations of what research nature that is suitable. Below are the four most common research natures presented by Höst, Regnell, and Runeson (2012).

- Exploratory is an investigatory method, it is suitable when there is limited or little information within the research area, and the research is looking to create a fundamental understanding.
- Descriptive research is used when a fundamental understanding of the research topic exists, and the goal is to describe a situation, problem, or a phenomenon.
- Explanatory research is suitable when it is desired to describe and explain a phenomenon, thus a combination of exploratory and descriptive.
- Problem-solving studies aim to find a solution to an identified problem. An important part of the process is to fully understand the problem at hand and contribute with knowledge and analyses.

Currently, there is a lack of guidelines and consistency in the decision making at the RSC department at Axis. This thesis is founded with the aim to determine and facilitate the decision making. With this background and Axis clear goal of solving and improving the situation of decision making the nature of this study is considered to be problem-solving.

2.3 Research approach

2.3.1 Inductive

According to Kotzab, Seuring, Müller, and Reiner (2006), the inductive approach aims to understand and explain a phenomenon. Briefly, the inductive approach suggests that the research process starts with acquiring knowledge and understand the phenomenon through data collection. For instance, one can gather data from field visits to observe the phenomenon in its natural habitat. The second step is to describe the phenomenon by including and exploring multiple dimensions and substances of the phenomena. Ultimately, this requires data from multiple sources in the form of, e.g., interviews, observations, and documents. Lastly, the outcome of this path is favorably a substantive theory based on descriptive data. Meaning, detailed qualitative data is analyzed and transferred to more general perspectives and expressed in some form of a model demonstrating the relationship of variables (Kotzab et al., 2006). To the left in Figure 2.2, the inductive approach is illustrated.

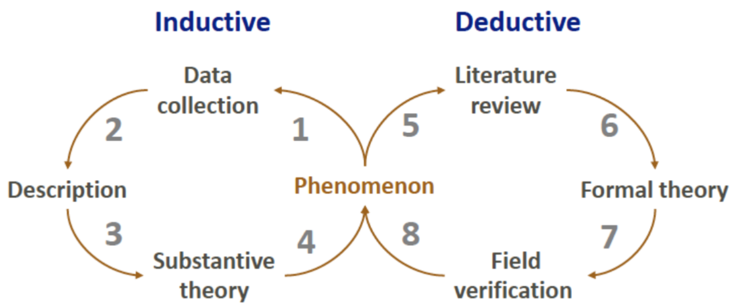

Figure 2.2: The Inductive and Deductive Approach (Source: Woodruff (2003) refereed to in Olhager (2018))

2.3.2 Deductive

The deductive approach is the most common research approach within logistics and supply chain phenomenon according to Kotzab et al. (2006). The goal is to add on to the existing knowledge, describe the phenomenon, and conversely to the inductive approach, predict the phenomenon. As illustrated in Figure 2.2, the process starts with a thorough literature review and creation of a conceptual framework that specifies variables and the potential relationship between them. In this stage, a researcher can collect data with the objective to clarify variables and its relationships. The next step is to design a formal theory based on existing theory (Kotzab et al., 2006). Formal theories are general and should both be able to predict the phenomena and be tested, using real-world data about the phenomenon (Hunt, 1991). Before entering the third and last step, the researcher proposes answers to the research questions that may or may not, be confirmed by the last step, data collection. The data collection aims to compare and hopefully strengthen the proposed relationship between variables in the phenomenon (Kotzab et al., 2006).

2.3.3 A balanced approach

Having explained the inductive and deductive approaches, Kotzab et al. (2006) discusses in their book the possibility to be in between these two approaches, tracking back and forth and carry out a somewhat balanced approach (or abductive approach). This is motivated by the dynamic and complex characteristics often seen in supply chain phenomena. In addition, in his article *Logistics needs qualitative research–especially action research*, Näslund (2002) emphasizes that supply chain phenomena are ill-structured and messy problems since they often involve more than one party. Therefore, according to Kotzab et al. (2006), when dealing with a new or complex phenomenon, one should consider starting with fully understanding the phenomenon (i.e., inductive approach) and then investigate potential relationships among variables (i.e., deductive approach). Ultimately, this results in a combination of the approaches - tracking back and forth.

2.3.4 Selected approach

In line with what Kotzab et al. (2006) discusses; tracking back and forth between inductive and deductive approach, the authors agree that building a comprehensive understanding of the problem through both empirical studies and literature simultaneously, is necessary for this study. When the problem is fully understood, the formal theory will be conducted, followed by a field verification and possible adjustments. Therefore, the authors argue that a balanced approach, tracking back and forth, is suitable for this research.

2.4 Research strategy

2.4.1 Research strategies

According to Yin (2018), three major conditions should be considered when deciding what research strategies to use. Table 2.1 points these out, and how the conditions are related to five research strategies: experiments, surveys, archival analysis, histories, and case studies. An experiment is an empirical investigation in a controlled environment with the aim to find root-causes and the effect of specific factors. A survey is a method to collect detailed data for a specific point of time. An archival analysis is a type of research involving seeking information and extracting information from original archival records. History research is used when no contemporary data or individual can explain a situation. Thus, historical archives are used and relied on in the research (Yin, 2018). According to Leonard-Barton (1990) a case study can be described as a history of a past or a current phenomenon, collected from multiple sources. The data can be direct observations, interviews or literature.

Table 2.1: Relevant situations for different research methods (Source: Yin (2018))

Method	Form of research question	Requires control over behavioral events	Focuses on Contemporary events
Experiment	How, why?	yes	yes
Survey	Who, what, where, how many, how much?	no	yes
Archival analysis	Who, what, where, how many, how much?	no	yes/no
History	How, why?	no	no
Case study	How, why?	no	yes

The research question can guide one to a suitable method. Yin (2018) mentions that there are different depths, of a question. For instance, a ”what” question can be ”What can be learned from...”, Yin also argues that ”how many”, ”how much” questions are derived forms of a ”what” question. The first example is a broader question, and any of the five methods could be suitable whereas the other type of ”what” questions are possible to quantify. Thus, the questions can be answered by statistic, hence a survey or analysis of archival data would be appropriate. Conversely, the ”how” and ”why” questions are more explanatory and are according to Yin (2018), likely to lead to the use of a case study, history, or experiment. The reason for this is because such questions consider a process over time, rather than samples or frequencies. Further, an experiment is the only method that requires control over behavioral events and all methods focuses on contemporary events, except for archival analysis in some cases and history.

2.4.2 Selection of research strategy

The authors have chosen to use the case study as the research strategy. Other methods mentioned in Table 2.1, experiments, for instance, requires separation between the phenomenon and its natural context, i.e., you need to control the process, which is not possible in this project. This project also focuses on the contemporary events, which is why historical research and archival analysis alone, would not be suitable. Finally, survey research would not be appropriate to this research because it does not provide the depth in answers required to fulfill the purpose of this project. Further, for research with the purpose to describe a phenomenon in its nature, without controlling the behavioral events, and the focus is on contemporary events, the case study methodology is suitable. Noteworthy, Yin (2018) also emphasizes that a case study is not limited to either quantitative or qualitative data, which strengthens the motivation of case study even more since the authors consider both quantitative and qualitative data.

2.5 Research data

The quality of any research can never be better than the quality of the data used. Therefore, high-quality data is key to any research. Data can be categorized into primary and secondary data. Primary data is for instance data from interviews where the data is collected to be used in a specific study. Secondary data is data from, for instance, articles or literature which have been produced for other reasons than the specific research or study, i.e., generic models, theories, etc. (Björklund & Paulsson, 2014).

2.5.1 Quantitative and qualitative data

Quantitative data are built on information that can be measured and evaluated. Quantitative data can be processed with statistic methods. However, everything cannot be measured by numbers and the use of quantitative data is therefore limited in terms of fewer opportunities to generalize situations (Höst et al., 2012; Björklund & Paulsson, 2014).

Qualitative data are suitable when the researcher wants to create a deeper understanding of a specific problem or situation. It consists of words rather than numbers and is generally a description or an explanation of a problem. Qualitative data can be analyzed by categorizing it and interpret patterns. For complex problems, a combination is often used, where quantitative data consisting of numbers are combined with qualitative data from, e.g., interviews (Höst et al., 2012; Björklund & Paulsson, 2014).

This thesis will combine both quantitative and qualitative data. The reason for this is that not all factors are numerical or measurable. Therefore, a combination is believed to be most suitable

2.5.2 Literature review

Literature is defined as all forms of written and reproduced material, e.g., books, publications, and articles. During the different phases of the thesis, the purpose of the literature review will change. The literature is divided into to blocks. In the early process of a thesis, the literature review is used to obtain knowledge about the subject. Later in the process, returning to the literature is a way to compare results (Höst et al., 2012). The strength of literary studies is the possibility to obtain a lot of information in short time in a relaxed environment (Björklund & Paulsson, 2014).

2.5.3 Interviews

Interviews are primary data and consists of various types of questioning which can occur face to face, through phone, web, or email, etc. Below, the most common forms of interviews are explained (Björklund & Paulsson, 2014).

- Structured interviews, meaning all questions are determined beforehand, asked in a specific order. The goal is that every interview should be executed as similar to each other as possible.

- Semi-structured interviews are interviews where the questions are determined beforehand but asked when the interviewer thinks it is suitable. The interview is more open and not as regulated as a structured interview.

- Unstructured interviews can be entirely in the form of a conversation without any preparation. This means that the conversation will be different every time and cannot be reproduced.

The different interview types are suitable for different situations. Structured interviews are suitable when it is essential to compare different interviews. Unstructured interviews are appropriate when the aim is to achieve depth in the interviews. Semi-structured interviews are something in between and are suitable when one aspire for both depth and the opportunity to compare results (Corbin & Morse, 2003).

In this thesis, the interviews will be of a semi-structured type. The reason for this is the importance of deeply understanding the problem. To do so, the authors believe it is essential to have the possibility to ask follow-up questions, which is not possible in structured interviews. Further, an unstructured interview would eliminate the opportunity to compare the different interviews. Therefore, semi-structured interviews are believed to be the most suitable method.

2.5.4 Data collection at Axis

Corporate documents from Axis are used to further understand the situation of Axis RSC. Some documents are in the form of literature while other are numerical data in the form of excel sheets. Some of the data is also classified as a company secret, and therefore some key numbers might be left out of this publication.

Obtaining one hundred percent true and updated data is hard, since data is continually changing. Therefore, there will be a point in time where the data will be obtained, meaning that new updates to the data will not be considered from that point. The reason for that is not to have to work with live data. Axis has a number of different tools for data extractions, these tools contain different information and are developed with a different focus. These tools, however, are still under development and demand certain access. Therefore, the data used will consist of an unprocessed Excel-files. This decision is made on the preference of having total control of the data regarding the exact point of extractions and processing.

2.6 Credibility

2.6.1 Validity, reliability, and objectivity

Validity, reliability, and objectivity are cornerstones in creating research of high quality. Below, the three concepts are described according to Björklund and Paulsson (2014).

- Validity is how accurate you measure what you actually sat out to measure.
- Reliability is how reliable your measurements are. For example, are you getting the same results if you measure on two different occasions?
- Objectivity is the authors' ability not to affect the studies. The goal is to let the facts and data guide the outcome and draw all conclusion based on data rather than personal beliefs.

The game of dart can illustrate validity and reliability. Validity is how good the player is to hit the bullseye. On the other hand, high reliability is how good the player is to get the darts in the same place at every throw. High validity and high reliability mean the players hit the bullseye over and over again this can be seen in Figure 2.3 (Björklund & Paulsson, 2014).

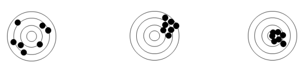

Figure 2.3: Illustration of validity and reliability (Björklund & Paulsson, 2014)

The picture to the left means low reliability and validity. The second picture has a high reliability but low validity. Finally, the picture to the right has high reliability and high validity (Björklund & Paulsson, 2014).

2.6.2 Increasing credibility

By using different perspectives and sources to investigate a situation the reliability of the research can be increased. Using two or more different methods on the same study object is called triangulation and is illustrated in Figure 2.4 (Björklund & Paulsson, 2014).

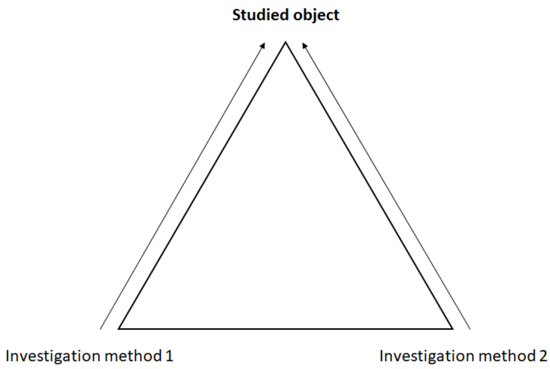

Figure 2.4: Illustration of triangulation (Source: Björklund and Paulsson (2014))

Triangulation can according to Björklund and Paulsson (2014) be decomposed to three different types. When various sources of data are used, it is referred to as data-triangulation. In the same manner, using or applying different theories to the same data is called theoretical triangulation. Further, sometimes the evaluation of a situation can be subjective and different between people, therefor evaluator-triangulation is an appropriate method to obtain a different perspective of a situation, meaning different people (i.e., evaluators) are used for the evaluation.

RSC is a relatively young research topic, and the existing literature is rather new. To strengthen up this new and sometimes limited cited sources, theoretical triangulation is used, hence the reliability of the later proposed conclusions is increased.

To achieve good validity, reliability and objectivity data triangulation will be used. Some of the interviews are, however, probably bias since people tend to talk good about their accomplishments. However, since multiple interviews will be conducted the risk of misguidance will be decreased. The fact that the research team consists of two authors is believed to improve the quality of the report. The authors will check each other's contributions and validate the other author's work.

2.7 Research Execution

The research execution can be divided into three phases, seen in Figure 2.5. It started with building a foundation for the problem, related theory and understanding Axis. The second phase was data collection at Axis and interviewing the reference companies, creating a deep understanding for how Axis works and what other strategies and approaches there are. The final phase was analyzing the information creating a conclusion and creating a common thread through the report.

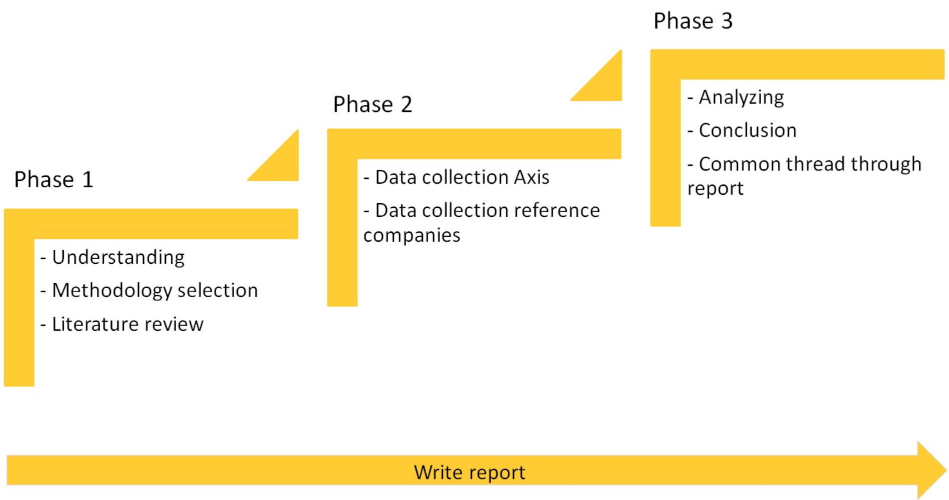

Figure 2.5: The three phases in the execution

2.7.1 Phase 1

The study began with an introduction to Axis, their business model, strategy and history. This was followed by an introduction of the RSC department and their responsibilities. Interviews, discussions and the literature review created the foundation of our understanding. Then methodology was discussed and selected.

2.7.2 Phase 2

The data collection consists of interviews with people at different departments and internal documents. External interviews with three reference companies where also conducted, where a lot of effort was put into finding companies with different approaches to handling returns but still having a product that in some sense is similar to Axis. During this phase the report was constantly updated and new findings were added.

2.7.3 Phase 3

Phase 3 was the final phase, the first part of phase 3 was analyzing all the empirical data that was collected. To some extent, a comparison between the literature and empirical data were also executed. This made it possible to answer the research questions and create a solid recommendation. Summarizing it all in the conclusion and making sure there was a common thread through the report.

Chapter 3

Literature Review

This chapter describes theory found in the literature. The goal is to give a solid understanding and present relevant research properly and understandably. The chapters are structured to build up the readers knowledge rather than in chronological order of usage in this thesis.

3.1 The reverse supply chain

The RSC is the coordination, cooperation between partners, and set of activities for products returned from end users to retailers, manufacturers or suppliers to either dispose the product or in any way reuse it (Hung Lau & Wang, 2009; Gupta, 2013; Guide Jr & Van Wassenhove, 2002).The prevalent definition of a RSC within operations management, devised in Guide Jr and Van Wassenhove (2002), is defined by the following processes, also illustrated in Figure 3.1:

- **Product acquisition -** The quality, quantity, and timing when acquiring products from a customer must be managed carefully. In contrast to forward supply chains, the product quality, and quantity, are unpredictable and can vary between cases. Thus, the consequences of careless product acquisition can be that companies are overwhelmed with products that deny an efficient flow (Guide Jr & Van Wassenhove, 2002).

- **Reverse logistics -** This term should not be confused with ”The reverse supply chain”

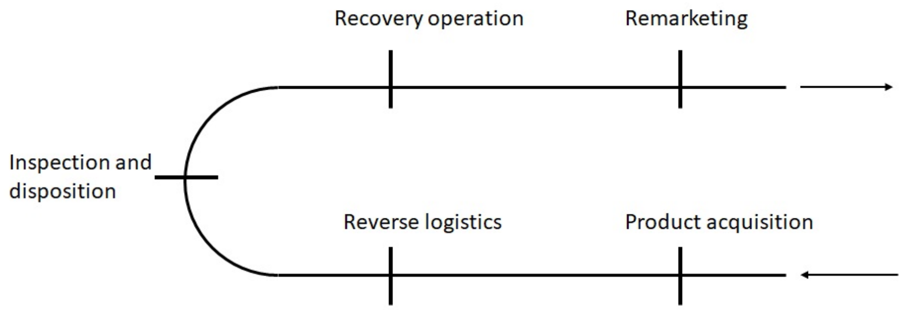

Figure 3.1: The reverse supply chain (Source: Adapted from Larsen and Jacobsen (2014))

although there are studies in the literature using the terms interchangeably. Reverse logistics is one of the elements in a RSC and is about the transportation, production planning, and inventory management (Gupta, 2013; Prahinski & Kocabasoglu, 2006). The reverse logistic design should be custom-made depending on the product characteristics, such as bulkiness, fragileness, and economic value. For instance, handling a tire is different than handling a camera. One should also consider the value, and the change in value, of a product during this phase. Which should be opposed to what type of transportation used and efficiency in the product handling (Guide Jr & Van Wassenhove, 2002).

- **Inspection, sorting, and disposition** - Once the product is collected, it needs to be tested, sorted and graded to determine the right recovery operation. This process is time-consuming, and any possibility for increased efficiency should be considered (Tibben-Lembke & Rogers, 2002). In this situation, the disposition decisions should be made as early as possible, i.e., decide the next step (i.e., what recovery operation to perform) for the product, depending on quality, product complexity, and other variables (Guide Jr & Van Wassenhove, 2002; Rogers, Lambert, Croxton, & García-Dastugue, 2002).

- **Recovery operation** - There are plenty of different options for a product to be distributed at this stage (Larsen & Jacobsen, 2014; Tibben-Lembke & Rogers, 2002; Guide Jr & Van Wassenhove, 2002). Potentially it only requires a repacking before it enters the market again. However, more work-intensive actions may be necessary such as repairing, refurbishing, or re-manufacturing (Gupta, 2013). Lastly, one could break down the recovery operations to product, component and material reprocessing (Geyer & Jackson, 2004).

- **Distribution and sales -** Depending on what kind of recovery operation that has been selected, the product is distributed to either the original or a new customer in the same or different market. There is a possibility that a market for refurbished products exists, containing customers who cannot afford the original product (Guide Jr & Van Wassenhove, 2002). In those cases the product is disassembled, the components or materials can re-enter the forward supply chain (Geyer & Jackson, 2004).

Further, these processes and a general flow of the forward supply chain are illustrated in Figure 3.2. The curved-edged boxes are related to the reverse flow, and the rectangles in the top are related to the forward flow. The arrows are representing a physical flow, and the upward pointing ones connect the RSC with the forward supply chain - creating what literature names closed-loop supply chain (Govindan, Soleimani, & Kannan, 2015; Guide Jr & Van Wassenhove, 2009; Savaskan, Bhattacharya, & Van Wassenhove, 2004).

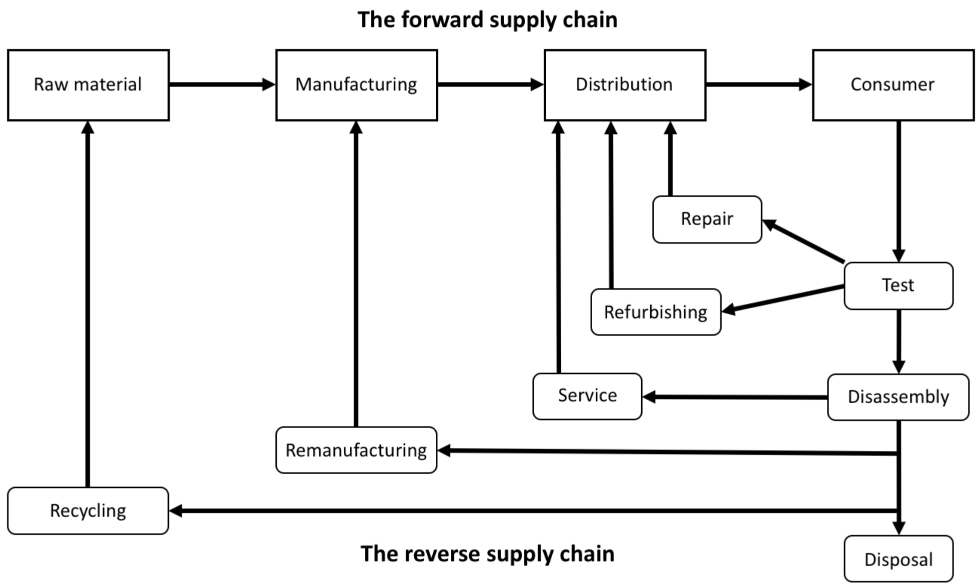

Figure 3.2: Flow diagram of a reverse and forward supply chain (Source: Adapted from Srivastava (2008))

Overall, companies that are successful with their RSC tend to integrate it with their forward supply chain. Meaning they apply a holistic approach and keep potential recovery operations in mind when, e.g., designing the products, contract suppliers, or manufacture the product (Guide Jr & Van Wassenhove, 2002).

3.2 Costs related to reverse supply chain

Larsen and Jacobsen (2014) conducts a literature review and a case study with the aim to identify the costs related to the RSC. The costs are separated into RSC investment costs and RSC operating costs. The case study was performed with three case firms in different industries (industrial measurement equipment, medical equipment, and water distribution equipment) who were performing different recovery operations. Further, the literature review identified operational cost parameters from Geyer, Van Wassenhove, and Atasu (2007) in terms of cost of collection, inspection, product recovery, and disposal. Atasu, Toktay, and Van Wassenhove (2013) elaborate further on the structure of collection costs. Moreover, Hu, Sheu, and Huang (2002) constructed a model with the objective to minimize the reverse logistic costs for treatment of hazardous waste. The included cost parameters were (1) total collection cost, (2) total storage cost, (3) total treatment cost, (4) total transportation cost for reusing processed wastes, and (5) total transportation cost for disposing of processed wastes.

Regarding investment costs for a RSC, Larsen and Jacobsen (2014) claims it is among the least described costs in the existing literature. This could be explained by that most processes in an RSC are performed manually. Thus it does not require substantial investments in machines etc. However, they identify a handful of them in their case study, presented in Table 3.1.

Table 3.1: RSC investment cost elements (Source: Adapted from Larsen and Jacobsen (2014))

Investment costs
Cost of introducing take-back of products with current customers
Cost of hiring and training new employees for dissasembly, product test, and logistics
Cost of new equipment for dissasembly and refurbishing
Cost of initial introduction of ”new” products to new and existing markets

Lastly, Larsen and Jacobsen (2014) present further findings from the literature review and the case study in a table similar to Table 3.2. The table presents a combination of operational cost elements identified from their literature review and their case study. The cost elements are divided into the five processes of an RSC, described in Section 3.1.

Table 3.2: RSC operating cost elements (Source: Adapted from Larsen and Jacobsen (2014))

Operational cost elements				
Product acquisition	**Reverse logistics**	**Inspection and disposition**	**Recovery operations**	**Remarketing**
Buy-back costs of items	Costs of collecting items	Cost of inspection and sorting	Costs of product dissasembly	Cost of continous remarkering to new and existing markets
Cost of adm. take-back from customer for local BU	Item inventory holding costs at local BU	Cost of initial product test	Cost of a standard exchange of wear components	Cost of selling products prior to recovery
Cost of initial screening (recovery or disposal)	Order picking and shipping costs from local BU	Cost of cleaning products and components	Cost of refurbishing and reassembly	Cost of administrating the order process
Cost of disposal of non-recoverable items	Transport costs from local BU to central site	Cost of inserting working products into forward flow	Cost of final product or component test	Cost of cannibalized virgin product sales
Adm. of payment between local BU and central site	Materials handling costs when receiving items			
	Item inventory holding costs at central site			

In the following subsections, the five critical areas of a RSC and its cost elements will be thoroughly investigated.

3.2.1 Product acquisition

In the broad context of product acquisition in RSC, literature highlights the buyback-price as the primary cost item within product acquisition (e.g., Guide Jr, Teunter, and Van Wassenhove (2003); Atasu et al. (2013)). The buyback-price is, for what price can one buy back a product from either a customer, third-party agency or a broker (Daniel, Guide Jr, & Jayaraman, 2000). In these cases, the quality, quantity, and timing can be somewhat controlled since the concerned entity place orders from their own requirements. Conversely, Mitra (2007) develops a pricing model to maximize the expected revenue from the recovered products, he provides a different perspective where he assumes that the producer is obligated to recover (or dispose) the returns. Due to the assumed obligation (which results in that the concerned entity cannot control quality, quantity, and timing), the acquisition price is not an issue. Furthermore, Larsen and Jacobsen (2014) also identified the aforementioned cost, along with other costs such as administrative costs, presented in Table 3.2.

3.2.2 Reverse logistics

Costs that are related to reverse logistics are associated with the different activities in the reverse logistic process such as transportation and inventory activities. Conversely to forward logistic; one to many, reverse logistic are many to one (Gupta, 2013; Tibben-Lembke & Rogers, 2002). As a result, the cube utilization in transportation is hard to maximize, and standardized pallets and processes are nearly impossible to achieve because of the variety of product types and quality. Consequently, these cost items are generally higher in the reverse flow (Gupta, 2013; Tibben-Lembke & Rogers, 2002). More precisely, Tibben-Lembke and Rogers (2002) points out that transportation costs and handling costs are significantly higher for reverse logistic compared to forward logistic. On the other hand, Teunter (2001); Tibben-Lembke and Rogers (2002) argues that the holding cost for products in the reverse flow are lower compared to in the forward flow since the holding cost is a percentage of a product's value.

In literature, numerous articles discuss, or develop models that optimizes the reverse logistic network design (e.g. Barker and Zabinsky (2011); Vahdani, Tavakkoli-Moghaddam, Modarres, and Baboli (2012); Srivastava (2008); Gupta (2013); Gobbi (2011)). For instance, Barker and Zabinsky (2011) present a multicriteria model for reverse logistic network design, using an analytic hierarchy process. Briefly, the model address three areas; collection, sort-test, and processing, each containing two alternatives. The collection is separated between *proprietary collection*, in which the producer only collect its own products, and *industry-wide collection*, in which multiple producer's products are collected in the same stream. Further, processes for sorting and testing are either *centralized*, where products are taken to the same location, or *distributed*, in which products are sorted and tested near the collection site. Finally, the processing is separated between *original facility*, where the producer uses its facilities, and *secondary facility*, where the facility, for example, could be shared with other producers. Ultimately, the model results in eight different outcomes for how a reverse logistic network could be designed. For instance, the model could propose that a company should have a *proprietary collection* with *centralized* testing and sorting in an *original facility*.

3.2.3 Inspection, sorting, and disposition

The next steps are inspection, sorting, and disposition (Genchev, Glenn Richey, & Gabler, 2011; Gupta, 2013). The inspection can be carried out as a physical inspection or with automated testing equipment (Genchev et al., 2011). Generally, inspection is a labor-intensive process that should be completed as quickly as possible to limit the expenses (Rogers et al., 2002). Moreover, Tibben-Lembke and Rogers (2002) emphasizes that the inspection is difficult and costly due to the lack of uniformity regarding product types and quality. Sorting is the next sub-process that directs a product to the right disposition point (Thierry, Salomon, Van Nunen, & Van Wassenhove, 1995). Disposition is the last process in reverse logistic (Agrawal, Singh, & Murtaza, 2015) and refers to what exit path the product will take (e.g., repair or refurbish) (Badenhorst, 2018). Genchev et al. (2011) stress the importance of creating formal disposition options (i.e., recovery operations), which will be reviewed in the following subsection.

3.2.4 Recovery operations

The goal of any product recovery operation is to bring as much economic value as possible from the product and thereby reducing the total cost. There are five different recovery options; repair, refurbishing, re-manufacturing, harvesting, and material recycling. The major differences in the various recovery operations are the quality, result, and the amount of work (Thierry et al., 1995). A overview of the different recovery operations and their differences are presented in Table 3.3.

3.2.4.1 Repair

Repairing is about making a product with malfunctions usable. The repairing procedures can look very different, and in some cases, the repair process means changing out entire components, while in others it means repairing malfunctioning components. This varies with the product, and the company policies (Cohen, Agrawal, & Agrawal, 2018; Thierry et al., 1995). The quality of a repaired product is generally inferior to the quality of a new product (Thierry et al., 1995). The cost of reparation is, the cost of disassembly, exchange of components, reassembly, final test, and staff training (Larsen & Jacobsen, 2014; Fowler, 1981).

Table 3.3: Comparison between product recovery options (Source: Thierry et al. (1995))

	Level of Disassembly	Quality Requirements	Resulting Product
Repair	To product level	Restore product to working order	Some parts fixed or replaced by spares
Refurbishing	To module level	Inspect all critical modules and upgrade to specified quality level	Some modules repaired/replaced; potential upgrade
Remanufacturing	To part level	Inspect all modules and parts and upgrade to *as new* quality	Used and new modules/parts combined into *new* product; potential upgrade
Harvesting	Selective retrieval of parts	Depends on process in which parts are reused	Some parts reused; remaining product recycled/disposed
Recycling	To material level	High for production of original parts; less for other parts	Materials reused to produce new parts

Yun, Murthy, and Jack (2008) investigates what servicing strategy that is optimal. They argue that a repaired product has a higher probability of failure than a new product. This problem is also discussed by Rao (2011). He argues that making an economic decision in warranty servicing, one needs to consider more than the immediate costs. One also has to take future potential costs of repair and replacements into consideration. There have been some different papers published in this area. Murthy and Nguyen (1988) propose a repair cost limit policy based on the immediate repair cost. Another strategy is presented by Biedenweg (1981), who propose replacing products which fail in the initial phase and to repair products that fail in the later part of the warranty.

3.2.4.2 Refurbish

A refurbished unit is referred to a unit that has been returned to the manufacturer who restores the unit to full-functioning conditions. A refurbished unit is often a unit that has been used lightly or very gentle by the previous owner. A warranty is often included when purchasing a refurbished product. However, the product has been used before, meaning there might be some minor flaws, and the lifetime is generally reduced when comparing to a new product (Thierry et al., 1995). The costs related to refurbishing a unit is similar to repairing one. The differences are described in Figure 3.3.

3.2.4.3 Re-manufacturing

Re-manufacturing is a more complex procedure than repair or refurbish. Re-manufacturing involve complete disassembly of the product where all modules are extensively inspected. Worn-out or out-dated parts are fixed, and there is extensive testing involved to ensure quality. The goal is to attain the unit to its original condition or better (Filip & Duta, 2015; Kumar & Ramachandran, 2016; Thierry et al., 1995). From a customer's viewpoint, the re-manufactured product can be considered the same as a new product (CRR, 2018). Figure 3.3 show the difference from repair and refurbish.

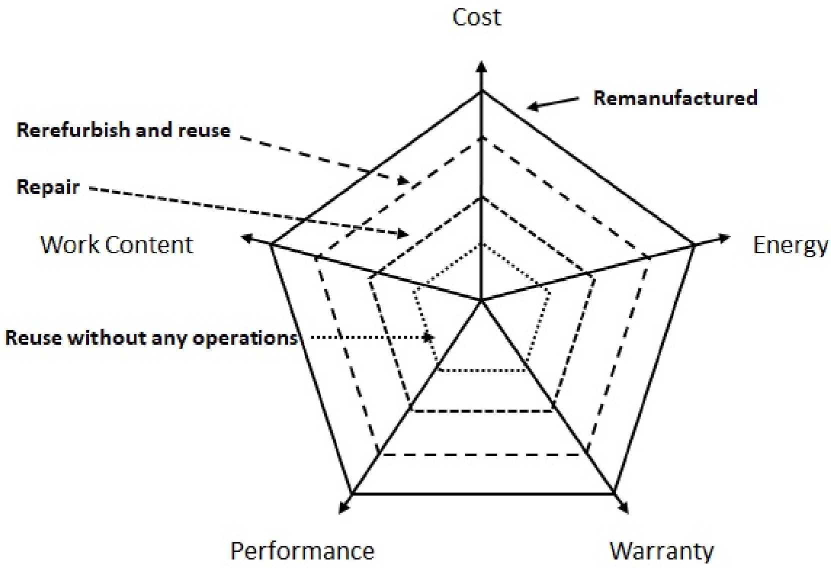

Figure 3.3: Comparison between different recovery options (Source: Adapted from Gharfalkar et al. (2016))

3.2.4.4 Harvesting

If none of the above recovery operations are appropriate, there is the opportunity to extract valuable components and resell or reuse them. This process is referred to as harvesting (FAMCe, 2018; Thierry et al., 1995).

Reusing harvested parts can vastly decrease reparation costs. However, it also has downsides which is discussed by Villasenor and Tehranipoor (2013). The paper is about the American airplane manufacturer Boeing bought used electronics and put them into critical components without testing or knowledge about their past, believing they purchased new components. When it later was discovered everything had to be re-manufactured immediately. Using harvested parts has a price, the quality of them is hard to know without extensive testing. The companies harvesting the parts often have to heat up critical parts to melt the solder. The handling and previous life of the components can profoundly affect the quality of the component (Villasenor & Tehranipoor, 2013).

3.2.4.5 Recycling and scrapping

The purpose of the previous recovery operations is to keep the functionality of a product or components. If this is not achievable, recycling or scrapping is an option. Recycling means reusing the material within the product. The material can then later be reused in the production of new products and components (Thierry et al., 1995). The economic impact related to recycling varies depending on the value of the material (Nelen et al., 2014). The last option is to scrap (or dispose) the unit, which involves land-filling or incinerating, however, this should be seen as the last resort when no other options are available (Badenhorst, 2018).

3.2.4.6 Disassembly process and cost structure

Before any repairing, refurbishing, or re-manufacturing can be started there has to be an investigation if it is economically feasible to take apart the product and to what degree, or if it should be harvested, recycled, or scrapped (Tang, Grubbström, & Zanoni, 2004). The economic impact of disassembling is illustrated in Figure 3.4 in which path B refers to a scenario where the components have little or no value, and the disassembly process is as expensive as the value of the parts. Another situation, where the product has valuable components that are easy to disassemble, then path A is an appropriate illustration. However, both these to scenarios are extreme representations as stated by Simon (1991). Usually, the parts having high value are spread out within the product.

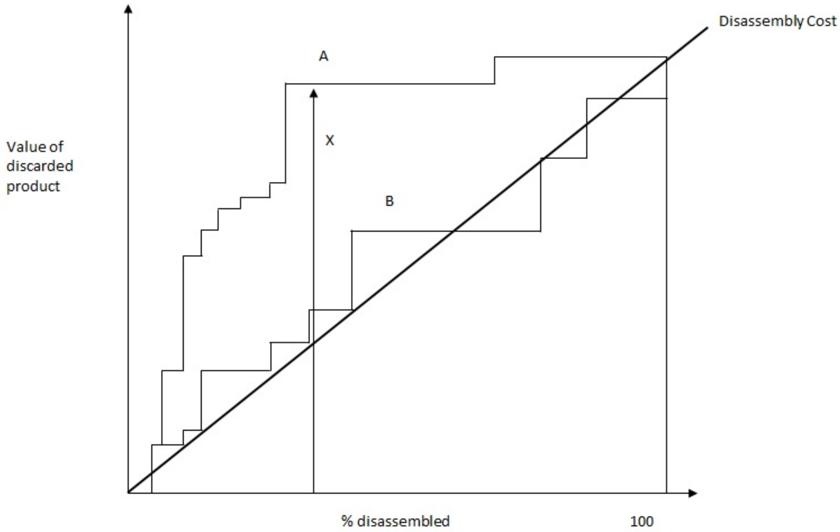

Figure 3.4: Profit maximizing in contrast to disassembly (Source: Adapted from Johnson and Wang (1998))

The figure is a simplification of the disassembly process, but according to Johnson and Wang (1998) it is showcasing two critical factors. The benefit of having high-value items easily accessible and the importance of optimizing the disassembly sequence to recover valuable component in the shortest possible time. Johnson and Wang (1998) argues that X is the point where the optimal economic value of the disassembly can be found or the end point of the disassembly.

Johnson and Wang (1998) argues that a decision has to be made about the product's components. Either you reclaim them from the product and repair them, or you dispose them. If no component in the entire product is worth reclaiming, the entire product is disposed. The different steps in the disassembly and the decisions can be visualized in a disassembly tree. Figure 3.5 is an illustration from a decision tree by Tang et al. (2004). A,B,C,D,E represent repaired or fully functional components, A',B',C',D' and E' represent broken components needing repair or replacement. The plus sign indicates a disassembly process.

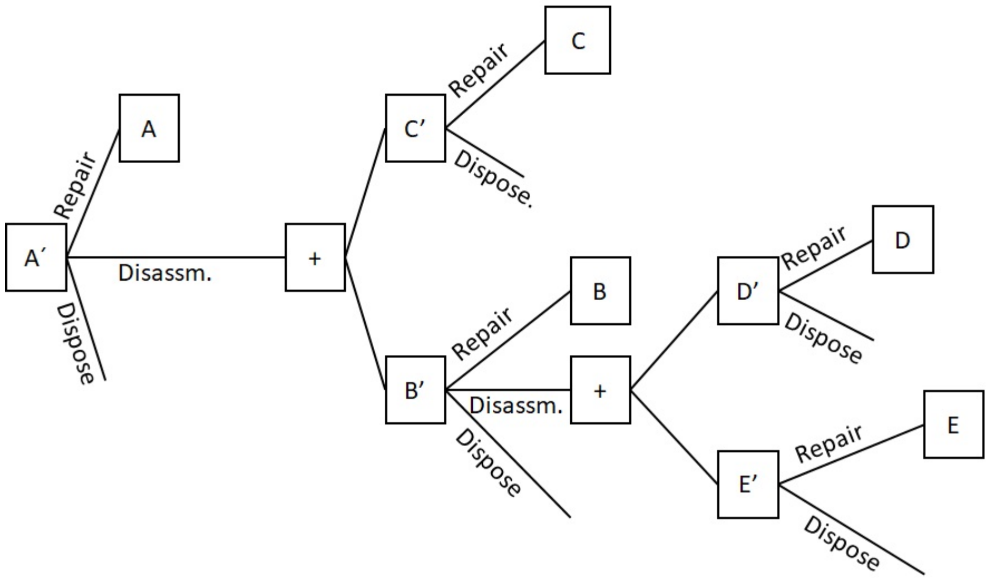

Figure 3.5: Disassembly tree of fictive product (Source: Adapted from Tang et al. (2004))

The disassembly tree should also contain the numeric value of the components in different steps and the repair cost, as well as any disposal value. By using the decision tree, one can facilitate the decision in whether it is worth disassembling or not (Tang et al., 2004).

3.2.5 Remarketing, distribution, and sales

The final step, to take the retrieved product back to the market is referred to as remarketing. It contains four main cost according to Larsen and Jacobsen (2014); (1) the cost of remarketing, (2) cost of selling products prior to recovery, (3) administrating the order process and (4) cost of cannibalized virgin product sales. Matsumoto, Chinen, and Endo (2017) stress the importance of creating an understanding and knowledge about the parts and their quality. If done correctly, this is believed to be the key to increase sales. The importance, and sometimes difficulties, of finding a market for the products are discussed by (Thierry et al., 1995; Kocabasoglu, Prahinski, & Klassen, 2007). When selling remanufactured products to the market, the seller is cannibalizing on his or her opportunity to sell new products. However, by selling the products to other segments, one can reach new customers they otherwise would not (Atasu, Guide Jr, & Van Wassenhove, 2010; Guide Jr & Li, 2010).

3.3 Warranty

A warranty is a contracted obligation from a seller, manufacturer or producer in connection with a sale of a product. Warranties are used as a way for sellers to convince the buyer of the quality of the product. With a warranty, the buyer is promised by the seller that the product will be repaired or replaced if any production malfunctions are found during a certain time or period (Murthy, 1992).

Warranties can either be one dimensional or two dimensional. A one dimensional is typically a warranty that lasts for a specified time (e.g., two years). However, when usage rates vary widely, the manufacturer might use a two-dimensional warranty. This is for example common within the automobile industry, where warranties, for instance, last either three years or 50 000 km whatever occurs first terminates the warranty (Rao, 2011).

3.4 Decision support model

According to William Starbuck, a decision is described as follows; *"Policy making could go on and on endlessly, and there are always resources to be allocated,"* he further states *"Decision' implies the end of deliberation and the beginning of action"* (Buchanan & O'Connell, 2006). Decision support models (DSM) are models to optimize the decisions being made (Konsynski, 1983). There exists a number of different DSM, like Decision matrix (Tague, 2004; Fabian, 2017) and Kano model (Togård, 2016).

3.4.1 Definition of a decision problem

Filip, Zamfirescu, and Ciurea (2016) talks about a decision problem as a situation that requires some action. For example, should I put the pizza in the oven or wait? Grünig and Kühn (2009) takes about the desire to reach a goal state with the decision. He further presents a decision problem as something that can be understood as a discrepancy between the target situation and the current situation, or where at least two options for action exist to deal with it.

Decision problems can be classified into two groups, simple or complex. According to Grünig and Kühn (2009), it is a complex problem when it consists of two or more of the following conditions:

- The decision makers are pursuing several goals at the same time. And some of the goals are not very precisely defined.
- The problem has a high number of possible problem-solving options.
- The future development of several environmental variables is uncertain.
- The decision makers possess limited experience about the consequences from the different problem-solving options.

According to Grünig and Kühn (2009), simple problems usually are well structured and are always a choice problem. Complex problems are on the other hand always ill-structured and mostly design problems.

3.4.2 Solving decision problems

There are a number of different ways to solve a decision problem presented by (Grünig & Kühn, 2009). It is possible to decide intuitively. Locke (2015) argues in the article *When It's Safe to Rely on Intuition (and When It's Not)* that the quality of the decision heavily depends on the expertise. Grünig and Kühn (2009) presents a second option which is by routinely resorting to solutions used in the past. Thirdly, they present a solution where you adopt a solution suggested by an expert. By doing so, you use their expertise within an area to get more knowledge than you had from the beginning. The fourth option is choosing at random. The final proposed deciding solution by Grünig and Kühn (2009) is using a systematic and rational thinking procedure. The different approaches can be classified into heuristic and analytic.

A heuristic approach uses simplifications that employs a practical method not guaranteed to be optimal. By using simplifications, a good enough solution can be found. The advantage is the lower execution cost, and the disadvantage is the non-optimal solution and a guarantee of any solution. In contrast to heuristic, an analytic approach guarantees the optimal solution but is more costly to apply. Figure 3.6 shows the heuristic approach in comparison to an analytic approach (Grünig & Kühn, 2009).

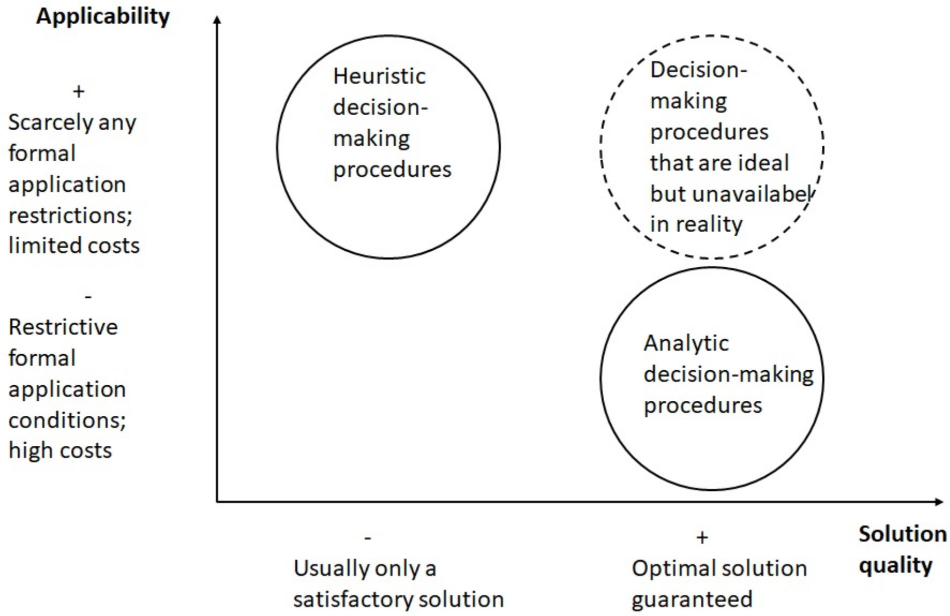

Figure 3.6: Heuristic decision making in contrast to analytic decision-making procedures (Source: Adapted from Grünig and Kühn (2009))

Chapter 4

Empirical Study

This chapter contains information collected from Axis, through interviews and data collection. The chapter is structured as follows: a thorough description of the studied return flow at Axis, followed by how EOL is managed. Lastly, data for the studied case products are presented.

4.1 Aftermarket

4.1.1 RMA-cases

Axis aftermarket services involves supporting customers with getting defective products repaired or replaced via Axis appointed channels. There are a three different RMA types, explained in Table 4.1. The RMA types describes how an item shall be handled towards the customer and how the main unit shall be handled by the RMA-partner. What kind of RMA type that a customer experiences depends on pre-defined agreement and the cause of error. If the product has exceeded the warranty period (out of warranty) or the cause of error is due to careless handling by the customer (warranty void), Axis offers to service the product whereupon the customer is charged for the service.

Table 4.1: The different types of RMA-cases and their presence (Source: Axis (2018))

RMA-type	Explanation	Distribution
Standard	The customer sends the reported main item to the RMA partner. The RMA partner will repair it and send it back to the customer. If a repair is not possible a replacement (new or refurbished) item is sent	63.3 %
Advance Replacement	The customer signs an agreement form that allows the RMA-partner to send a replacement item to the customer before the reported main item is returned	29.4 %
Dead on arrival (DOA)	Similar to the Advance Replacement process, instead a new sales unit is sent to the customer	7.3 %

The flow of products entering Axis RSC differs depending on the RMA type. Below, the flow for Standard and Advance Replacement are explained, the majority of returns are standard returns. The process for a standard return starts with the customer contacting Axis and the department Technical Services Engineer (TSE). They try to help the customer over the phone, to solve the situation. If it can't be solved over the phone, they prepare and authorizes an RMA-case. The unit is then shipped by the customer to an assigned RMA-partner. Further, an Incoming Quality Control (IQC) is performed to the unit. If the unit passes the IQC, it proceeds to testing, during the process the case is updated via a tool where Axis RSC-team can follow the process. If the unit can be repaired directly it is done, otherwise a refurbished or new unit is sent out as a replacement. If possible, the broken unit is later repaired by either the RMA-partner or the EMS and added into the RMA-pool. The RMA-pool is a collection of new and repaired units that are sent out as replacement units. The units in the RMA-pool is located at different RMA-partners, thus there are no single warehouse for the RMA-pool, the units are distributed all over the world.

The advance replacement process is somewhat different from the standard in the way that the customer gets the unit before returning the broken one. The process starts with the customer contacting Axis TSE. They try to solve it over phone, but if that does not work, they prepare and authorize a RMA-case. A replacement unit is then shipped to the customer who replace the broken unit and send it to an assigned RMA-partner. When received at the RMA-partner the process is the same as for a standard case. Flowcharts for the standard and advance replacements are presented in Appendix A.

4.1.2 RMA-partners

Axis has developed a network of RMA-partners all over the world, see Figure 4.1. There are three types of RMA-partners; supply controlled, supply non-controlled, and in some cases Axis office acts as RMA-partner. However, there is another distinctive factor yet to be introduced. Axis has three RMA-partners they also call RMA-sites, RMA01 in Sweden, RMA03 in Hungary, and RMA04 in America, these three sites are also ”ordinary” RMA-partners but they also acts as a consolidation points. Approximately 70 % of the RMA-cases are handled by RMA03 and RMA04, and 6 % is handled by RMA01. To clarify, if a RMA-partner (e.g. RMA06) receives a broken unit and after analysis realize they are unable to repair it, they send the unit to one of the RMA-sites (e.g. RMA03). They will in some cases try to repair it themselves, and in some cases they consolidate broken units received from multiple RMA-partner which are sent to the EMS. In addition, these three RMA-sites are located in the same building as CLC1, CLC3, and CLC4.

Figure 4.1: Axis global presence (Source: Axis (2018))

There are essentially three fundamentals that is required by a RMA-partner to repair a unit; knowledge, equipment, and spare-parts, all which varies between partners. The technical knowledge is for instance hard to obtain in Atlanta where RMA04 is located, furthermore, some partners tend to be better at solving complex problems with limited equipment than others. RMA-partners need equipment to mount and pick the cameras apart, as well as equipment for testing. The testing equipment allows one to ensure that a repaired unit is complete and functioning. To facilitate the repair process, Axis establishes repair manuals for all products that are used by the RMA-partners. A repair manual describes what parts and equipment that are required to repair a unit and also specific working instructions. Regarding spare-parts, the Supply group at Axis RSC department maintain and replenish stock to full-fill the demand. Components and spare-parts for tech-products are however scarce and hard to acquire in today's market, according to the RSC team. The spare-parts are in most cases funded by Axis but stored at the RMA-partners.

The first location for a faulty unit is often determined by the geographical location of the customer and RMA-partner. It is however not certain that the appointed RMA-partner can solve the problem, due to lack of the three fundamentals explained above. This entails that a faulty unit sometimes turns up at a RMA-partner, then a RMA-site, and lastly a EMS. In general, the RMA-sites have more equipment, knowledge, and spare-parts than other RMA-partners. A simplification of the flow is presented in Figure 4.2

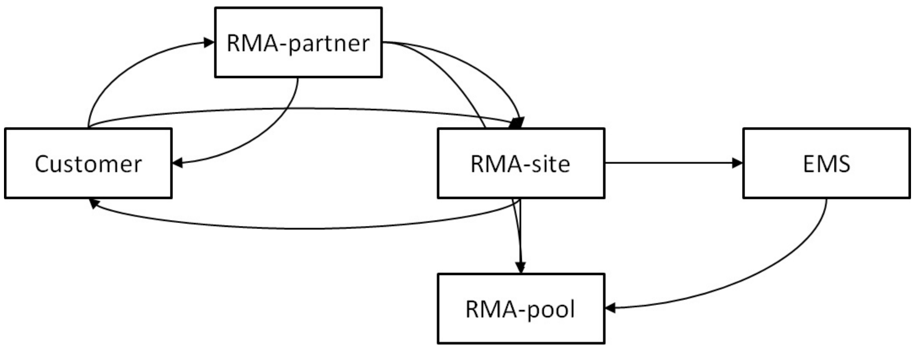

Figure 4.2: Simplification of the return flow (Source: Axis (2018))

Since November 2016 RMA04 have been trying a different strategy than used by other RMAs. Instead of following the Product Handling List (PHL)(the PHL is further explained in subsection 4.1.5) they have stopped with all repairs and instead been sending everything to the EMS. They do however inspect the unit to assure that it is something wrong with it. Axis thought this strategy would lower the cost, and improve the RSC. However, there have been no or little follow up on this. Although, Axis are now moving towards increasing repairs at RMA04, once again they believe it will lower the cost.

4.1.3 EMS

Axis uses six EMSs located around the world, see Figure 4.3. Besides production, the EMSs has a responsibility to repair faulty units and is the last resort following RMA-partners (or RMA-site).

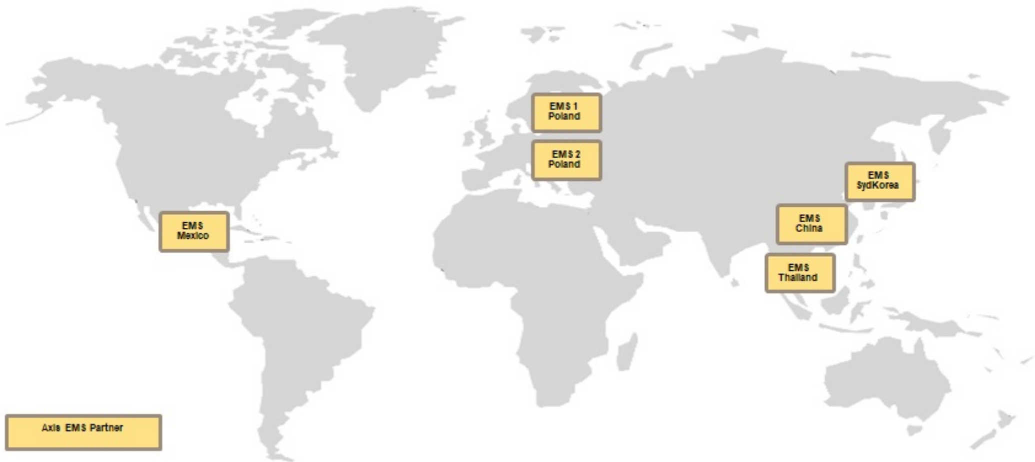

Figure 4.3: Axis EMS partners (Source: Axis (2018))

When a product is received at the EMS they start by inspecting the product to find the cause of failure. Even though one could think that some of the failures likely could be derived to the EMS, it is seldom the case that the EMS actually takes the responsibility for it. Meaning, it is uncommon that a EMS repairs a unit and the burden of cost is put on themselves, instead the cost is put on Axis. The cost of the repair depends on the components and time needed. Different EMSs has different limits on the maximum repair cost correlated to the COGS value. The EMS in Thailand and Mexico has a limit of 75 % of the COGS-value while the other EMSs has a limit of 50 %. To exemplify, if a product has the COGS-value $100 and the repair cost is estimated to be $60 the unit should not be repaired by the EMS, unless if it is the EMS in Thailand or Mexico.

When a product has entered EOL-state it becomes a lot harder to repair. The reason for this is that when a EMS stop producing a product they empty their stock of parts related to that specific product. Consequently, it is likely that a EOL product can't be repaired by the EMS unless Axis provides them with parts.

4.1.4 Testing equipment

To verify the quality and configure the products during production and after repairs the products are put through a number of test. The number of tests and equipment needed varies depending on camera, and the actions taken on the product. The most simple reparations only require a short functionality test, while more complex repair work demands more testing. Some equipment is generic but a lot of the equipment is also specific for a certain product.

The tests needed after a reparation is specified in the repair manual. However, since the price of the equipment often is estimated to be high, Axis tries to minimize the equipment at every RMA-partner, only providing them with the necessary equipment. This limits the reparations that can be done, and leads to reparations being sent from RMA-partners to the EMSs. The tests are divided on UA-level (EMS) and PU-level (RMA), depending on the repair performed. All equipment are bought by Axis and then supplied to the facilities needing them. There are however, poor documentation of location and quantity for the equipment. This makes it hard for the RSC-team at Axis to know if a partner has the appropriate equipment needed.

When a product enters EOL the CLCs are noticed and as soon as the production stops they usually contact Axis to get a decision on what to do with the testing equipment used for production. Since the contacted department aren't in connection to the RSC-team, nine out of ten times, the equipment is scrapped. This creates a lack of testing equipment since this equipment often is used by the RMA-partners (as mentioned earlier, RMA03, CLC3 and RMA04 and CLC4 are located on the same location). The same situation is also typical at the EMSs, when a product enter EOL the forward production often gets rid of the testing equipment they have.

Testing is done on three levels, first the products is tested on component level. These test are focused on the PCB and sensors. Secondly, the product is tested on UA level at the EMS. When all software is installed at the CLCs, the product is tested on PU level. The equipment can either be generic or specific for the products. There are also some generic equipment only used for more complex products, this is primarily connected to sensor calibration, for instance IBAS. Further, the testing equipment for case product J and case product E is specified in Table 4.2 and Table 4.3 respectively.

Table 4.2: Price for testing equipment for product J

Ref	Test equipment	Generic/specific	Price ($)	Level
33153	Efini Test Station Extended Version	Generic	5640	PCB
56527	TEQ NAIL FIXTURE PCBA	Specific	2350	UA
52711	Spider Test Station	Generic	2585	PCB/Sensor/UA/PU
55746	TEQ FIXTURE PRE IBAS	Specific	2938	Sensor/UA
54293	TEQ COLLIMATOR BOX	Specific	2350	Sensor/UA
	IBAS	Generic	46948	Sensor/UA
54683	TEQ FIXTURE Sensor ASS	Specific	2350	Sensor/UA
54576	PCB ASS AXIS HCT BOARD LF E1	Specific	153	PU
63256	TEQ FIXTURE UA	Generic	2938	PU
	Mount for camera to TEQ FIXTURE UA	Specific	764	PU
1584770	TEQ CABLE D-SUBSOCKET 9P	Specific	12	PU

Table 4.3: Price for testing testing equipment for product E

Ref	Test equipment	Generic/specific	Price ($)	Level
33153	Efini Test Station Extended Version	Generic	5640	UA/PU
35493	TEQ TEST IMAGE TWIRL AXIS M3014 E1	Generic	18	PU/UA
48364	TOOL FOCUS P1214-E E1	Specific	353	PU/UA
28866	TEQ TEST IMAGE SIEMENS FOCUS STAR	Specific	35	PU/UA
33075	CABLE TEST 1.0 MM DC PLUG TO 28942	Specific	12	UA
47487	TEQ CABLE TEST 22058 TO 20242	Specific	12	UA
1098620	OPTICAL ASS FRONT P1214-E E1	Specific	33	UA
1093941	UNIT ASS MAIN P1214 E1	Specific	92	UA

The price for all testing equipment varies a lot between the products. The reason for this is that product J is more complex than product E. Product J needs the IBAS equipment for sensor calibration which is almost ten times more expensive than any other equipment. The two products, gives two boundaries in pricing for testing equipment. There are very few products that needs more equipment than presented in 4.2.

4.1.5 PHL document

The PHL is a document containing information about actions to take when a product arrives to a RMA-partner. The document is used by RMA-partners and its purpose is to facilitate the decision making. The document is continuously updated by members of the RMA-tech team at Axis RSC department and it contains action points for Axis's entire product assortment. The PHL presents primary actions and secondary actions, the latter one is applied if the primary actions is unfeasible. The primary actions are repair, return to vendor (i.e. send back to EMS) (RTV), scrap or other. However, the primary action is, with some exceptions, always repair. The secondary actions are RTV, scrap or other. The action ”other” is usually a instruction that the broken unit should be sent to Axis HQ and a member of the RSC-team for a thorough analysis and troubleshooting to identify the root cause of failure. This is often the case when a new product is released, hence this action is applied on a minority of the units.

The RMA-partners return all products they can’t repair to the EMS if the secondary action is RTV. This results in that some products are to damage to be repaired but are sent to the EMS anyway. This is a known problem, and something Axis works with, they want the RMA-partners understand that if the product is too damaged, for example, filled with water (a common problem among this cases), there is no need to return it to the EMS.

The decision on primary and secondary actions are made by the RMA-tech team and the list is updated periodically every second week. The guidelines when deciding primary and secondary actions are that the primary action should in general be repair and the secondary action is RTV if the COGS value exceed $150 and scrap if below $150.

4.1.6 Predicted return rate

In another thesis, Axis has together with students from Lund University developed an algorithm that predicts the return rate periodically each month for each product. The algorithm is a negative binomial distribution developed in Phyton. The predicted return rate is embedded into Axis software and is fairly new. The predicted return rate (PRR) is used by Axis R&D to discover if adjustments in software or hardware is necessary to avoid sending potentially faulty units to customers and to keep the return rate at acceptable levels. The use of the PRR by the RSC team is limited. The common opinion is that they want to evaluate the algorithm before putting their trust to it. So far there hasn’t been any evaluation by the RSC-team on accuracy, the common opinion is that it is not reliable.

4.2 EOL handling

The market for surveillance cameras is constantly developing. Therefore, Axis are constantly pushing out new products to the market, with new or updated features. Consequently, some cameras in the product portfolio becomes outdated and removed from sales. Regardless, customers is entitled to their warranty, and thus Axis need to manage these cases, either by repairing or replacing the product with a new one.

The decision to remove a product is taken by the product management team. These decisions are often taken far in advance but kept secret for the organization because it affects sales. The RSC-team is noticed and the EOL calendar is updated three months before EOL. From the RSC-department it is necessary to investigate potential replacement products and what spare-parts that are critical to purchase (i.e. LTB parts). Regarding the concerned EMS, they usually empty their stock of parts related to the product to make room for new products. Consequently, repairing at EMS is hampered when a product is no longer produced. In some cases, Axis purchase parts and store them at the EMSs or at the RMA-partners in order to enable repairing. There is however no clear guideline for what and how much to purchase.

When a unit has entered the EOL-state, there are three different options to handle a warranty case. The first one is to repair the product, using stocked spare-parts. The second solution is to send out a new or refurbished unit. The last alternative is to send out a replacement product with similar design and features. This could either be a new or refurbished unit. In relation to these three alternatives, The RSC-team at Axis decides how much parts and new products to stock in order to meet the demand. To their help, they can acquire a repair BOM-list from EMS to know what parts that have been used in previous repair cases. In some cases they decide to not purchase parts and instead replace an EOL-product with an upgraded one that is in production, there are however no guidelines on when this is appropriate.

4.3 Case products

Data for eleven case products have been gathered. The data describes the reverse flow for each product. For instance, how many units have been sold, returned, repaired, where it have been sent etc. This is further presented in the next section. The eleven products were chosen based on number of returns during the products life-time and the COGS-value, presented in Table 4.4.

Table 4.4: Case products categorization

Return Volume	**COGS-value**		
	Low	**Medum**	**High**
High	Product I & K	Product D & G	Product A
Low	Product E & H	Product F & J	Product B & C

In accordance to Table 4.4 there are six different categories for the case products. Each category contains two products, except for one category, this is due to lack of data. The separation between high and low volume is determined by the total number of returns for the specific camera where above 1500 units is considered as high return volume and below 1500 units is considered as low return volume. Regarding COGS-value, up to $120, $120 - $300, and $300 - $700, are the boundaries for low, medium, and high.

4.3.1 Data related to the physical flow

The data presented in this section have been collected to present an as-is state for the products A-K. The data that contains information from end-user to RMA-partner originates from one source whereas the data with information from the EMS originates from another source. This means that when an RMA-partner consider a case closed the data collection for that case is canceled. The case is however not solved in Axis perspective if it has been shipped to the EMS where the data collection and reporting is different. Reports from the EMSs are received in Excel-sheets with information about the units. This transition also leads to missing data and makes it hard to follow a specific product. There are also some exceptions which are not in either data system. This is, for example, the case at RMA04 where there are a number of products going to EMS according to the first data source but actually, are stored at RMA04 to be repaired in the future. This entails that there are products that aren't in any data set.

Table 4.5 presents data related to the flow for each product. The first segment in the table explains how many returns a product have had in its lifetime, and also how many have been returned to RMA03 and RMA04. In total, 69 % of the returns have been handled by RMA03 or RMA04 for the case products. The next segment explains all returns received at RMA03 and the distribution of the products end location. The last segment is similar

Table 4.5: Data describing the return flow

Product	Number of returns			From RMA03 to End Location					From RMA04 to End Location				
	Total	RMA03	RMA04	Axis	Customer	EMS	RMA-pool	Scrap	Axis	Customer	EMS	RMA-pool	Scrap
A	4439	961	1930	0,3%	41,2%	41,1%	9,4%	8,0%	0,4%	25,3%	46,3%	15,6%	12,5%
B	597	160	272	5,2%	18,0%	59,3%	12,8%	4,7%	0,7%	2,1%	81,2%	3,5%	12,4%
C	229	60	155	10,4%	32,8%	14,9%	40,3%	1,5%	0,6%	1,9%	84,5%	4,5%	8,4%
D	1624	441	969	4,0%	18,9%	61,3%	8,0%	7,8%	2,3%	1,6%	73,2%	6,5%	16,4%
E	394	87	138	0,0%	52,7%	28,6%	6,6%	12,1%	0,7%	4,8%	65,5%	20,7%	8,3%
F	658	49	494	0,0%	38,9%	29,6%	29,6%	1,9%	0,2%	11,6%	47,0%	39,0%	2,2%
G	2885	447	2119	5,0%	34,8%	27,5%	29,2%	3,5%	0,5%	18,9%	46,4%	25,7%	8,5%
H	478	359	42	4,3%	53,3%	29,9%	12,0%	0,5%	0,0%	2,4%	92,9%	4,8%	0,0%
I	4371	508	945	0,6%	26,9%	63,3%	4,5%	4,7%	1,1%	7,0%	54,0%	20,6%	17,4%
J	263	36	184	2,8%	8,3%	77,8%	8,3%	2,8%	1,1%	0,5%	62,9%	11,3%	24,2%
K	3855	615	2684	3,3%	38,0%	34,5%	22,4%	1,8%	0,6%	14,0%	53,2%	27,7%	4,4%

to the previous one, except it contains data regarding RMA04. The end location ”EMS” is however not an end location, since it either gets scrapped or repaired and sent back to the RMA-pool by the EMS. The reason for the RMA-sites to not repair is documented and presented in Figure 4.4 and Figure 4.5.

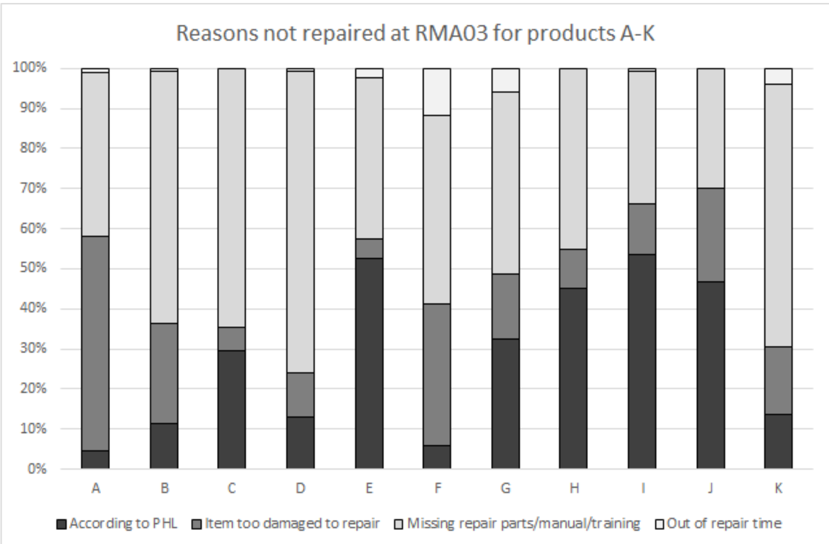

Figure 4.4: Reasons not repaired at RMA03

The information presented in Figure 4.4 is filled in by staff at RMA03. Overall, the most common reasons not to repair is due to missing repair parts, manuals, and training.

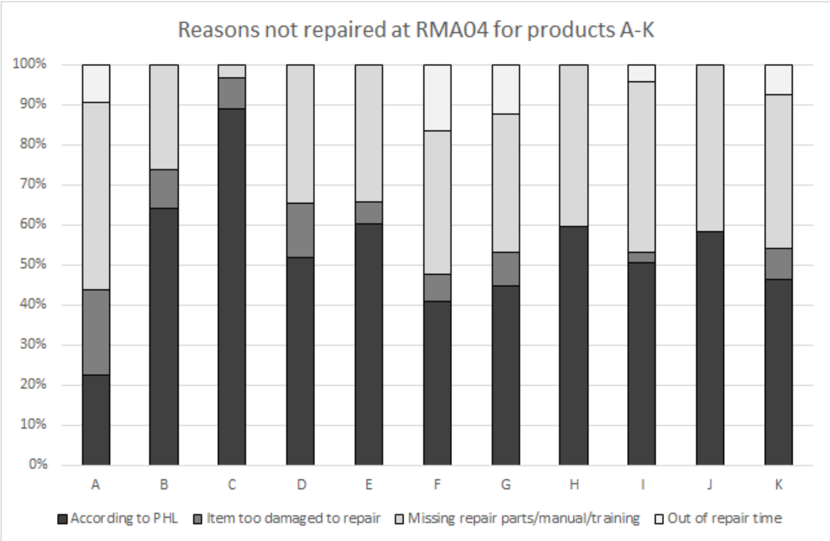

Figure 4.5: Reasons not repaired at RMA04

Similarly, the information presented in Figure 4.5 is filled in by staff at RMA04. Overall, the most common reasons not to repair is due to directions from the PHL. This preponderance could be due to the fact that RMA04 have stopped repairing and are solely shipping cameras to the EMS since November 2016.

Table 4.6 presents data for all products that first are received at RMA03 or RMA04 and later on shipped to the EMS. The data presents the location for the concerned EMS, how many they successfully repaired and how many they scrapped. RMA03 and RMA04 are in this table separated since they at times send units to different EMSs.

Table 4.6: End location for products received at EMS

Product	End location after EMS (Received from RMA03)			End location after EMS (Received from RMA04)		
	EMS location	RMA-pool	Scrapped	EMS location	RMA-pool	Scrapped
A	Poland	89,7%	10,3%	Poland	93,0%	7,0%
B	Poland	75,2%	24,8%	Poland	89,1%	10,9%
C	Poland	83,3%	16,7%	Mexico	73,3%	26,7%
D	Thailand	92,9%	7,1%	Thailand	91,4%	8,6%
E	Mexico	100,0%	0,0%	Mexico	66,7%	33,3%
F	Poland	82,1%	17,9%	Poland	71,7%	28,3%
G	Thailand	100,0%	0,0%	Mexico	94,2%	5,8%
H	Poland	100,0%	0,0%	Poland	100,0%	0,0%
I	Thailand	83,6%	16,4%	Thailand	96,9%	3,1%
J	Mexico	49,5%	50,5%	Mexico	89,3%	10,7%
K	Thailand	92,1%	7,9%	Mexico	93,1%	6,9%

To clarify Table 4.5 and Table 4.6, an example is brought out. For instance, product G have 2885 returns in total, of which 2119 units have been sent to RMA04. A total of 46,4 % (983 units) of those units have been sent to the EMS which in this case is located in Mexico. The EMS repaired and sent back 94,2 % of the received units and scrapped 5,8 %. An example is also illustrated in Figure 4.6 which represent the flow for product B. The distribution is visualized using a Sankey diagram, corresponding diagrams for other case products can be found in Appendix D.

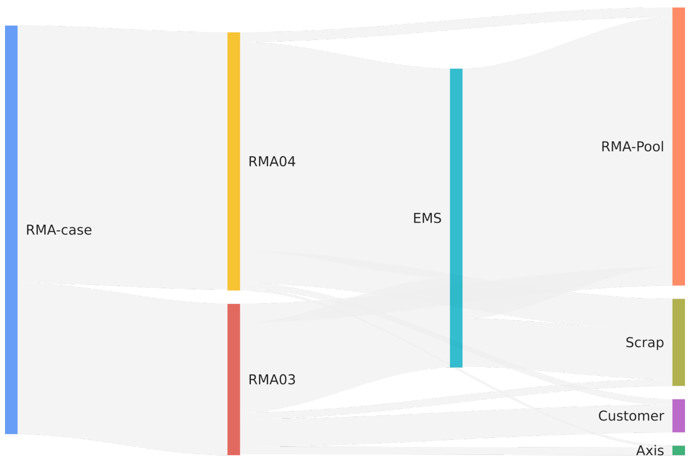

Figure 4.6: Product flow and distribution for product B

As illustrated in Figure 4.6 RMA03 sends a more significant share of the products back to customer compared to RMA04 that sends the majority of products to EMS. The majority of products end up in the RMA-pool and could potentially be used as a replacement product in the future.

The products that are shipped to the EMS are consolidated and shipped on pallets. When received at EMS, they inspect it and estimate the reparation cost. Depending on the predicted cost and allowance for maximum repair cost relative to the COGS-value the EMS either repair it or scrap it, these limits are explained and stated in Subsection 4.1.3. The lead-times for this step varies depending on repair time, available components, transportation time, customs, and prioritization made by the EMS. The average lead-time for the case products are presented in Table 4.7. The lead-times represent the time from when a unit is shipped from RMA-site to when it is repaired and received again at the RMA-site. Table 4.7 presents the lead-time for all case products during its entire lifetime but also for 2017 and 2018.

Table 4.7: The lead-time for EMS reparation

	Lead-times (days) Shipped from RMA03			**Lead-times Shipped from RMA04**		
Product	**Lifetime**	**Received during 2017**	**Received during 2018**	**Lifetime**	**Received during 2017**	**Received during 2018**
A	115	57	50	218	90	209
B	57	58	66	100	81	178
C	65	44	70	53	57	N/A
D	78	76	78	123	83	80
E	68	N/A	68	214	40	36
F	45	53	50	150	109	178
G	115	73	62	148	51	46
H	43	41	56	94	76	185
I	143	53	N/A	286	N/A	N/A
J	318	N/A	N/A	229	N/A	N/A
K	87	69	62	46	44	52
Average	**103**	**58**	**62**	**151**	**70**	**121**

4.3.2 Data for costs

Costs associated with a RMA-case are presented in Table 4.8. There are however underlying assumptions and simplifications due to the complexity of a flow with thousands of customers situated in unique locations. Thus, a simplification is made that the shipping between the RMAs and the customer are shipped in parcel between a certain city and the RMA. Moreover, the size and weight have been accounted for, and two categories were created which considers both dimensions and weight. The shipping between the RMAs and the EMSs are assumed to be consolidated and shipped on pallets. The location for the EMSs and RMAs are known, hence there are no other simplifications made. Moreover, the costs presented in the table represents a one-way shipment, the return journey is assumed to be the same. The cost for parts that are presented in Table 4.8 are data received from the EMSs, i.e., the average cost for parts per repaired product at the EMS. It is however assumed that the cost for parts when repairing at one of the RMAs' are equal.

Table 4.8: Operational costs for the case products

	Shipping cost ($) between RMA03 and		Shipping cost ($) between RMA04 and		Fee per case ($) (*)indicates the RTV or scrap cost				Cost for parts ($)
Product	**Customer**	**EMS**	**Customer**	**EMS**	**RMA03**	**RMA04**	**RMA04***	**EMS**	**RMA0X and EMS**
A	34,4	3,0	34,4	15,2	58,6	148,7	81,1	55,3	33,2
B	34,4	3,2	34,4	16,7	58,6	148,7	81,1	53,4	32,1
C	34,4	4,7	34,4	15,5	58,6	148,7	81,1	34,7	80,6
D	31,7	3,4	31,7	3,9	58,6	148,7	81,1	21,8	57,3
E	31,7	4,1	31,7	2,1	58,6	148,7	81,1	18,2	29,2
F	31,7	1,1	31,7	5,8	58,6	148,7	81,1	35,3	7,3
G	34,4	8,7	34,4	7,7	58,6	148,7	81,1	20,8	46,4
H	31,7	0,3	31,7	1,8	58,6	148,7	81,1	34,4	8,7
I	31,7	1,0	31,7	1,1	58,6	148,7	81,1	6,3	10,1
J	31,7	10,5	31,7	5,2	58,6	148,7	81,1	39,1	96,5
K	34,4	8,1	34,4	7,2	58,6	148,7	81,1	17,2	43,3

In the column "Fee per case" one can see that RMA03 charges the same fee for each case, and don't consider the time spent or the outcome. There is a fixed price for a case which is $41, however, there are also an environmental fee and a pallet storage fee added which in total results in a fee of $58,6 per case. RMA04 charges per hour spent on a case, thus the presented fees are an average value. The values presented for RMA04 considers not only the cost for reparation and other activities associated with a reparation (testing, disassemble, etc.), but also administration cost, supervision cost, cost for space, and cost for blue collar labor that receive and ship the units. Since there is a significant difference in the time spent between repairing and sending back the unit to the EMS (RTV) or scrap it, there is a distinction made between them. There are however no data concerning repair time/cost for specific products at RMA04, thus an average value is presented for all products. For both RMA03 and RMA04, and the EMSs the costs are for the work performed, thus the cost of parts have to be added as well. It should also be noted that the scrap fee at the EMSs are zero except for one of the EMSs in Poland that charges $17 to scrap per unit.

Chapter 5

Reference Companies

This chapter contains information collected from reference companies. The companies have asked to be anonymous, therefore no names are mentioned. The companies business are, however, briefly introduced in the introduction. The interviews are divided into seven different topics, together covering the return process. The interviews were of a semi-structured type and the interview questions can be found in Appendix B.

5.1 Reference Company A

5.1.1 Introduction

Reference Company A is located in the southern parts of Sweden and is part of a company group located in Asia. The office in Sweden is working with hardware development globally and software development for the European market for mobile phones. The strategy for Reference Company A is to turn a loss to profit by focusing on high-end market while decreasing warranty costs. The interview victim's title is Repair Network Planner at Reference Company A who have been working with supporting business units in handling after-market processes and are involved before and after product launches. The company sells products to resellers, distributors, and end-customers.

5.1.2 Product type

The lifetime of their products is relatively short, and today they have 40-50 active products in their RSC. The difference between the products in a technical and service perspective is considerable. Meaning that different equipment and parts are required when servicing different products. Refurbished products are to some degree used in the RSC as swap-units, i.e., replacement units. The warranty offered are different, for Sweden it is two years with three additional months to cover the shelf-life.

5.1.3 RSC

A customer has multiple options of returning broken products to Reference Company A. In some regions, there is the option go through Reference Company A's channel. Otherwise, the most common is to go through the reseller where the customer drops and picks up the product. From the company's perspective the repairs are handled by service partners, normally there is one partner in every country that the company is present in. There are some exceptions, for example, Denmark where they have a logistical hub from where defective units are shipped to Sweden. If the product can't be repaired at a service partner, the error can likely be derived to the printed circuit assembly board (PCA). In those cases, the PCA-board is then locally swapped to a functional one. The faulty PCA-board is shipped to Singapore and further distributed to various EMSs in Asia. The service-time differs between B2B, B2C, and regions. In Sweden, the service-time goal is five days for B2C and three days for B2B cases. Advance replacements are offered to some extent. The goal is to repair as many units as possible, and the share of units being swapped is a carefully monitored KPI. This is due to economic benefits of repairing. With guidelines from Reference Company A, the service partners manage and own the stock of spare parts. They are also responsible for purchasing assembly and test-equipment required for all units.

5.1.4 Service

When a product arrives at a service partner, they first inspect it and conclude if it is an in warranty or out of warranty case. If the product is under warranty, Reference Company A covers all the costs. Otherwise, it has to be covered by the customer. The out of warranty repairs has a higher margin for the service partners since the end-customer is not Reference

Company A, but it is the end-customer. The company have been cutting staff and moved business overseas the last couple of years. The R&D have for instance been relocated which have led to less ”design for repair” thinking. However, before it was integrated well with ”module thinking” etc. As the mobiles are getting more complicated, thinner and water resistant for example repairs are becoming more complex. Reference Company A has three levels of service partners; software, mechanical and electrical, different equipment is needed depending on the level.

When a new product is launched the goal is that the service partners already should know the types of faults coming in and parts needed. This information is gathered by extensive testing and by looking at similar designs and the fault on those products. During the entire product development of a new product, the warranty cost for the product is part of the project, being updated as the projects go on. The company also claims that they are quite good in predicting this. Lessons learned from other products so to say. There are also cases where they launch a product knowing it is not 100 % they will fix the software later.

5.1.5 End of life

Before a product enters EOL, the service partners are encouraged to stock up necessary parts to handle repairs for the coming years. They are also supporting them in what amounts they need to stock to handle the service. During this time Reference Company A is stocking up PCA-boards to be able to handle the need for them because the EMS are stopping to produce them. If a PCA can’t be repaired after EOL, it is recycled by the service partner, and a new one is used. Some of the parts that are recycled have value, and thus they make money from it.

5.1.6 Harvesting and Recycling

For units that can’t be repaired, the PCA is harvested and sent to repair. A new unit is then sent to the customer, and this can both be the same type or an updated one. Reference Company A recycles all components that won’t be used, and for some components, they get paid to recycle. They do keep some control of who is buying the units to avoid components etc. to end up in the hands of wrong people.

5.2 Reference Company B

5.2.1 Introduction

Reference Company B develops, manufactures and sells tools for the construction and mining industry, mainly to the professional end-user. The company has an office in Malmö handling sales, distribution and aftermarket services. Globally the company is present in 120 countries. Reference Company B stands-out in its business model. They have their own stores, and around 75 % of the staff works directly towards the end-customer. Products are sold in two ways, the first option is that the customer buys the product and pays the full price. The second option is leasing the tool, and this concept is called ”Fleet management” where service, theft insurance, and upgrades after a certain period is included. The price for the fleet management concept is 5-10 % higher, and the two options are roughly equivalent in the number of sales. The primary concern regarding repairs from the customers of Reference Company B is time, to minimize the downtime. The interview victim's title is *Local Logistics Expert*, and primarily work with transportation questions on a tactical level. Besides this, he also works with strategic questions concerning logistics and supports the planning team in England. Reference Company B has a direct sales model, where you only can buy the product directly from them and nowhere else. The products are sold in stores, online web-shop and by traveling sales staff. Reference Company B owns the entire supply chain from production to the end customer, the only part of the supply chain they don't hold is the transportation where they work with different partners. The company puts a lot of resources and focus on R&D, and the strategy is to deliver innovative products with high quality. However, products do break down, and on average they service and repair 200-250 products per day in Sweden by a team of 25 people.

5.2.2 Type of products

The product lifetime is long, and there are a lot of active products. The products vary a lot both in usage area and technicality. Meaning different equipment and parts are needed when repairing and servicing the different products. Reference Company B do not resell or use any refurbished or remanufactured products. The reason for this is that they believe it would damage the brand. All products are sold with a lifetime warranty if the cause of the error can be derived to the production.

5.2.3 RSC

When a customer experience problem with a product they contact the company. They schedule a mode of transport for the product. The product is then picked up by a partner and transported to the national service facility. From the time of pickup Reference Company B has a policy of returning the product within three days (for all regions below Gävle, if above Gävle it is five days) something they do in 98,5 % of the cases. If the product is not repaired within that time window, the company stands for all cost of repairing the products. The 1,5 % not being fixed in time is caused by lack of spare parts. Even though the company is holding an extensive stock, all parts cannot be stored locally. The company has a central warehouse, providing materials for the local warehouses. There is a big variation in the time needed for repairing different products, and smaller units take around 15 min while bigger units can require up to 7 hours. When the product is repaired, it is sent back to the customer through a transport partner. Advance replacements are offered in some cases, but it is very rare.

5.2.4 Service

Reference Company B's strategy is to be able to service the product for ten years after the last sold unit. However, parts are not stored in the same quantity at the local warehouses after production has ended. So the repair might take a bit longer and is therefore not in the three-day repair window. The repair station is optimized for servicing specific products, with all needed tools arranged in front of the operator. To be able to handle the three-day promise they only have one day to repair every single product, all products arriving in the morning has to be completed by 16.00. All repaired products are extracted for data, and the data is sent to R&D and used in future product development and for product improvements.

5.2.5 End Of Life

The repair procedures are the same for products in the EOL-state as products still being produced. The planning and restocking are sourced globally from the headquarters outside of Sweden. The stock consists of parts with the goal of handling all returns for the coming ten years globally. In this phase more stock is situated in the central warehouse.

5.2.6 Harvesting & Recycling

The company does not harvest any parts from broken units, a product that can't be repaired is recycled. This is due to regulations about working with tools that vibrate. A builder or miner is only allowed to work with a certain amount of vibrating tools for a certain time. Used products tend to vibrate more and are therefore change out. Worn out products are recycled to material level, and for some of the material, they receive payment.

5.3 Reference Company C

5.3.1 Introduction

Reference Company C is producing and selling automatic entrance products and services. They are present worldwide, and the products are primarily used in commercial real estates like shopping malls, hospitals and supermarkets. Reference Company C has a business model where they sell their products both directly to customers and distributors. The customer can buy complete doors or the automatic function and apply it to their own door. The product lifetime is considered long, and it is not uncommon that the products are used for 15 years. Customers rates quality and reliability as the most important factors. When the product breakdown, the service is done at the customer's facility. The reparation is made on module level, meaning no component repair is conducted. Concerning repair, rapid service is the most important factor. The time-window for the repair differs, but the most demanding customers request a service technician to arrive within two hours. The interview victims title is *field operations manager*, he is globally responsible for installations and services. The total return rate is below 1 %.

5.3.2 Type of products

Reference Company C servicing around 50 different product variants. The number of new products sold is however fewer. The products are divided into a number of subgroups, the similarity between them are however limited. Meaning there is little similarity in parts used for example. Reference Company C are refurbishing products on the USA market, small local establishments also refurbish and resell their products elsewhere, but that is outside of Reference Company C business. The reason for not refurbishing on other markets are the risk of damaging the brand and to ensure the product quality. The length and extent of the warranty differs between markets. The warranty in Sweden is three to five years. The customer also have the possibility to add service contracts to their product that cover service, parts, etc.

5.3.3 RSC

The service market within this type of products is a market on its own, and there are a lot of companies wanting to perform them. Reference Company C, for instance, servicing its competitors products. If there is a problem with the door, the customer contacts Reference Company C service department and a service technician is given the task. All technicians are connected to a service system where they can see information, stats and where they are supposed to go. The system is a custom solution, built 10-12 years ago that have all data in the same place. Reference Company C have a method they call Symptom, Problem, Fix. When a product is not working the customer is asked to describe the symptom, the company are also increasing the customers possibility to read a error code from the product. Error codes gives them more information about the error and what is wrong. This information give the company the possibility to prepare before sending a technician. If the technician can't fix it directly, they order the missing parts and come back later. In Europe, if the parts are ordered before 12.00, the technician has the part on the morning the day after. The parts a technician has in the service car is carefully monitored and optimized in coordination to his or her skills. Reference Company C have had problems with big stock and are now working with lowering the stock levels while maintaining the service level. All repairs are being logged and stored, and this data is then later used to evaluate repair time, driving time, etc. Reference Company C have the data sorted for country, region down to a specific technician. The time window for a technician to be at the customers site differs depending on contract, and some customers has agreements where the repair has to start within two hours. To be able to handle this a combination of partners and in-house technicians are used. Some geographic areas are simply too big or hard to get to within the time-window in a economical way, and partners are therefore believed to be a necessity. In these areas, small contractors are used that may have another profession and business, but service Reference Company C doors when needed. The reference company on average manage to repair 98 % of its products in time.

5.3.4 Service

Commercial doors are regulated by laws concerning quality and functionality. To be able to ensure this, service is a must, a lot of customers also want preventative maintenance to ensure quality, which also is recommended by Reference Company C. The service can be divided into three areas; (1) preventive maintenance and change of worn out parts, (2) break down service, and (3) upgrades. The lifetime of the product is long, and service is provided after the warranty has expired. Reference Company C also sell upgrading kits to their product to prolong the lifetime. The upgrades are sold with a promise of being able to continue delivering service and repair. Reference Company C works closely with R&D to keep service in mind when developing products.

5.3.5 End of Life

Reference Company C informs all customer five years before they stop servicing a product. Many of their components is not considered as scarce however and EOL is not expressed as an issue.

5.3.6 Harvesting & Recycling

There is no harvesting concerning the doors or the parts during service. They believe reusing parts could damage the quality of their products and brand. Since the products are physical installed to a building the products are not sent back to the company for recycling, by nature the recycling is up to the owner. During service and upgrading, the leftover parts are taken care of by the technician for recycling.

Chapter 6

Analysis

This Chapter analyze the theory and collected data in regards to research question one and two. The chapter also contains an analysis of various influencing aspects in Sections 6.3 - 6-5 which are necessary in order to answer research question three. The recommended decision model and the answer to research question three is presented in Chapter 7.

6.1 Cost elements

Information from theory and data from the empirical study will be analyzed to find answers to the first research question regarding the cost elements related to handling an RMA-case. This section will point out the cost parameters suggested by literature and highlight the ones that have been identified in handling an RMA-case. Larsen and Jacobsen (2014) provides two tables with cost elements, one for investment cost elements and the other containing operational cost elements. The tables are used as a reference in this analysis to facilitate the visualization.

Regarding investment costs, the empirical study has identified two out of four cost elements that were suggested by theory, presented in Table 6.1.

Table 6.1: Investment cost elements observed in theory compared to the empirical study

Investment cost elements	Identified?
1. Cost of introducing take-back of products with current customers	no
2. Cost of hiring and training new employees for dissasembly, product test, and logistics	yes
3. Cost of new equipment for dissasembly and refurbishing	yes
4. Cost of initial introduction of ”new” products to new and existing markets	no

The second cost in Table 6.1 is identified in RMA-cases and is derived to the creation of repair manuals and other instructions that are needed. These are documents created and funded by Axis. The third cost is identified in the testing and assembly equipment required to repair a unit. This equipment is bought by Axis and distributed to the RMA-partners. The other two costs have not been recognized which could be due to that observed literature within RSC propose frameworks, models and theories for RSCs that buy back products, rework and re-market them. Axis RSC distinguish from this since it only handles warranty cases.

Moreover, the operational cost elements are presented in Figure 6.2. The cells with the grey background and white text color are identified in the empirical study. Conversely, cells with white background and black text color are not identified. Below, the operating cost elements are argumented for why or why not they are identified.

Table 6.2: Operational cost elements observed in theory compared to the empirical study

Operational cost elements				
Product acquisition	**Reverse logistics**	**Inspection and disposition**	**Recovery operations**	**Remarketing**
Buy-back costs of items	Costs of collecting items	Cost of inspection and sorting	Costs of product dissasembly	Cost of continous remarkering to new and existing markets
Cost of adm. take-back from customer for local BU	Item inventory holding costs at local BU	Cost of initial product test	Cost of a standard exchange of wear components	Cost of selling products prior to recovery
Cost of initial screening (recovery or disposal)	Order picking and shipping costs from local BU	Cost of cleaning products and components	Cost of refurbishing and reassembly	Cost of administrating the order process
Cost of disposal of non-recoverable items	Transport costs from local BU to central site	Cost of inserting working products into forward flow	Cost of final product or component test	Cost of cannibalized virgin product sales
Adm. of payment between local BU and central site	Materials handling costs when receiving items			
	Item inventory holding costs at central site			

In the Product acquisition category, there are only two cost elements identified. The administrative cost for take-back and cost of initial screening is the cost of helping the customer over the phone and if necessary setting up an RMA-case, done by members of Axis TSE team. The buy-back cost does not exist for Axis, and this is pointed out by Mitra (2007) for the situations where the producer is obligated to recover the returns. Neither is there any situations where Axis dispose their products prior to inspection nor any transactions between local and central site.

All cost elements in the segment Reverse logistics in Table 6.2 are identified. Cost of collecting items are represented by the transportation cost from customer to RMA-partner. The holding costs are not assessed, but they are however existing since Axis holds a pool of products that are used as replacement products. The third and fourth cost is also found in the cases where RMA-partner sends a unit further to RMA-site that renders in a picking cost and transportation cost. Lastly, RMA04 specify and charge for the time spent and cost for receiving the units.

Further, the cost elements inspection, sorting, and initial product test in the segment Inspection and disposition are all activities performed by the RMA-partners. The cost of inserting working products into forward flow is related to when no fault is found on a unit, and it is sent back to the customer, which the RMA-partner charges Axis for. There is no coordinated process of cleaning products and components hence it is left out.

In the segment Recovery operations, all activities have been identified. Products that are in need of reparation are always disassembled, and components are repaired or replaced. There are also repairs on a modular level which according to Thierry et al. (1995) is the definition of refurbishing. The cost of testing is identified in the UA-level and PU-level tests performed by EMSs and RMA-partners.

Regarding the category Remarketing, there is one cost element identified which is related to the activity of packing and shipping the repaired or replaced camera to the customer. The others are not identified which again is due to the fact that the found literature discuss RSC in terms of buying back products and re-sell them, which is not the case at Axis.

6.2 Reference companies

The three reference companies are all working with high-end products but in vastly different areas. How the companies work with repairs and services also differs a lot. As seen in Table 6.3, Reference Company A work exclusively with malfunctions units. While Reference Company B and C work a lot with preventive service. This is partly due to regulations connected to their products.

Table 6.3: Comparison of the reference companies

	Reference Company A	**Reference Company B**	**Reference Company C**
Customer segment	High end	High end	Middle/High end
Customer	Distributors, retailers and end users	End user	Distributors, retailers and end user
Product complexity	High	Medium	Low/Medium
Product life-time	Short/Medium	Medium	Long
Does the customer receive same or different unit	Same shell, might be new PCB	Same	Same
Return rate	-	-	1%<
Number of active products	Few/Moderate	Moderate/Many	Few/Moderate
Difference between products (in a technical perspective)	Considerable	Medium	Low/Medium
Warranty length	2 years, depends on country	Lifetime warranty on production faults	3 years, depends on country
Offers extended warranty	No	No	No
Offers service agreements	No	Yes	Yes
Time-frame to solve customers problem	7 days, depends on country	3-5 days	2 hours - 2 days
Share of returns handled within time-frame	-	98,5%	98%
Perform service in-house or outsource	Service partners	In-house	Combination
Ownership of repair parts and equipment	Service partners	-	Service partners
EMS is used for repairs	Yes, PCA-boards	No	No
Service time after EOL	5 years	10 years	5 years
Is out of warranty service an important area	Medium importance	Important	Important
Stocking units to handle EOL	Yes(Only PCA-boards)	No	No
Tracability of repair	High	High	High
Statistics connected to repair	High	High	High
Complexity of RSC goods flow	High	Low	Medium

To be able to keep certifications and be within regulations their products need to be serviced at specified intervals. This creates an aftermarket service that does not exist for Reference Company A whose products might need some software updates during its lifetime performed by the user. This means Reference Company A exclusively handles units that have malfunctions while B and C service both broken units and working units.

Reference Company A and C are using partners to handle some repairs. Company C uses partners in geographical areas where they have a low volume of repairs while company A solely outsources it. They both let the partners stock up on parts and necessary equipment. When using partners company A puts a lot of trust in their skills and knowledge and are relying on them to deliver. To be able to track their performance, data traceability is essential for them. Company C perform its repair at the customer location, at the same time they want to minimize the spare part in stock. A crucial part of their service organization is, therefore, short lead-times when delivering spare parts to technicians. This strategy has helped company C to lower their stock while keeping a high service level. Attaining quick spare part replenishment globally is, of course, expensive but company C have concluded that the reduced stock is worth it.

The repair process differs between the companies, both A and B collects the product from the customer. The process when the product is collected, however, varies. Company B repairs everything at first point of arrival. Company A repairs some fault at the location, but if the product is to damaged to be repaired, they switch out the PCA and send it away for repair at the EMS. Using this strategy creates a need for extra PCA stock since the time for an EMS to repair is slow. Further, company A moves all the complex repairs to one location, making it possible to use more inexperienced staff at the first point of repair.

The time for a repair between the companies differs. Company C promises to be at the location within a specified time depending on the contract. It is not sure however, that the technicians can repair the product. The technician might need additional parts, but 98 % of the cases are repaired in time. Company B has one day to repair the product, the rest of the time window, two to four days (depending on location) is transport time. In total, they are able to handle 98,5 % of all cases in time. When repairing locally the complexity of the flow is low, and there is no need for customs handling for example which can be complicated and expensive. Local repairs, however, demands to have the full spread of technical competence and spare parts at every service site.

All of the case companies have put a lot of effort into being able to track the return process and different data about the process. Company A, for example, described how they were able to investigate specific operators bounce rate. Being able to follow the products, seeing the time used in the different process helps them to find bottlenecks and improvements areas. Reference Company C have guidelines for how long time a particular repair should take which they follow up, evaluate and report to the service organization. If the service partners performance is poor they investigate the root cause, and perhaps more training is necessary or improved stock management. Reference Company A use its data to benchmark the different service partners against each other to optimize their performance. Trying to make them improve, and understand why some companies are better than others.

It is essential to take the level of repair into consideration on the repairs. Reference Company A repair some parts of the product down to components on the PCA while Reference Company C works on a module level. Working on module level means a reparation might be more expensive since you have to change a number of components, however, the technical knowledge required can be lower. The different strategies used by the references companies all have there strength and weaknesses, a summary is presented in Table 6.4.

Table 6.4: Advantages, disadvantages and requirements of the different repair strategies

	Reference Company A	Reference Company B	Reference Company C
Advantages	- Limited technical knowledge at service partners - Customer receives same product back as sent in - Benchmarking of service partners	- Short lead-times - Simple flow of goods - Direct customer contact and feedback	- Short lead-times - No backward flow of goods - Direct customer contact and feedback
Disadvantages	- Extensive stock of PCA-cards - Long lead-time for complex problems - The flow of goods is complex - Highly dependent on the service partners	- Stock of all parts at every local repair shop - All service facilities needs all testing equipment - Expensive	- All technicians need all repair equipment - High spread in spare parts - Economies of scale in repairs is limited - High transportation cost for technicians
Requirements	- Data traceability - High volume of returns	- Data traceability - High spare part availability - Highly skilled service technicians	- Data traceability - A big network of service technicians - Simple repair procedures - Express spare parts replenishment

All of the different strategies have different advantages and disadvantages. Whats important is having a service strategy matching the product, amount of returns, the customers and the chosen company strategy. Some strategies are perhaps not that cost efficient but service another perspective and are therefore beneficial for the company as a whole. Something that is key for them all is however the ability to trace products and having high-quality data. The quote *If you can't measure it, you can't improve it*, fits the return process very well.

6.3 Predicted return rate performance

As mentioned before, Axis has together with two students in another master thesis developed an algorithm to predict the return rate which is periodically updated each month. The PRR is however not applied in any of the processes at the RSC department of Axis due to lack of knowledge about its preciseness. One area where the PRR could be applied to is when a product enters EOL state. Predicting how many returns that will occur would facilitate the process of purchasing parts and products. Therefore, an evaluation of the performance of the algorithm is desirable. Data has been collected for 21 products that entered EOL state in 2015, presented in Appendix C. Table C.1 presents EOL date, PRR at the moment of EOL, sold quantity, number of returns and predicted number of returns, which is data available to all members of the RSC team at Axis. With the assumptions that the 21 products have the majority of its return already received at Axis one can evaluate how precise the PRR was when the product entered EOL state. Computing the quota between predicted returns and actual returns one can see with how many percentages the PRR algorithm over- or underestimated the number of returns. Gather this quota for all 21 products and assuming a normal distribution results in a mean value with an associated confidence interval of the algorithms preciseness, presented in Table 6.5.

Table 6.5: Performance of the PRR algorithm

	Boundaries		
Confidence interval	**Lower**	**Mean**	**Higher**
95%	-4,4%	1,5%	7,3%
99%	-6,2%	1,5%	9,1%

Table 6.5 shows that the PRR algorithm on average overestimates the predicted returns with 1,5%, the boundaries for a 95% and a 99% confidence interval is presented as well. The PRR is not reflecting the reality to a certainty but the performance of the algorithm is arguably more accurate than guesses and estimations. It would be further interesting to measure the PRR against the results of methods used during the last years. This data is however not available.

6.4 Axis return flow

Axis's return flow handles a lot of different products with high complexity. There are lot of possible ways to handle returns and there are many goals to achieve, quality, low cost, service level and a good customer experience. According to Grünig and Kühn (2009), this entails that making decisions concerning returns is a complex problem. In addition, the timing of the product acquisition cannot be controlled which add another level of complexity and hamper the efficiency of the reverse supply chain, something Guide Jr and Van Wassenhove (2002) discuss in their paper. The first step in the return process is the RMA-partner or RMA-site. At the moment, Axis two biggest RMA-sites have different repair strategies. This limits the possibilities for benchmarking and using benefits from one facility to another. The number of exceptions or differences of handling the same situation at different facilities is perceived as high at Axis. The contractual agreements with RMA03 and RMA04 are one example, RMA04 are paid by the hour while RMA03 are paid per case. The incentives for RMA04 to speed up their processes and handle more cases per time unit are low, which could be the reason for why RMA04 in general are more expensive than RMA03 as seen in Table 4.8. Conversely, the incentives for RMA03 to repair and fix more complex problems are low since those problems likely require more repair time. The first may be more favourable than the second, but the differences in incentives attracted attention and questioned if they are aligned with Axis's strategy. The lack of standardized processes and contractual agreements with the RMA-sites leads to more administration and difficulties to achieve economies of scale which is conflicting with Axis vision of a scalable supply chain.

Some of the exceptions however are unavoidable, but these are limited. The inconstancy of many processes makes it complicated to understand the flow and makes everyone in the RMA-team very valuable since there are few other people that understand the flow equally as good. The consequence is also that the team members have limited exchange with each other since the flow and processes are so varying. When comparing Axis to the reference companies, there is a big difference in this area. Many of the references company tried to be very consistent in their approaches of how to handle the return process both geographical and within the organization.

When comparing the RMA-sites in Table 4.5 the percentage that is scrapped differs. For instance product J, the difference is above 20 percentage units between the two RMA-sites. There is no apparent reason that explains this contrast, but one explanation could be that the judgment of what is too damaged to repair is inconsistent.

Axis uses EMS to be cost efficient, and the downside is the lead-time. The RMA-partners have a lead-time to solve an RMA-case, either by repairing, scrapping or RTV, of five days. Further, the RMA-sites are supposed to ship the products that are RTV at least every 14 days to the EMS for repair. Which leads to that a product on average is waiting seven days to be shipped. Depending on if the goods are shipped from RMA03 or RMA04 additional 62 days and 131 days can be added. Giving an average of 74 for RMA03 and 143 days for RMA04. To handle this lead-time Axis have to keep a lot of products in the RMA-pool. In accordance with Guide Jr and Van Wassenhove (2002), one should also consider the value, and the change in value of a product that is the subject of a long lead-time. During the EOL decision, it is essential to take this into considerations since the RMA-pool has to be able to handle this lead-time on its own without possible replenishment from production. The lead-times when shipping to the EMSs add another level of complexity to the supply chain and increases the stock levels in the RMA-pool and also the obsolescence risk.

Reference Company A has a similar approach as Axis. They send the most complicated repairs to the EMS, the difference however is that they only send away components, not the entire unit. By doing so they lower the value in the supply chain and replace and send back the same unit/shell to the customer. In addition to reducing the value of product shipped to EMS, they also lower the transportation cost because of less weight and smaller dimensions. A lot of Axis's products have heavy shells and mountings while the technical components are fairly light weighted. The R&D at Reference Company A have developed the product in a way that it is possible to change and extract parts within a reasonable time and cost. This is also discussed and suggested by Johnson and Wang (1998), putting valuable components easy accessible. It would be further interesting to map the costs associated with the different failures occurring, that way one could decide what kind of repairs that economical favourable. One way of doing this is applying the disassembly tree suggested by Tang et al. (2004).

Primarily Axis wants to service only what cannot be repaired at the RMA-site at the EMS. When looking at Table 4.4 and 4.5 there are a lot of products where the reason for not repairing is missing repair parts, manual or training. This showcases that the RMA-sites potentially could repair a lot more with further support from Axis. Additionally, as a result many units have been inspected and analyzed multiple times. In the empirical study, and from literature (Tibben-Lembke & Rogers, 2002), its established that repeating these processes are expensive.

The EMSs has a lower limit for repair connected to the COGS-value of a product. However, the products are always sent to an RMA-partner or RMA-site for inspection and analysis in the first instance. As the empirical study and Table 4.8 shows, the first instance is always associated with a cost; $58,6 at RMA03 and at least $81,1 at RMA04. Once again, this cost is the same no matter the outcome (repair, scrap or RTV) at RMA03. For RMA04 the average price for scrapping or RTV is $81,1 and $147,7 for repairing. Again, one could question the payment structure towards RMA03 and RMA04 but the cost of scrapping seems unreasonable.

6.5 Costs for handling the case products

In Chapter 4, data concerning the flow and costs for the case products were presented together with its assumptions and simplifications. In this section, the total operational cost for handling an RMA-case depending on its outcome will be presented for further analysis. The outcomes have been packaged in four different possibilities. Ultimately, a broken unit sent in by a customer is either repaired or scrapped by an RMA-partner, or it is repaired or scrapped by the EMS. In this analysis, the units that counts as repaired are the units that end up in the hands of the customer, or in the RMA-pool. In Table 6.6 and Table 6.7 the costs are presented, which originates from Table 4.8 but are summed up for different outcomes. The cost of repair at the RMAs is the sum of transportation cost, personnel/repair cost, and the cost of parts. The scrap and replace cost contains cost for transportation, personnel/analysis cost, and the cost of sending another unit to the customer (which is equal to the COGS-value). The cost for repairing at EMS is the transport cost from customer to RMA-site, personnel/analysis cost at RMA-site, transportation to EMS, personnel/repair cost at EMS, cost of parts, transportation back to RMA-site and to the customer. The scrap and replace cost at EMS is the transport cost from customer to RMA-site, personnel/analysis cost at RMA-site, transportation to EMS, scrap fee (only at one of the EMSs), and the cost for sending another unit to the customer. To the right in Table 6.6 and Table 6.7, the average cost per case, and the hypothetical cost of a RMA-case if scrapping not were associated with a cost, are presented. The average cost per case is computed with the recently explained costs applied to the distribution of the flow which was earlier declared in Table 4.5. Further, the last column is a hypothetical value where the scrap fee is not accounted for, thus it includes transportation to RMA-site and the cost of sending another unit to the customer.

Table 6.6: Operational costs related to outcome for case products first sent to RMA03

		RMA03		EMS			
Product	**COGS ($)**	**Repair ($)**	**Scrap and replace ($)**	**Repair ($)**	**Scrap and replace ($)**	**Average cost per case ($)**	**If scrapping was free ($)**
A	485	161	613	222	633	241	554
B	583	160	711	219	731	325	652
C	688	208	816	251	838	302	757
D	205	179	327	207	348	220	268
E	92	151	214	178	235	167	155
F	184	129	306	167	324	152	247
G	191	174	319	211	344	196	260
H	90	130	212	165	230	145	153
I	91	132	213	140	231	151	154
J	147	218	269	278	297	275	210
K	113	171	241	204	266	188	182

From Table 6.6 one can conclude that the most profitable way to handle an RMA-case is to repair RMA03. Scrap and replace is always more expensive than repairing at either RMA03 or EMS. If scrapping was free however, it would on average be more profitable to scrap and replace for product E, J and K. Products H and I is on the borderline and with an additional average cost of $3 and $8 respectively they would also be more profitable to scrap if it was free.

Table 6.7: Operational costs related to outcome for case products first sent to RMA04

		RMA04		EMS			
Product	**Cogs ($)**	**Repair ($)**	**Scrap and replace ($)**	**Repair ($)**	**Scrap and replace ($)**	**Average cost per case ($)**	**If scrapping was free ($)**
A	485	252	635	268	667	322	554
B	583	251	733	268	767	372	652
C	688	299	838	295	854	470	757
D	205	270	349	230	353	263	268
E	92	242	236	196	238	220	155
F	184	220	328	198	351	233	247
G	191	265	341	231	348	261	260
H	90	221	234	190	253	192	153
I	91	223	235	163	236	194	154
J	147	309	291	290	296	293	210
K	113	262	263	224	270	244	182

From Table 6.7 one can conclude that the majority of products are cheaper to repair at the EMS compared to RMA04, which could be due to the fact that RMA04 are paid by the hour and not by case and that the repair fee at the EMSs is significantly lower. The lead-time for repairing at the EMSs are however significantly higher compared to repairing at RMA04. If scrapping was free it would be more profitable to scrap and replace for products E, G, H, I, J and K. For product D the average cost is $5 lower compared to free scrapping and replace with another unit. Comparing the cost per case for RMA03 and RMA04 shows that RMA03 is cheaper in every aspect, the relevance of this comparison can however be discussed since they operate in different parts of the world.

The idea of free scrapping and recycling stems from Reference Company A and B that actually gets paid for some of their components. One could argue that Axis should be able to achieve this as well with their RMA-partners since their products contains valuable components. Obviously this approach has the premise that the partners don't inspect and analyze, but simply scrap and recycle incoming units. Another option could be to explore the market for recycling companies with a business of recycling products similar to Axis. This would as previously stated be a beneficial strategy for some of their products. An illustration of which products this would be appropriate for is presented in Figure 6.1. The products are placed with regards to the average cost per case compared to the cost if scrapping not were associated with a fee. The black dots are on average more profitable to keep repairing whereas the white dots would benefit from a scrap and replace strategy. The gray dots are on the verge (less than $10) of being profitable to scrap and replace.

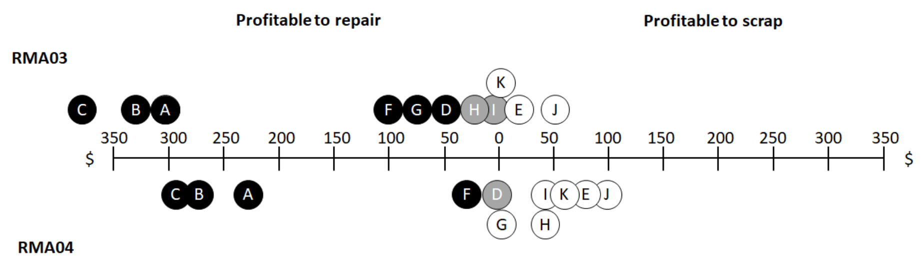

Figure 6.1: Most profitable action for case products A-K

To identify if there is any pattern in this result with regards to what category the products belong to, a merge of the results in Figure 6.1 and the categorization made in Section 4.3 is performed, presented in Table 6.8.

Table 6.8:

Return Volume	COGS-value		
	Low	**Medium**	**High**
High	Product I & K ◍ ○ ○ ○	Product D & G ● ● ◍ ○	Product A ● ●
Low	Product E & H ◍ ○ ○ ○	Product F & J ● ● ○ ○	Product B & C ● ● ● ●

As seen in Table 6.8, this study indicates that a majority of the case products in the segment of low COGS-value (below $120), for both high and low return volume, would be more profitable to scrap and replace if scrapping were not associated with a cost. Having this as a predetermined decision would also minimize the inspection and is in line with what Guide Jr and Van Wassenhove (2002); Rogers et al. (2002) recommend; make the disposition decision as early as possible. It should also be noted that product I and H at RMA03 are very near the limit of being profitable, which would render in a total conviction of applying such strategy.

There are some indications that it could be profitable applying a scrap and replace strategy for the products with medium ($120 - $300) COGS-value but not for the products with high ($300 - $700) COGS-value. The study does not confirm any impact regarding the return volume. Moreover, for the case products in the categories medium and high COGS-value it is more profitable to repair at RMA-site compared to EMS in nine out of fourteen times.

Chapter 7

Recommendation

This chapter starts with some general recommendations to Axis. Further, the recommendation connected to research question three is presented which is divided in two different sections, depending on the products COGS-value.

In the two following sections, recommendations are presented depending on the COGS-value. There are however, some recommendations that are general to Axis RSC department. First, it is recommended to increase the traceability of their product in the return process and increase the quality of the data. Today, there are a lot of data gaps, especially between RMA-partners and EMSs. Secondly, during EOL, Axis are recommended to keep the majority of parts and units at RMA03 and RMA04. In this stage it is also recommended that the RSC department takes ownership of the testing equipment and start mapping what exists at the different sites. Lastly, we recommend Axis to monitor the RMA-pool avoiding it to increase more than needed.

7.1 Products with low COGS-value

The conducted study implicates that having a limit for what products to repair, and which ones to not repair, could be beneficial for Axis. The premises for this approach is that Axis can find agreements with their current or new partners to receive a product and immediately scrap and recycle it for free of charge. The decisive factor for what products this approach is suitable for is primarily the products COGS-value. Another factor that have been considered is the return volume, however, the study does not confirm any evident impact of the return volume. The research therefore suggest that for cameras with a COGS-value of $120 dollar or less should be scrapped, recycled, and replaced with a new unit. When the product enters EOL, Axis should first seek to find if there is any replacement product that is in production. If there is, that unit should be used as swap-unit in the EOL period. If no replacement product is found, it is recommended that the RSC-department purchases the soon to be EOL product, and place it in the RMA-pool. The amount of cameras to purchase should be determined by applying the PRR algorithm to estimate the number of returns that will arise during the remaining service period.

To implement this, it is required from Axis RSC-department to:

- Find contractual agreement with current or new partners that can scrap and recycle Axis cameras free of charge
- Implement the strategy for all products that currently are in production and for future products
- Inform Axis TSE, all concerned partners, and other stakeholders

This change would free up time to for the personnel at Axis RSC-department to focus on replenishing spare parts, providing detailed repair manuals, and train the RMA-partners in the areas where they can improve for products with higher value.

7.2 Products with medium and high COGS-value

For products with a COGS-value above $120 it is recommended to continue on a similar path as today with some adjustments. To achieve a scalable reverse supply chain, Axis needs to standardize their processes. Therefore, it is recommended to use the same strategy at both RMA03 and RMA04; reduce the number of repairs done at EMSs and repair what is feasible at the RMA-sites. In addition, the pricing structure and its incentives should be evaluated to find a consensus in which direction to go.

Further, it is recommended to assist and improve the RMA-sites with right training, manuals, and spare parts inventory. By doing so, more of the units can be repaired directly at the first instance and fewer units will be affected by the long lead-time that occurs when shipping to the EMSs. This will also lead to more customers receiving the same unit back and a decreased number of units necessary to stock in the RMA-pool. The units that have more complex failures and thus cannot be repaired at the RMA-sites should be sent to the EMS if it is assessed that they are able to repair the unit. Training the RMA-sites in assessing what is repairable at the EMSs is of key importance to avoid sending units to the EMSs for scrapping.

Regarding the EOL treatment, a rationale process is recommended with the help of the PRR algorithm. When a statement is made that a product will enter EOL, the RSC department needs to obtain values for the variables presented in Table 7.1.

Table 7.1: Variables to obtain in order to handle EOL

Variable	**Definition**
T_u	number of remaining returns for product u
R_u	repair rate for product u
L_u	stock level of unit u in RMA-pool and EMS
$C_{u,i}$	average component consumption for component $i = 1, 2, 3...n$

To calculate T_u the PRR-algorithm is applied which will return the total number of returns for product u. Subtract this with the number of returns received so far and T_u is obtained. R_u is the repair rate for both the RMA-partners but also for the EMS. L_u is both what currently is placed in the RMA-pool, but one also have to account for the units that have been shipped to the EMS for repair and are expected to come back. For $C_{u,i}$ it is necessary to calculate the average component consumption per repaired product for each component listed at the repair-BOM. With all these values obtained, one can use the decision model presented in Figure 7.1

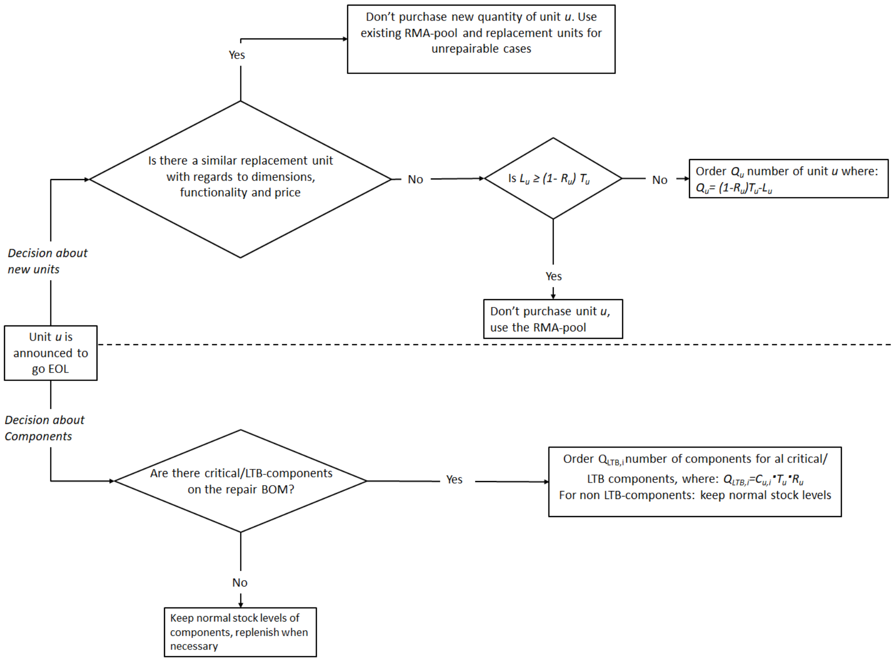

Figure 7.1: Decision model for EOL treatment, medium and high COGS-value (Source: Jiremark & Hansson, 2018)

Chapter 8

Conclusion

This chapter contains the conclusion of this master thesis. First the research questions are answered. Lastly, future research topics within the area is suggested and followed by a discussion about contribution to theory.

8.1 RQ1 - *What are the cost elements related to handling a RMA-case?*

The cost related to handling a RMA-case is divided into investment and operational cost elements. The identified investment cost elements are presented in Table 8.1.

Table 8.1: Identified investment cost elements

Investment cost elements
Cost of training service partners and creating repair manuals
Cost of acquiring testing and assembly equipment to service partners

The identified operational cost elements are presented in Table 8.2. The cells with gray background and white text color are cost elements directly in connection to Axis personnel. The other costs are indirectly in connection to Axis but the activities are performed by external partners.

Table 8.2: Identified operational cost elements

Operational cost elements				
Product acquisition	**Reverse logistics**	**Inspection and disposition**	**Recovery operations**	**Remarketing**
Cost of initial screening and troubleshooting by Axis TSE	Costs of collecting items	Cost of inspection and sorting	Costs of product dissasembly	Cost of administrating the return process
Cost of adm. take-back from customer to RMA-partner	Item inventory holding costs at RMA-site	Cost of initial product test	Cost of a standard exchange of wear components	
	Order picking and shipping costs from RMA-site	Cost of inserting working products into forward flow	Cost of refurbishing and reassembly	
	Transport costs from RMA-site to EMS		Cost of final product or component test	
	Materials handling costs when receiving items at RMA-site			
	Item inventory holding costs at EMS			

8.2 RQ2 - *What strategies are other companies using for similar repair cases?*

Repairs are handled in a number off different ways, three companies have been interviewed, all having different strategies. Reference Company A have a strategy of collecting the product to their local repair partner where they repair simple and standard problems. More complex problems are sent to the EMS located in Asia. By swapping malfunctioning modules in unit, the customer always receives the same shell back. With this strategy they minimize the repair time while consolidating parts and ship them overseas for more complex repairs.

Reference Company B collects all products and repair them in their own repair shop. In most countries they sell products, they also have a repair shop. They succeed to repair their products within one day in 98,5 % of the cases, giving the customer a service time of total three days including transport. This however, put a very high demand on spare part availability and technical knowledge at the repair sites. This strategy creates a very short lead-time and a simple flow of goods. It is however, expensive.

Reference Company C differs from the other two companies since they repair their products at the customers location. They also use a combination of their own service technicians and service partners. The reason for this is to be able to handle services in a bigger geographic area. Since some of the partners have limited technical knowledge, the product is repaired on a modular level. With this way of working the customer receives fast service while the technical competence is not required to be overwhelming. The disadvantage are however the spread of spare parts and transportation cost.

All the companies had a similar focus of the importance of product traceability and the quality of the data. The data is used to track returns and to monitor the return flow.

8.3 RQ3 - *How should Axis decision model be constructed to handle their product repairs?*

Axis is recommended to segment their products with regards to the COGS-value. The required actions will depend on which phase the product is in, according to Table 8.3. The primary and most desirable action for products with medium and high COGS-value in all phases is to repair at the RMA-partners to avoid long lead-times and excessive stock in the RMA-pool. The most significant actions are taken when the product is announced to enter EOL state.

Table 8.3: Decision model for Axis product repair

COGS-value	**Product phase**		
	New	**Mature**	**EOL**
Low **less than $120**	Scrap and replace	Scrap and replace	Scrap and replace When EOL is announced; if no similar replacement is found, replenish the RMA-pool according to recommendations
Medium **$120 - $300**	Send first units to Axis HQ for analysis Primary action: repair at RMA-partner Secondary action: RTV	Primary action: repair at RMA-partner Secondary action: RTV	Primary action: repair at RMA-partner Secondary action: RTV When EOL is announced; follow the suggested decision model
High **$300 - $700**	Send first units to Axis HQ for analysis Primary action: repair at RMA-partner Secondary action: RTV	Primary action: repair at RMA-partner Secondary action: RTV	Primary action: repair at RMA-partner Secondary action: RTV When EOL is announced; follow the suggested decision model

It should be noted that the scrap and replace strategy for products with low COGS-value requires agreement with current or new partners to scrap and recycle cameras without charging for it, which is accomplished at the reference companies. Furthermore, the required actions when a product enters EOL is highly dependant on estimating the remaining number of returns for a product. This thesis have validated, and proposed to apply, an existing algorithm to perform that estimation.

8.4 Future research

Axis is growing and the production sites used are constantly changing. Therefore, it would be interesting to do a similar study in five years to see how these changes have affected the return handling.

Another area that would be interesting to study is best practice for how a repair should be done. By creating more specific tutorials and manuals for how to find and repair faults in a camera, the demanded technical competence at the service partners can be reduced. It would also would contribute to solving the competence problem experienced in USA.

Further topics to study on a strategic level is if Axis's RSC strategy is aligned with the overall strategy of Axis. During this thesis, there have been questions about Axis as a whole perusing a responsive strategy while the RSC-department pursue a cost efficient strategy. If there is a discrepancy; what are the consequences? how can the RSC department approach the overall company strategy? These are questions that would be interesting to find answers to.

8.5 Contribution to theory

RSC has got a lot of attention during recent years. A lot of the studied literature focuses on RSCs that buy back products from customers, rework them and lastly re-market them while the literature of RSCs that manage warranty cases are limited. This thesis has identified cost elements associated with handling warranty cases which is something the authors argue for is currently non existent. Hence, the contribution to theory is knowledge about cost elements in RSCs handling warranty cases.

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Appendix A

Return flow

This appendix present flow diagrams for the processes of standard and advanced replacement. The process involves the customer, Axis TSE, and the RMA-partner.

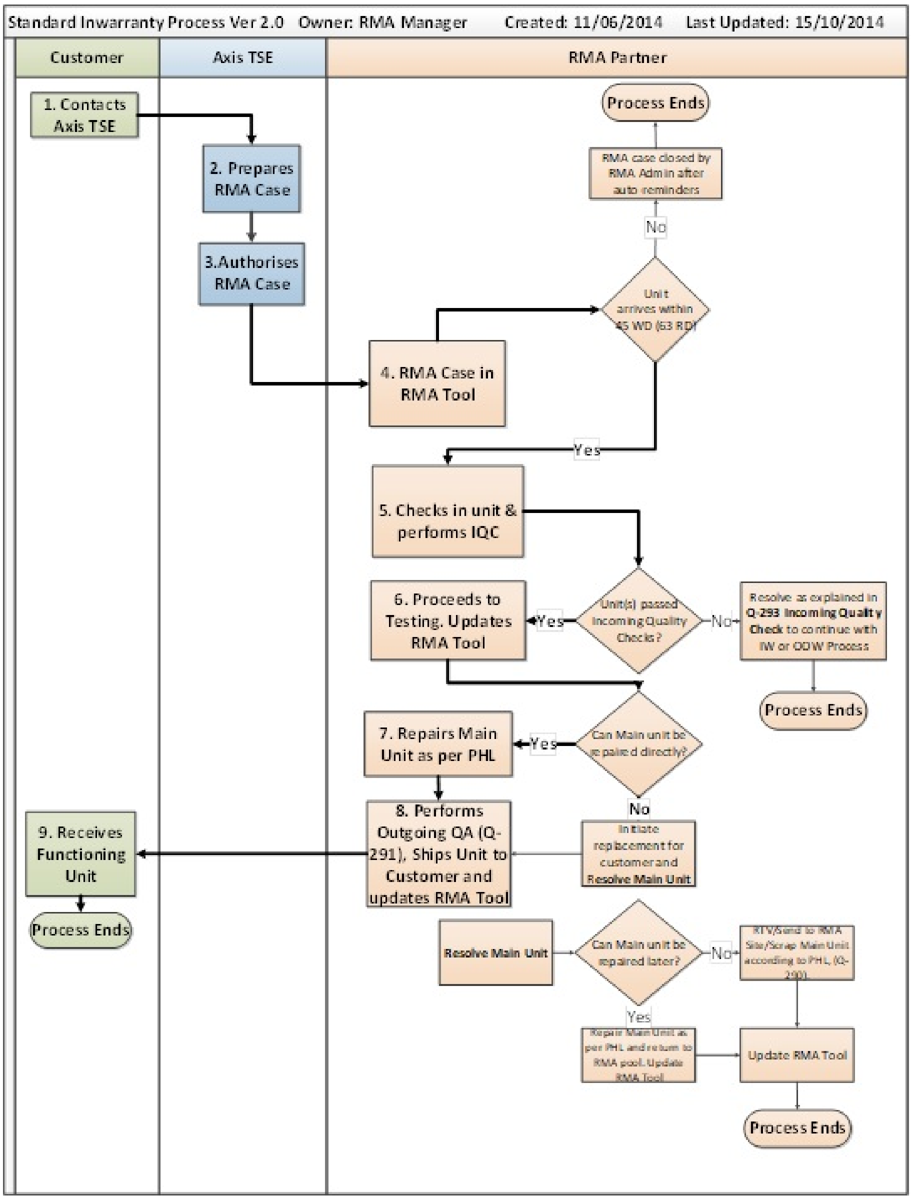

Figure A.1: Standard return flow

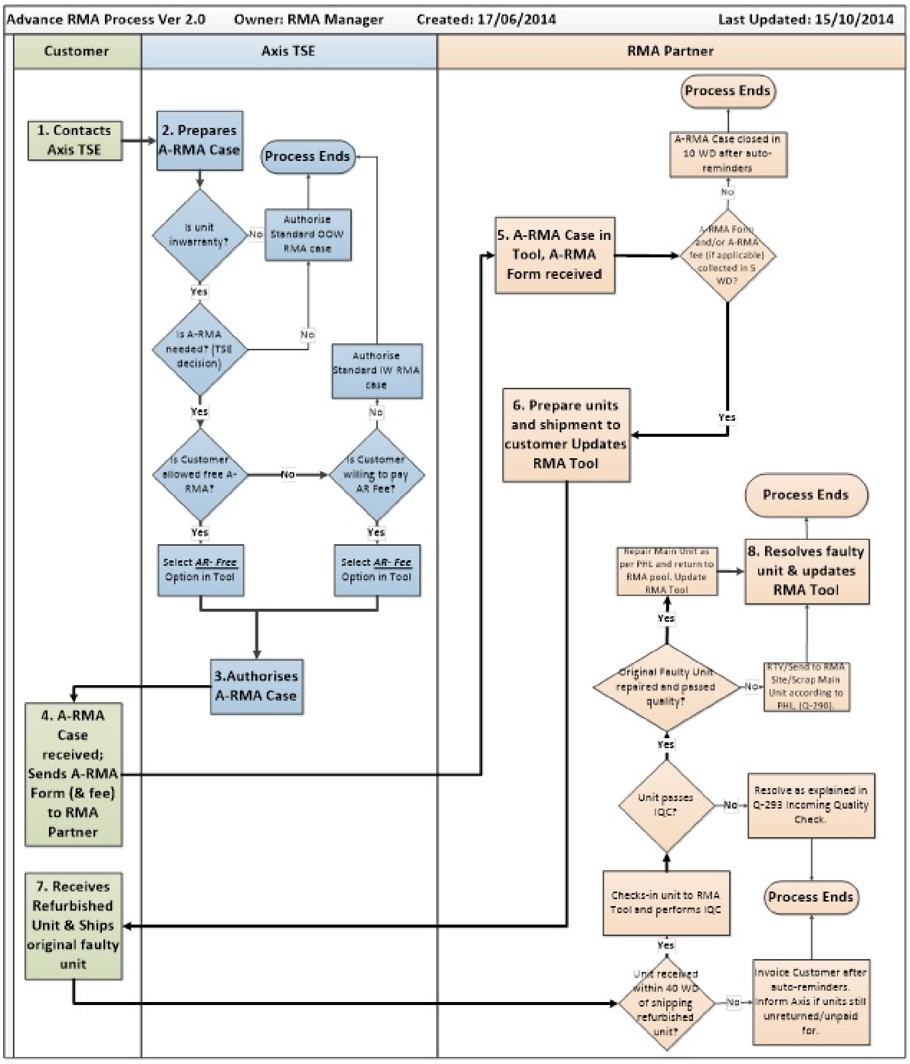

Figure A.2: Advance return flow

Appendix B

Interviews

The interview questions are divided into different categories to make it easier to understand the context. These questions were asked during the visits at the three reference companies.

Introduction

- What is your name and position?
- What is your definition of RSC?
- Who are your customers (end customer, re-sellers or both)?
- What are you return rate in average for your products?

Type of product

- How many active products do you have?
- How much differs between your products from a technical and service perspective?
- Do you provide any type of refurbished or remanufactured products?
- If Yes, on what markets?
- If Yes, what type of warranties do you offer on these products?
- If No, is there a reason for this?
- What type of warranties do you give on sold products?
- Do you offer any type of extended warranties?

RSC

- How does a return process looks like from a customer perspective?
- How does a return process looks like from the company's perspective?
- How many stages are there in the return flow? (i.e. how many parties are involved from end-customer to the RMA-site, EMS)?
- How many days is a return process supposed to take?
- How many of the cases do you handle in that time window?
- Do you perform these actions on your own or by using a service partner?
- If yes, what happens if the service partner can repair?
- How is the decision process for what type of actions you perform?
- How was this decision model created?
- Do you offer advanced replacement?

Service

- Do you offer service after warranty?
- What type of service on the products do you offer?
- Do you work with R&D to minimize returns?
- Do you work with R&D to make service faster and more simple (putting valuable components easy to reach etc.)?

End of life

- Is the process the same for EOL-products?
- How do you prepare handling returns when the production has stopped for a certain unit?
- How do you estimate the amount of returns coming back at this stage?
- Do you stock up old models to handle the warranties that cannot be repaired or do you send out new models, or a combination?

Harvesting

- Do you harvest any parts before recycling the products?
- If No: Why not?
- If Yes: What parts are you harvesting and why those parts?

- If Yes: What do you do with the harvested parts?

Recycling

- Do you recycle the of the material?
- Do you get paid for your recycled material?

Reference

- Can we refer direct to you and your company or do you want us to referee to you as company A etc
- Is it okay to contact you again if we have any additional questions?

Appendix C

Predicted return rate

Table C.1: Data used evaluating the PRR algorithm

Product	PRR (at EOL-date)	Quantity sold (at EOL-date)	Actual Returns (May 2018)	Predicted returns (at EOL-date)	Difference (PR/AR)
X1	1,10%	17651	294	194	66,04%
X2	4,62%	16556	749	765	102,12%
X3	5,98%	50294	2952	3008	101,88%
X4	0,41%	35360	139	145	104,30%
X5	0,65%	22834	140	148	106,02%
X6	0,71%	42054	287	299	104,04%
X7	0,80%	144520	1067	1156	108,36%
X8	0,68%	18939	127	129	101,41%
X9	0,76%	36351	287	276	96,26%
X10	3,30%	515	21	17	80,93%
X11	6,20%	2769	194	172	88,49%
X12	7,55%	7669	500	579	115,80%
X13	12,27%	13277	1598	1629	101,95%
X14	12,78%	36022	3229	4604	142,57%
X15	12,47%	36715	4443	4578	103,05%
X16	2,98%	34573	1073	1030	96,02%
X17	8,97%	25900	2179	2323	106,62%
X18	0,48%	139291	654	669	102,23%
X19	3,91%	2384	92	93	101,32%
X20	1,04%	12466	128	130	101,29%
X21	0,90%	64185	577	578	100,12%

Appendix D

Sankey diagrams

The sankey diagrams are an illustration of the physical flow related to each case product. The diagram for product B is included in the report.

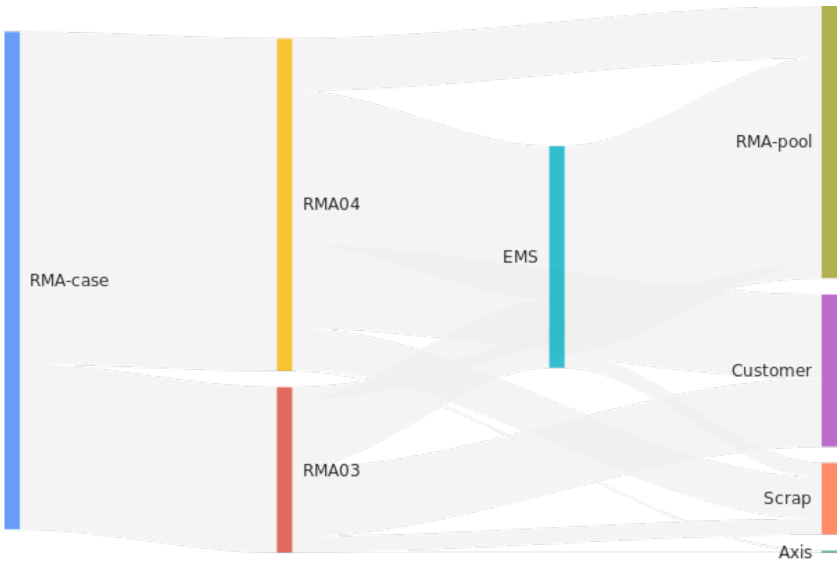

Figure D.1: Product flow and distribution for product A

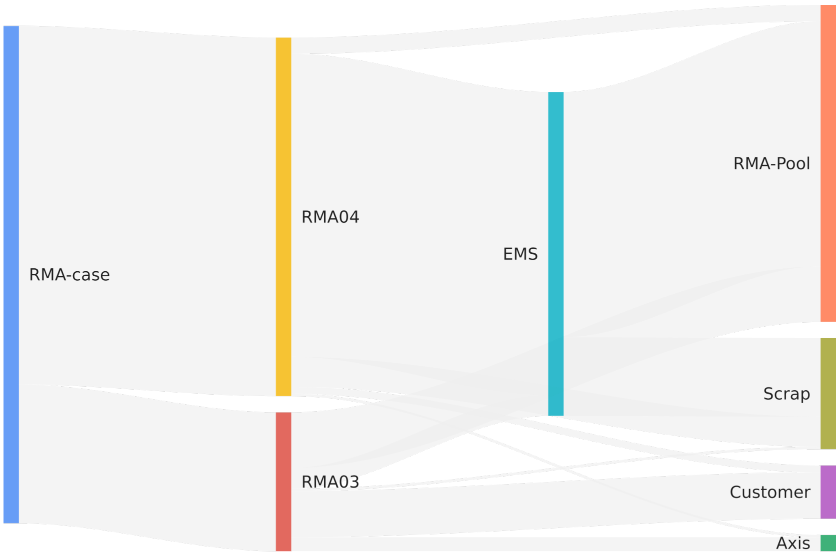

Figure D.2: Product flow and distribution for product C

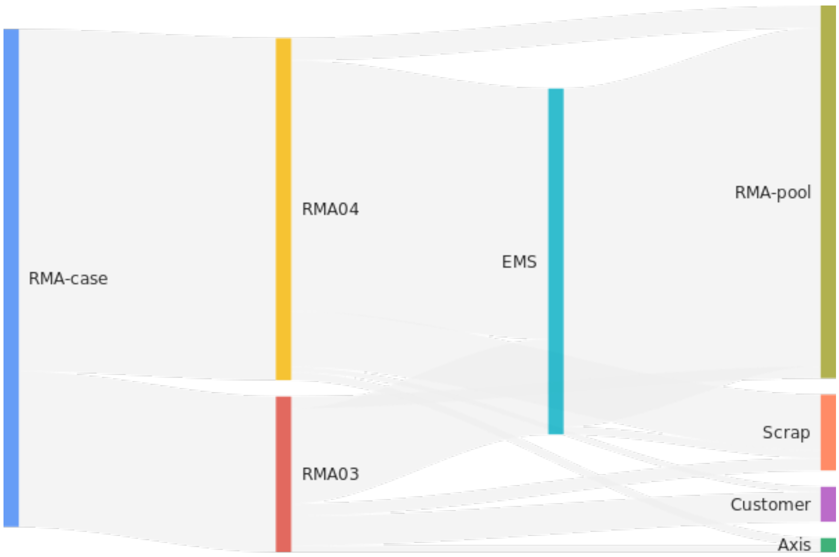

Figure D.3: Product flow and distribution for product D

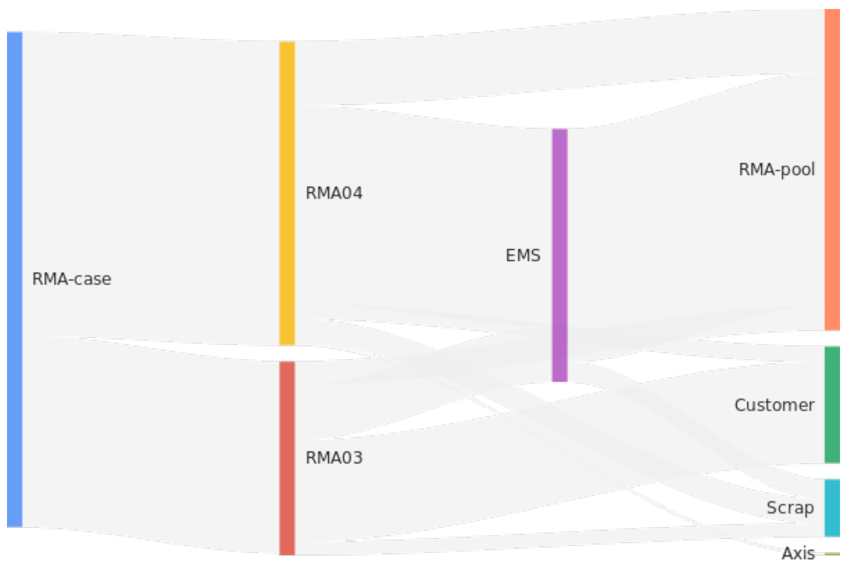

Figure D.4: Product flow and distribution for product E

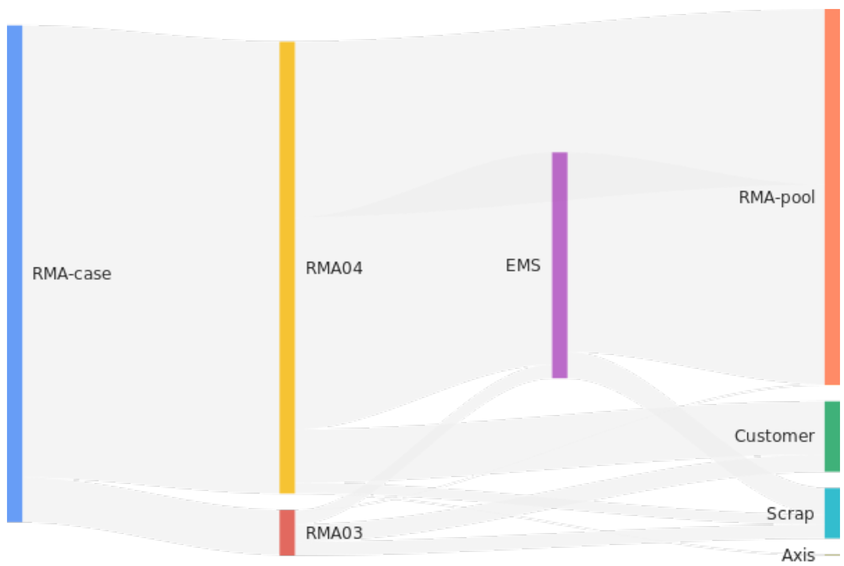

Figure D.5: Product flow and distribution for product F

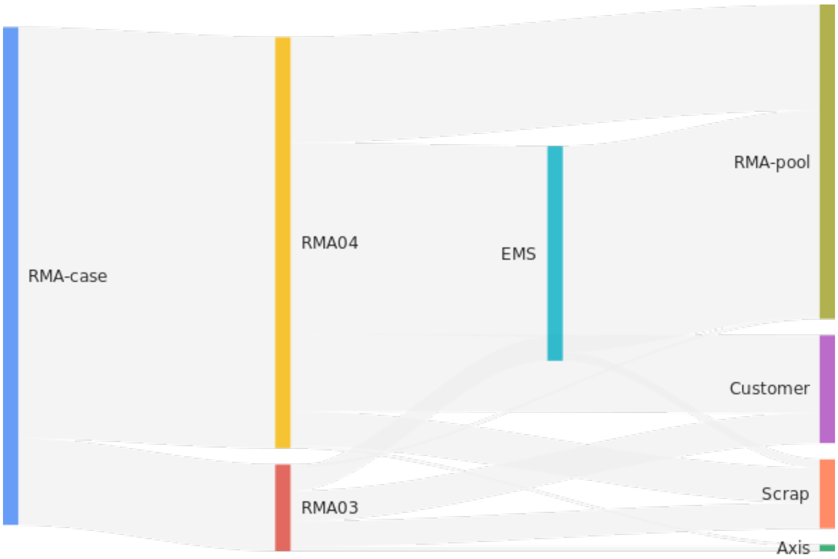

Figure D.6: Product flow and distribution for product G

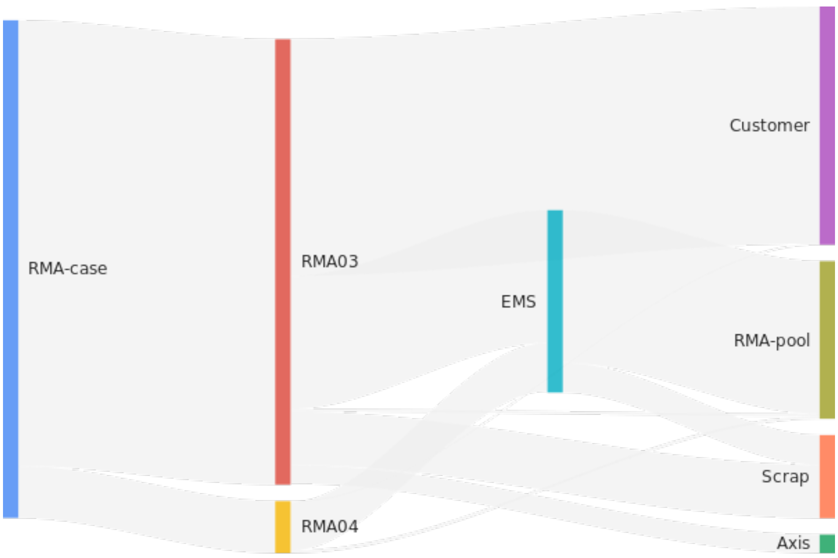

Figure D.7: Product flow and distribution for product H

Figure D.8: Product flow and distribution for product I

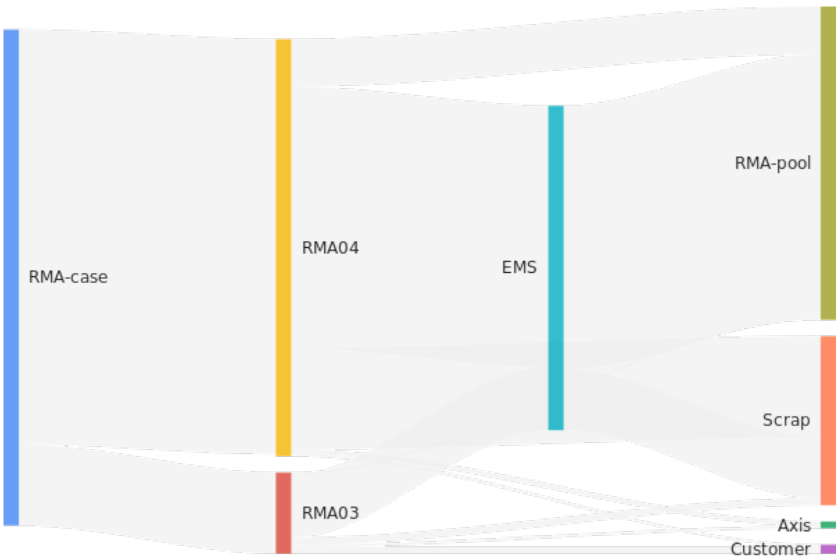

Figure D.9: Product flow and distribution for product J

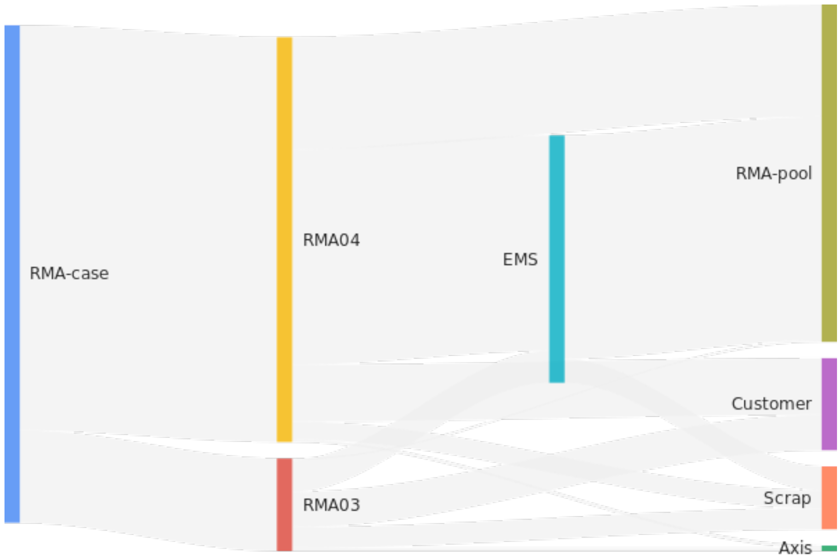

Figure D.10: Product flow and distribution for product K