Exploring the industrial packaging of components for complex electrical products and its sustainability and circularity

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Executive summary

The executive summary provides a concise overview of the key findings and recommendations from the master's thesis report focused on mapping and critically analyzing the industrial packaging system between suppliers and Electronic Manufacturing Service (EMS) for components packaging of two complex electronic products.

The lack of proper communication and documentation regarding packaging materials has hindered a comprehensive understanding of the system. Therefore, the study aimed to examine the structure of the packaging system, assess its circularity in terms of handling packaging materials, and identify opportunities and challenges for making the system more circular in the future.

The study employed a methodology that included supply chain mapping, data collection from Axis databases and interviews, material flow analysis, energy and carbon dioxide analysis, SWOT analysis, and a sustainable packaging scorecard. These methods enabled a comprehensive assessment of the industrial packaging system's sustainability and circularity.

The study's findings provided valuable insights. Firstly, there is a lack of comprehensive information and specifications about packaging materials, which limits a complete understanding of the packaging system. As a result, actions are often reactive rather than proactive. In terms of recycling, the study revealed encouraging results, with high percentages of component packaging being recycled. However, the focus of waste management is still towards a linear approach rather than embracing circular practices. The findings also highlighted opportunities for improvement. Enhancing communication, promoting greater material reuse, and investing in improved recycling facilities emerged as potential paths for progress. However, challenges such as varying stakeholder locations and differing sustainability perspectives pose obstacles to achieving a fully circular packaging system.

Based on the study's findings, several recommendations are proposed. Firstly, it is crucial to enhance the communication and documentation of packaging information among the actors involved in the supply chain. This will facilitate a better understanding of the industrial packaging system and enable proactive management. Secondly, efforts should be made to promote the circular handling of packaging. This can be achieved by exploring strategies to increase the reusability of packaging materials through standardization of materials and sizes. Lastly, conducting a comprehensive life cycle analysis of the entire supply chain will provide a comprehensive evaluation of its sustainability and circularity. This analysis will identify additional areas for improvement and guide future decision-making.

Acknowledgments

This master thesis has been conducted during the spring of 2023 at the Division of Packaging Logistics. Both authors have equally contributed and have been involved through every part of the thesis. However due to working from separate locations access to certain databases was handled on-site by Felix Strömberg. The thesis was conducted as a exploratory case study in collaboration with Axis Communication in Lund, Sweden.

We would like to first thank Axis Communication and its employees for helping us with interviews, database access and additional support throughout the whole process. An extra thanks to our supervisor and the sourcing department. At the Division of Packaging Logistics, we would like to express our sincere gratitude to our supervisor Henrik Pålsson for his valuable support, feedback and patience. We would also like to thank Klas Hjort for his valuable feedback and interesting discussion.

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Abstract

This master's thesis explores the sustainability and the circularity of industrial packaging of components for complex electronic products. The research aims to gain insight into the structure of the packaging system between the suppliers and the manufacturers (EMS) and evaluate its circularity to identify the opportunities and challenges for future improvement.

The study examines the packaging for components used in two products. All components are sourced from Asia and handled at the manufacturing and assembly unit (EMS). By analyzing the used packaging materials recycling rates, it is determined that the packaging of product A and B have recycling rates of 74% and 88% respectively. The research also utilizes environmental indicators including, the Cumulative Energy Demand (CED) and Carbon dioxide equivalence (CO_2-eq) to assess the environmental impact of different packaging materials. Together with a sustainable packaging scorecard analysis the packaging materials to avoid or replace if possible were identified to be bubble wrap, plastic covers and Styrofoam.

Challenges related to varying recycling conditions and lack of universal packaging language are recognized, highlighting the need for improved communication and documentation in the supply chain. Recommendations are provided to improve the accessibility and documentation of packaging information, enabling stakeholders to make informed decisions to improve the sustainability and circularity. The study suggests a comprehensive life cycle assessment for high accuracy and visibility.

In conclusion, the study provides valuable insights into the sustainability and circularity of the industrial packaging for complex electronic products. The analysis of recycling rates, environmental impact indicators, and challenges associated with circularity contributes to the understanding of the packaging system in this case study. The findings provide guidance to stakeholders to adopt more sustainable packaging approaches and contribute to the development of a circular economy.

List of abbreviations

Axis

Axis communication AB

EMS

Electronics manufacturing service

EPS

Expanded Polystyrene

ESD

Electrostatic discharge

HDPE

High-density Polyethylene

LTH

Lunds tekniska högskola

LDPE

Low-density Polyethylene

CO2-eq

Carbon Dioxide Equivalent

LCA

Life Cycle assessment

PCB

Printed Circuit Board

PE

Polyethylene

PET

Polyethylene Terephthalate

PTZ

Pan-Tilt-Zoom

SC

Supply Chain

BOM

Bill Of Materials

CED

Cumulative Energy Demand

PLM

Product Lifecycle Management

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1. Introduction

1.1 Background

In a world of global cooperation and trade, companies have established vast global networks to source the most competitive material and components. This global trade has generally been a force for good. However, with growing concerns about how international trade can affect the environment, many international organizations have pushed for a more environmentally sustainable trade. (WTO, 2018)

Among the many aspects of international trading, packaging plays a significant role in the performance of the supply chains. Defining the packaging system can act as a foundation for informed decisions which can both reduce supply chain costs and environmental impact (Pålsson, 2018). Packaging should fulfill six basic functions: *Protection, Containment, Apportionment, Unitization, Communication, and Convenience* (Livingstone & Sparks, 1994). These functions do affect sustainability, but the packaging's environmental impact is not always considered. Packaging systems affect both directly and indirectly the environment and thus sustainability are becoming a large part of the packaging.

Sustainability has become an integral part of any business across the world particularly in the European Union (EU) due to demanding laws and regulations that are being constantly updated. Among many things, this encourages companies to improve their supply chain regarding sustainability. But it is difficult to measure and regulate as the laws and regulations differ between countries and continents. However, a company such as Axis Communications can develop and encourage the other actors of their supply chain to become more sustainable and circular regarding industrial packaging. Consequently, it is important to define the current performance of packaging for suppliers' components when sustainability and circularity are concerned to map the scope for improvement in the future.

One of the more easily measured and researched environmental impacts is the direct impact of packaging waste. (Pålsson, 2018) To address the issue of packaging waste and to support sustainable packaging solutions, companies have increasingly been incentivized by legislation and taxation (Rossi et al., 2015). An increased focus on sustainability and circularity is not just perceived as an extra layer of complexion and difficulties but as also an opportunity to improve the overall performance of the supply chain (Silva & Pålsson, 2022).

Axis, who is one of the main actors in the supply chain for this project has the ability to impact the working conditions of its suppliers and their environmental impact. As such, Axis also has a responsibility for helping to ensure that the products are manufactured in a sustainable and responsible way (Axis Communication, 2021) which is the main motivation for concentrating on suppliers' packaging towards circularity.

1.2 Research problem

With the growing awareness of the importance of sustainability, organizations are focusing on ongoing projects to pave the way for a sustainable and a circular future. However, there remains a lack of understanding on the impact of packaging materials on the supply chain's circularity and their potential contribution to sustainable development in the specific case study. Projects combining sustainability and packaging are scarce in the organization, making it essential to prioritize them to improve overall sustainability and circularity performance. Effective communication and understanding of the relative sustainability of packaging are vital within company departments, business-to-business communication in the packaged goods supply chain, and meeting customers' expectations (Verghese, 2012). However, the company in the specific case study has not invested in evaluating the sustainability status and circularity level of suppliers' packaging due to challenges such as lack of information sharing and inconsistency in updating available information. To improve circularity, innovative models and environmental analyses are required, including accurate data collection and transparency in data sharing between supply chain actors. The history of packaging research shows that recycling has been a primary concern, and the search for alternative materials and end-of-life routes plays a vital role in the present and future of packaging's life cycle assessment (LCA) (Burros M.V, 2019). Accurate data on the packaging system and transparency in data sharing are important for various environmental analyses. Data collection should focus on the factors that researchers aim to control, measure and understand, driven by the basic models used to analyze the data (Perlis, 1983). Consequently, the project to map the supply chain and material flow of a camera model's packaging aims to understand the current circularity performance of the packaging materials, and this thesis will provide a foundation for further investigation and analysis. The study's findings will contribute to the growing further understanding of sustainable packaging and supply chain management, providing recommendations for future research and action towards a more sustainable future.

1.3 Purpose of the thesis

The purpose of this study is to map and critically analyze the industrial packaging system between the suppliers and Electronic Manufacturing Service (EMS) for all components included in two complex electronic products and determine how sustainable and circular the handling of the packaging system is.

Three research questions have been formulated based on this purpose:

- How is the industrial packaging system structured for different components in two complex electronic products between the suppliers and the manufacturing?
- How circular is the industrial packaging system for the components regarding handling of packaging materials?
- For the packaging system to become more circular, what are the possible opportunities and challenges for the future?

1.4 Goal

The goal is to gain insight, map and evaluate the industrial packaging system of different components for two complex electronic products between suppliers and manufacturing to determine its circularity.

1.5 Thesis outline

Chapter 1: Introduction

This chapter serves as an introduction to the academic report, providing essential background information and clearly stating the research problem. The purpose, goal and the outline of the thesis are also outlined.

Chapter 2: Methodology

This chapter explains the research design and approach used in the study, focusing on the chosen methodology and its suitability for the purpose of the research.

Chapter 3: Frame of reference

The theoretical framework and the analytical references that support the research are presented in this chapter. A comprehensive review of relevant literature is done to establish a foundational concept for the study

Chapter 4: Analysis and Results

This chapter revolves around the empirical data gathered during the study. Various analytical studies like packaging analysis as well as supply chain mapping and material flow analysis are used to interpret the collected information. The results obtained are reported objectively, aligning well with the research questions.

Chapter 5: Discussion

The results obtained are critically analyzed in this chapter. Meaningful insights are derived from the finding while addressing the limitations and challenges. The implications and significance of the study within a broader academic context are explored comprehensively.

Chapter 6: Conclusion and Future recommendations

This chapter involves the summary of the thesis to answer all the research questions. Also, the recommendations are offered for future research by suggesting potential areas of exploration inspired by the study.

1. Methodology

With the basic understanding of the problem and the goal of the case study, the methodology chapter will describe the approach for the study and why this approach was chosen. Constraints and limitations will also be discussed along with data credibility. This chapter will start by discussing the research design for basic understanding followed by a research approach to explore more on the process of the study and concluding with data credibility to ensure the reliability of the information shared.

2.1 Research Design

For the best fitted method, three major conditions should be considered. Firstly, the categorizing line of questions ``how", "what ","why ","who", "where ". Secondly, can the researcher manipulate the event around the study? And lastly if the study focuses on historical events or contemporary. (Yin, 2007)

The unit of analysis is the component packaging system of the two products. With limited understanding and information from Axis regarding their current industrial packaging system, this study took the form of an exploratory study where the goal was to create a fundamental understanding of how the component packaging system of the two complex electronic products in the supply chain are structured and why. (Yin, 2007) This will be achieved by doing case studies where the two products are investigated and analyzed. The analysis will combine the two cases as one since the aim is to derive a holistic view. The decision to study two cases was to improve the accuracy of the analysis. It was also to gain insight into the overall industrial packaging in the supply chain to answer the third research question.

The study will be conducted in three phases centered around the visit to the EMS. The first phase includes using the available data to establish a foundation and a general understanding of the components packaging and their suppliers. Key areas of interest should be identified and what missing data is required for further analysis. The second phase is the visit to the EMS where on-hand information regarding its capabilities and views are acquired. The third phase will include the complete analysis of the system in order to answer the stated research questions.

2.1.3 Chosen approach

Based on the stated research questions an *inductive* approach was chosen since it aims to understand a phenomenon in a wide sense. With this the study can add to the body of knowledge with a theory that explains the phenomena in question. Starting off by collecting available quantitative data by observing the system and then following it up by describing it with qualitative methods such as interviews. (Kotzab, et al., 2005)

2.1.4 Framework

The framework for the study was based on Pålsson (2018). The packaging performance methodology shown in figure 1 below aims to assess a packaging system's overall supply chain performance. The methodology describes the overall packaging performance from a zoom-out perspective to identify the potential improvements in the packaging system. The process had been categorized into four stages: supply chain mapping, data capturing for evaluation determination, Visualization of data, and the improvement of the packaging system. The methodology would facilitate the determination of the different functionalities of the packaging system at different levels in specific.

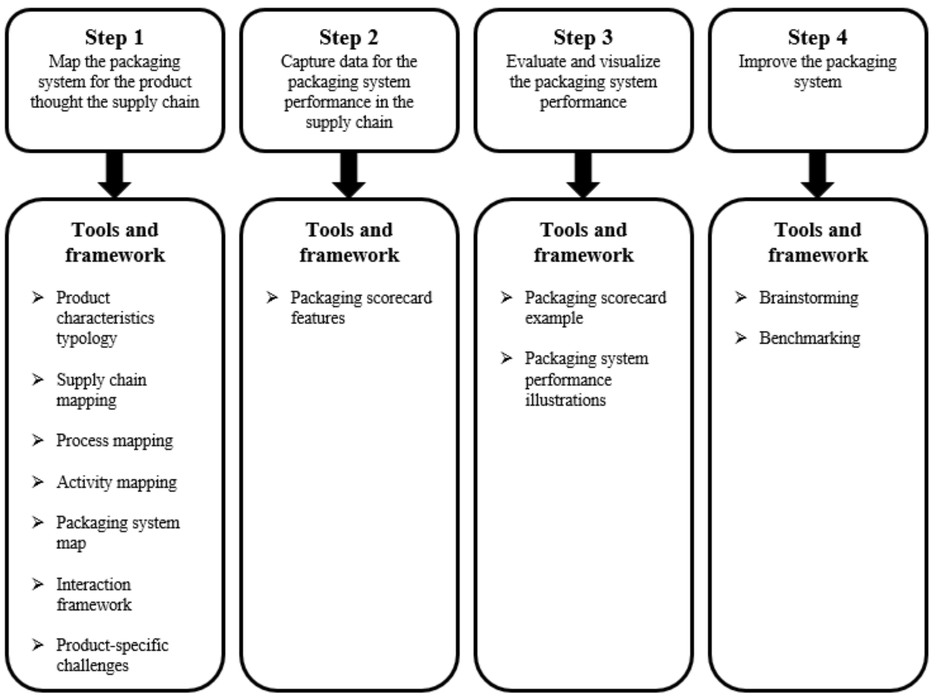

Figure 1: Steps and supporting tools in packaging performance methodology (Pålsson, 2018)

The framework was well-suited for the determination of improvements in the packaging system from a zoom-out perspective. But a more concrete methodology would be required for the specific problem-oriented evaluation and solution

2.1.5 Chosen Methodology

The chosen methodology was a compilation of different research methodologies. The methodology will be pointed out below in sequential order:

- Supply Chain Mapping: Mapping of the supply chain to determine the product characteristics, and different packaging levels and to identify the different actors involved in the supply chain.
- Data Collection: Quantitative data acquired from Axis databases. Qualitative data acquired through interviews with different key actors throughout the supply chain.
- Material Flow Analysis: Material flow performed by analyzing the inflow of material with the outflow into the waste stream.
- Energy and Carbon dioxide equivalent analysis: Determining the amount of energy needed and carbon dioxide equivalent produced by the packaging.
- SWOT Analysis: SWOT analysis performed on different packaging materials to identify positive and negative contributions to the product and the environment respectively.
- Sustainable Packaging Scorecard: A five-point scale for three different principles, effective, efficient, and cyclic with different functionalities.

2.1.6 Why Axis and their products?

Axis Communication were well suited for the study since they had identified this as an important part in their goal of becoming more circular. They had a keen interest in further understanding their industrial packaging system upstream. Their complex electrical products are assembled with hundreds of components from several global suppliers and make compelling cases to study. Axis has close ties with LTH and as such values these kinds of studies and is willing to cooperate to great extent. The chosen cases should predict either similar or different results (Yin, 2007). The cases are predicted to be similar since they are manufactured at the same site. Since similar results are predicted, between two and three cases is a suitable amount.

The two cases (products) chosen were based on three criteria. First, they should represent Axis packaging logistics as a whole to derive approximate conclusions. They should also be sufficiently complex to fulfill the purpose of the research question. Lastly, they should be relatively easy to investigate with suppliers and EMS willing to cooperate and have available packaging data.

2.1.7 Data collection and the sources

To be able to answer the stated research questions three key areas and three key actors were studied. The key areas were packaging, sustainability and sourcing, and the key actors were Axis, the EMS and the suppliers of the components. Axis provided the main body of packaging data as well as information regarding how the packaging were established and their approach to sustainability. The EMS provided information regarding their waste management capabilities as well as on-site information on how packaging material was processed. Lastly there were the suppliers who provided the packaging details on their components, as well as information regarding how they approached packaging. Seen below in Table 1 is what kind of information that was expected from each party, where "data" refers to quantitative data and "interview" qualitative.

Table 1: Data collection at respective parties.

	AXIS	EMS	SUPPLIERS
Packaging data	x	x	x
Packaging interview	x	x	x
Sustainability data	x	x	
Sustainability interview	x	x	
Sourcing data	x		
Sourcing interview	x		

2.1.8 Early limitations and approximations.

With the exploratory nature of the study as well as the limited time and data, there were several limitations established before conducting the study. Firstly, the study will only look at the logistics of the packaging material and its circularity and direct impact on sustainability. Thus, other direct and indirect areas key to sustainability were not pursued. Another limitation is that it only investigates one EMS located in Poland, and as such is limited in drawing any general conclusions regarding Axis since they use several other EMS around the world.

2.2 Research Approach

This section will discuss how the study was conducted based on the chosen methodology. The Study was divided in three phases starting from a broad approach in the first phase to a narrower focus on the key areas of interest in later phases.

2.2.1 Phase One

Considering the exploratory nature of the study the first step was to map and analyze the components in the BOM and their corresponding suppliers. The complexity of the investigated products and the limited information and time compelled the study to identify and categorize the components regarding their relevance in the packaging system.

After determining the most relevant components for our study, the next step was the supply chain mapping with the goal of gaining an understanding of the packaging system, the supply chain characteristics, and the product characteristics that affect packaging. Several tools and considerations were used to map the product characteristics, the supply chain, the packaging system, and the challenges encountered (Cooper & Gardner, 2003). These are further elaborated and discussed in chapter 3 frame of reference.

The supply chain was mapped to identify and understand the different actors involved in the supply chain. To complement and further understand the SC map interviews with different actors in the supply chain were performed. Unlike the packaging scorecard from the textbook, a more concrete approach for the interview questionnaire was designed to capture the accurate challenges in the supply chain that acted as hindrances to being more sustainable and circular. The interview focused mainly on packaging material usage and wastage throughout the supply chain. As mentioned before, the scorecard would be helpful to identify the specific area for improvement but to be able to dive deep into the specific problem, a qualitative approach would be required to clearly understand the base problem.

2.2.2 Phase Two

The next phase was to visit the EMS in Poland. The goal of the visit was to get a first-hand look into the handling of packaging material throughout their process and their waste management. Data were collected by a walkthrough of their operation as well as interviews with an on-site industrial engineer and environmental leader (See appendix A). With the collected data in phase two a detailed process map on the material flow of packaging material from suppliers to end of life was created.

Another important aspect of the visit was to validate the packaging information from Axis databases. Ensuring that the data used in the study coincided with the actual packaging.

2.2.3 Phase Three

The last phase was to narrow down and focus on the identified areas of interest. This included sending a short questionnaire to the key suppliers as well as an interview with the Axis engineers responsible for the audit process of new components (See appendix A). The direct environmental impact of the packaging was calculated based on other life-cycle analysis for the same packaging material.

Whereas phase one and two mainly focus on the “how”, phase three's main goal is to understand the “why” aspects. With the understanding of the capabilities and wants of the involved parties a packaging analysis was conducted to evaluate the packaging material used in the system.

2.3 Data credibility

To ensure that the findings are reliable the credibility of the collected data is vital. The study bases its data credibility on the three pillars, *validity*, *reliability*, and *objectivity*. (Björklund and Paulsson, 2014)

To ensure validity the study used multiple empirical sources as well as discussing and reviewing interview questions with supervisors at Axis and LTH before the interviews.

The reliability of data is determined if the same results are given, and the conditions are consistent. Confirming that the given data given from the suppliers to Axis matches the data at the EMS is vital to the accuracy of the study. Objectivity is expected to be increased when the researcher is impartial to not affect the outcome of the study. By measuring the dimensions of the packaging at the EMS as well as taking material samples, the validity of the packaging information in Axis databases could be confirmed. If the measurement did not align with the stated packaging information notes were taken and the measured data from the EMS prioritized. The objectivity was ensured by basing the analysis on previously reported data and measurement, not the intentions and stated goals of the stakeholders.

3. Frame of reference:

This chapter of the report focuses on the literature relevant to the research. It is divided into two parts. The first part reviews important concepts that are essential for understanding the study. This theoretical background helps establish a strong foundation for the analysis. The second part examines different models and tools used for analytical research, specifically those relevant to the study. This research is crucial for identifying and selecting the most relevant analytical tools for the case study.

3.1 Theoretical Background

In this subsection, the theoretical foundation for the project is discussed. The three main topics shown below in figure 2, Packaging, supply chain management, and circularity are discussed while explaining how they are interrelated for this study.

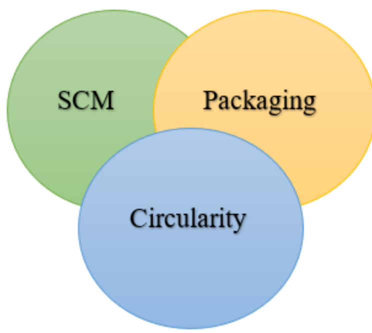

Figure 2: Literature frame of references

3.1.1 Supply chain management

In this part, detailed definitions of supply chain management are discussed to facilitate the reader to have a clear understanding of the foundation. The in-depth focus areas in the SCM are addressed like supply chain integration, system theory, and their contribution in maintaining an effective supply chain are discussed.

Supply chain management aims to minimize the total cost of these flows while optimizing the services provided throughout the supply chain (Harland, 1996). It's important to recognize that supply chains are complex systems that involve various stages and flow of goods, information, and finance, as well as coordination and integration between different parties (Chopra and Meindl, 2001). However, as shown in figure 3 below, they can be simplified to gain a basic understanding.

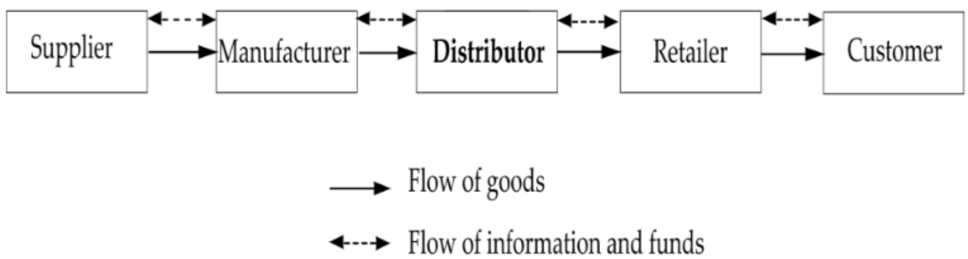

Figure 3: Basic supply chain flow (Chopra and Meindl, 2001)

Supply chain integration is crucial for achieving this optimization, and it involves the coordination and integration of different parts of the supply chain as a single unit (Pålsson, 2018). And so, it is important to view supply chains as systems that interact with and are influenced by their external environment (Bertalanffy, 1969). Systems theory facilitates an approach to studying complex systems like supply chains, as it allows for a holistic view of the system (Pålsson, 2018) and the identification of subsystems can contribute to a better understanding of the dynamics within the supply chain over time (Miller, 1978). Applying a systems approach to studying supply chains involves zooming in and out repeatedly to understand the links and overall influence of different components of the system, and to identify the effect of a change to one part over the other and also on the whole system. Illustrated in figure 4. This helps to avoid sub-optimization and helps to achieve a coordinated and synchronized approach (Pålsson, 2018).

In conclusion, viewing supply chains as complex systems and applying a systems approach to their management can help organizations better understand and optimize the flow of goods, information, and finance, and ultimately improve efficiency and sustainability across the entire supply chain (Pålsson, 2018 and Chopra and Meindl, 2001).

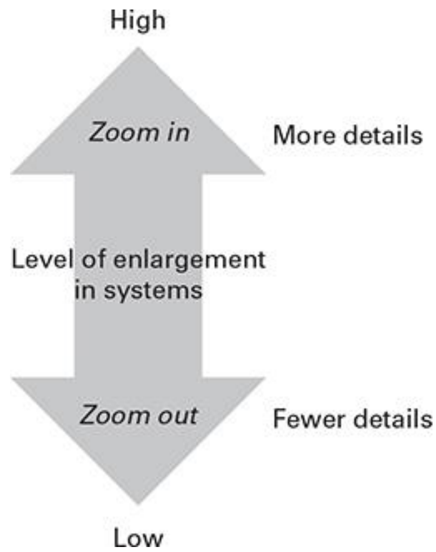

Figure 4: Level of enlargement in systems by zooming in and out (Pålsson, 2018)

Understanding the principles of supply chain management is important when conducting the study. How the suppliers, the EMS and Axis are connected, and their respective roles is of great interest when investigating the industrial packaging.

3.1.2 Packaging

In this part, the packaging functions and levels will be discussed alongside the interrelationship between packaging and logistics systems, as well as the impact of packaging on the environment, to optimize the supply chain and circularity.

Packaging plays a vital role in the supply chain as it provides protection, containment, unitization, apportionment, communication, and convenience for products (Pålsson, 2018 and Lockamy III, 1995). Packaging can be viewed as a system that consists of three interrelated packaging levels shown in figure 5 - primary, secondary, and tertiary (Bjärnemo, 2000). The primary packaging is the package that is closest to the product. Secondary packaging contains several primary packages, while tertiary packaging, such as a pallet, contains several secondary packages (Pålsson, 2018).

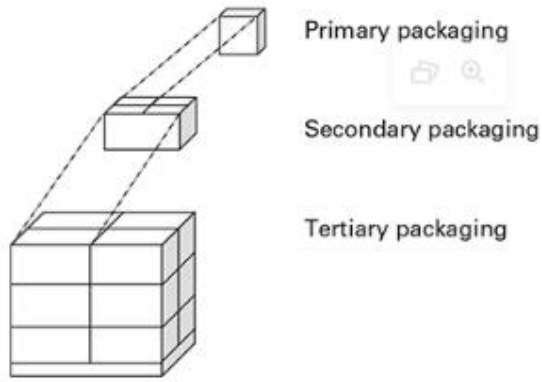

Figure 5: The three interrelated packaging levels (Pålsson, 2018)

Packaging is a key element in logistics systems and has a significant impact on logistics costs and performance, as well as the supply chain's effectiveness and efficiency (Hellstrom, 2007). However, there is often a lack of knowledge about how the logistics system affects the packaging system and vice versa. Understanding this relationship between the logistics system and the packaging system is critical to optimizing the supply chain (Johnsson, 1998).

Packaging also has an impact on marketing and the environment. It can also contribute to the environmental impact of the supply chain, especially in terms of waste and recycling. Hence, considering the environmental impact of packaging is important for sustainable supply chain management (Saghir, 2004).

3.1.3 Circularity

Based on the concept of circular economy (CE) this section will discuss circularity in industrial packaging and the 9R framework

Circular economy is a model which aims to keep material goods as long as possible within the economy. Circular economy stands as a departure from the traditional take-make-consume-throw away type of linear economy, which relies on large quantities of easily accessible, cheap material. The circular economy model aims to reduce waste by extending the life cycle of products and material, thereby also creating further value. (European Parliament, 2023) Circular economy can be seen as an extension of environmental sustainability where focus lies in maximizing the value of products and material instead of just reducing the material flow. (Silva & Pålsson, 2022)

Industrial packaging has major potential to contribute to sustainability and circularity in the supply chain. Companies have greater control of the material life cycle in industrial packaging due to the nature of business-to-business and its ability to create shared agreement, especially in comparison with customer packaging where waste ends up in households. (Silva & Pålsson, 2022)

3.1.4 9R framework

The 9R framework shown in figure 6 below is an hieratical framework where the bottom represents the traditional linear economy and for each step up from R9 to R0, the more circular the handling is. (Kirchherr et al., 2017)

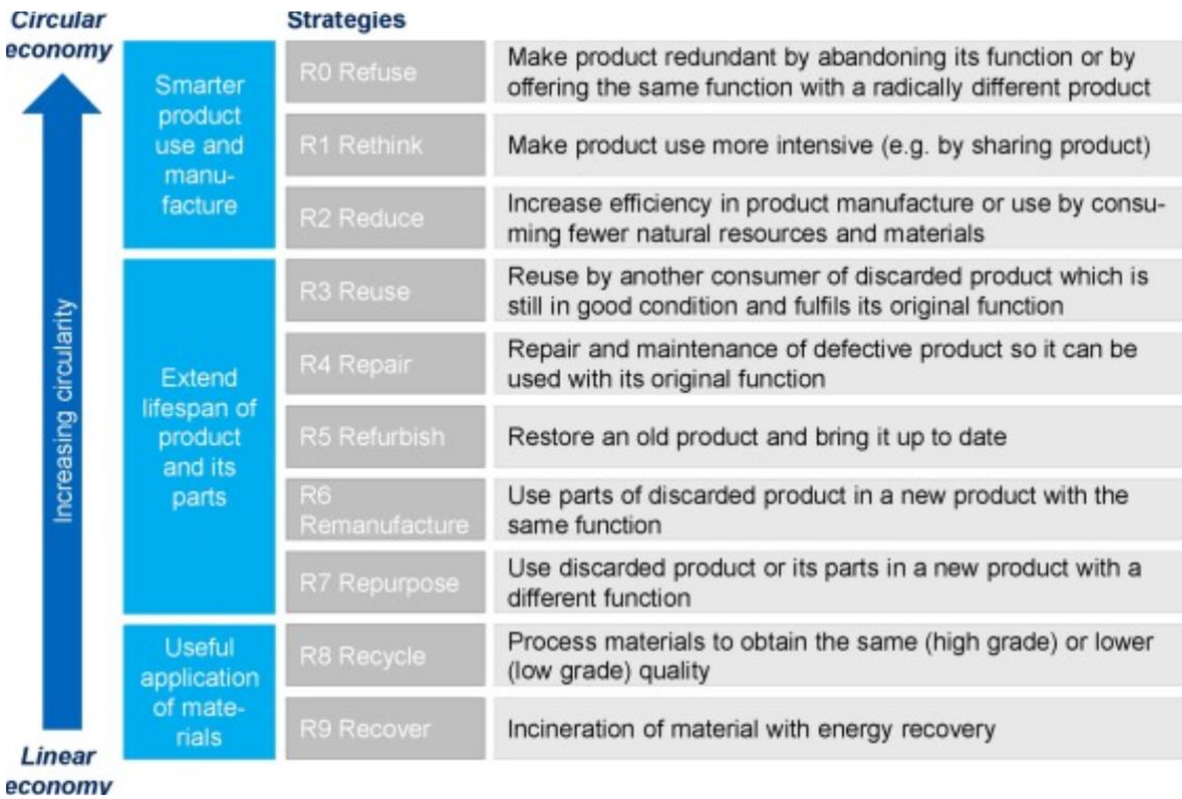

Figure 6: The 9R framework (Kirchherr et al., 2017)

In this study concerning the handling of industrial packaging material, the "R"s most relevant are: R9 recover, R8 recycle, R3 reuse and R2 reduce. The framework will be used in the packaging analysis as well as when discussing future improvement.

3.2 Analytical framework

In this section the analytical tools and frameworks are discussed. These will help in the analysis of the data by applying academically established models in order to answer the stated research questions. The mapping will help us analyze the supply chain and the flow of packaging material at the EMS. The packaging analysis will help when evaluating the circularity of the identified packaging.

3.2.1 Supply chain Mapping

Supply chain Mapping can be a useful tool to clarify channel dynamics, provide a common perspective and enhance communication. In essence a map is a graphical construct that communicates items of information and despite being simplified, should capture the essence of the environment. Table 2 below describes the orientation, level of detail and purpose of the two most common map types as well as legends of the symbols used. (Norrman, 2020) (Cooper & Gardner, 2003)

Table 2: Characteristics of SC and process mapping (Cooper & Gardner, 2003)

	Supply Chain Mapping	Process Mapping
Orientation	External	Internal (typically)
Level of Detail	Low to moderate	High
Purpose	Strategic	Tactical

Supply chain Strategic supply chain mapping focuses on how goods, information and money flows through the supply chain. There are different approaches to developing a SC map depending on the perspective needed. Since this study focuses on the SC between suppliers and EMS that is what the map will focus on (Norrman, 2020)**.** A process map often encompasses a single operation or system within a company. Thus, it can have a higher level of detail and emphasize a certain system on a tactical level. In this study's case the flow of packaging material in and around the EMS. (Cooper & Gardner, 2003) By combining the SC map from suppliers to the EMS with a process map of the flow of packaging material a valuable analytical tool was formed. This tool will be applied to the products in the study to give an almost complete, although simplified, overview of the life cycle of the packaging.

3.2.2 CED and CO2-eq

To evaluate packaging, there are two different perspectives, one of which is to calculate the end-of-life methods of the packaging and the second is to evaluate the environmental impact indications using different indicators like Cumulative Energy Demand (CED) and Global Warming Potential (GWP) (Pasqualino, Meneses and Castells, 2011). Life cycle Assessment (LCA) is usually done to calculate the entire life cycle of the material considering all the processes involved. However, if faced with a complex study, a lack of information, or time constraints that make it impractical to conduct a full LCA, using an energy analysis is a suitable method to gain an initial understanding of the environmental impacts (Patel, 2003). CED is an indicator used in packaging analysis to assess the total energy consumption associated with the life cycle of packaging materials (Smith et al., 2019). For this study, it is used to evaluate the energy consumption during the manufacturing of the different packaging and how that is contributing to the environmental impact. Carbon dioxide equivalence (CO2-eq) is used to analyze the carbon emission of the packaging throughout the life inclusive of all the processes (Bala et al., 2021). CO2-eq is also helpful in analyzing and comparing different greenhouse gases like methane, nitrous oxide and carbon dioxide depending on their Global Warming Potential (GWPg) for a specific period (IPCC, 2013).

The above-mentioned indicators will help in evaluating the environmental impact caused during the manufacturing of different packaging materials that has a great impact on material selection and improvement of the particular case study.

3.2.3 Packaging analysis

There are a multitude of different packaging materials, and they have different attributes. Identifying and matching these attributes with the preferences of the packaging system can establish which materials to prefer and which to avoid.

SWOT

"SWOT analysis is a tool used in trying to identify and examine the existing resources, both internally and externally, investigating their trends and patterns that may have either positive or negative impacts on businesses" (Namugenyia & Nimmagadda, 2019). SWOT analysis was abbreviated as Strengths, Weaknesses, Opportunities, and Threats of the specific developmental study. SWOT analysis is a valuable tool for businesses of all sizes, enabling them to adapt to changing circumstances, seize emerging opportunities, and maintain a competitive edge in their industries (Hill & Westbrook, 1997).

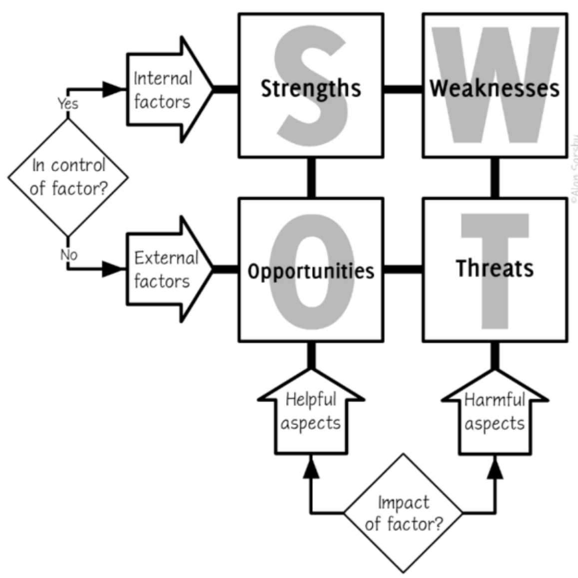

Figure 7: SWOT Analysis Framework (Sarsby, 2016)

Scorecard

Scorecards can be a valuable method when comparing different methods or materials. A packaging material scorecard inspired by the Sustainable Packaging Principle was created. Sustainable Packaging Alliance (SPA) in Figure 8 below first established four sustainable packaging principles under the labels Effective, Efficient, Cyclical, and Safe (Sustainable Packaging Alliance, 2010). The scorecard is used in this study considering the three relevant principles out of four from the SPA for the study and they are effective, efficient and cyclic. The specific features related to them are considered as individual functionalities which are scored individually. The scorecard is ranged between 1 to 5, 1 being the least and 5 being the most. The scores are plotted based on the analysis during the EMS visit and experts suggestions from different supply chain actors. The average score is also measured to observe the overall performance of the packaging but the potential areas of improvement can also be identified using the scorecard with the individual scores for various functionalities of the packaging.

Effective: Adds economic and social value • Reduces product waste • Improves functionality • Prevents over-packaging • Reduces business costs • Achieves satisfactory return on Investment (ROI	**Efficient: Minimum use of material and energy** • Improves product / packaging ratio • Improves efficiency of logistics • Improves energy efficiency (embodied energy) • Improves materials efficiency (total amount of material used) • Improves water efficiency (embodied water) • Increases recycled content • Reduces waste to landfill
Cyclic: Recyclable or compostable • Returnable • Reusable (alternative purpose) • Recyclable (technically recyclable and system exists for collection and reprocessing) • Biodegradable	**Safe** • Reduces airborne emissions • Reduces waterborne emissions • Reduces greenhouse gas emissions • Reduces toxicity • Reduces litter impacts

Figure 8: Sustainable Packaging compilation (Chopra & Satyan, 2022)

Combining these two analytical tools creates a more extensive way to evaluate the packaging material. This will be used when analyzing the packaging material currently in use for the industrial packaging systems of the two complex electronic products.

4. Analysis and Results:

This chapter will describe the empirical data and analysis in a narrative sense following the studies' three phases. (Paulsson, 2020) First, how the selection and mapping of components and suppliers were conducted based on their relevance to the study, followed by analyzing the process flow map of the used packaging from supplier to end-of-life are discussed. The third and last phase will present the supplier's perspective, the recycling rate, and the direct environmental impact. The last phase concludes with the packaging analysis.

4.1 Phase one

4.1.1 The Products

The products chosen in the study were recommended by Axis and are two of their more popular products shown in figure 9. Product A is a larger camera model with Pan-Tilt-Zoom (PTZ) functions and consists of around 600 components in the BOM. Product B is a smaller camera model consisting of around 350 components in the BOM.

Figure 9: Product A (Left) and Product B (Right)

4.1.2 Information gathering from databases (PLM)

The quantitative information was gathered from the Axis PLM system where BOM, Component information, and supplier information is available. However, there is only limited information on the packaging from the suppliers. A large part of the components in the BOM have no packaging information, often small and electrical components. The ones that have packaging information vary in the amount and quality of data. The information given are the different layers of packaging from secondary to primary. No tertiary packaging information is given. As shown in figure 10 below the information includes product quantity, packaging name, material and dimensions. In some cases pictures of the packaging process were also included. The packaging material specified in the documents is often only stated as *Plastic* or *Paper* and gives no further specification. This together with only the packaging dimensions limited the accuracy of the analysis. In order to compile the data for further analysis several approximations were needed. These approximations were based on:

- Determine the specific type of material based on limited descriptions, photos and samples
- Packaging dimension to material volume/weight

Name of packaging type	Raw material	Size
Carton	Paper	415 X 305 X 200 MM
Layer Pad	Paper	400 X 290 MM
Nesting (a/b)	Paper	289 X 58 MM (a) / 289 X 58 MM (b)
Plastic Bag	Plastic	4 X 6 X 0.02 MM

Figure 10: Example of given packaging information on a component in the PLM

4.1.3 Categorizations of the BOM

The BOM for the two products were first sorted and categorized into groups based on the type of components. Nonphysical items in the BOM were removed e.g. zero quantity items and test items. The next step was to determine the relevance of the item groups from a packaging perspective. The groups were categorized in three overarching categories shown below in figure 11 and 12 for respective products. These were *PCB Components, Small components* and *Larger components.*

The *PCB Components* are all the small electrical components placed on the PCB such as resistors, capacitors, etc. This group makes up the large majority of the BOM due to the complexity of the PCB and the large variants of similar components. For instance, there can be up to a hundred different types of resistors in one product.

Each item group can have several different suppliers depending on the variability of the components. The components in this group are packaged in the thousands, often on plastic reels. Based on inadequate packaging information, quantity of suppliers and low impact on overall packaging material per product, this category was not further analyzed.

The *Small components* category includes small items such as screws, adhesives, fittings, etc. Many of these items are used in several Axis products and are kept at the EMS in large quantities. As these components are small, packaged in the thousands, and had limited to no packaging information were not further analyzed.

The *Larger components* are the focus of this study and make up the large majority of the overall weight and volume of the products. These item groups are often sourced from a single supplier and have in most cases available packaging information.

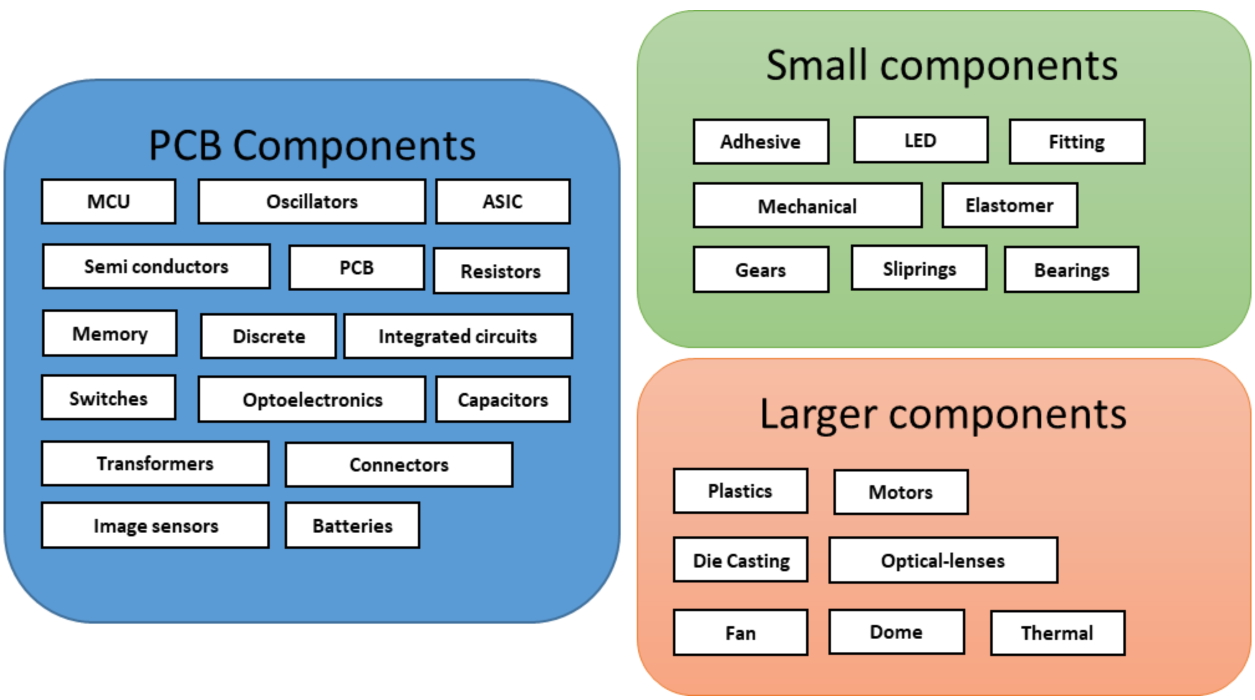

Figure 11: Component categories for Product A

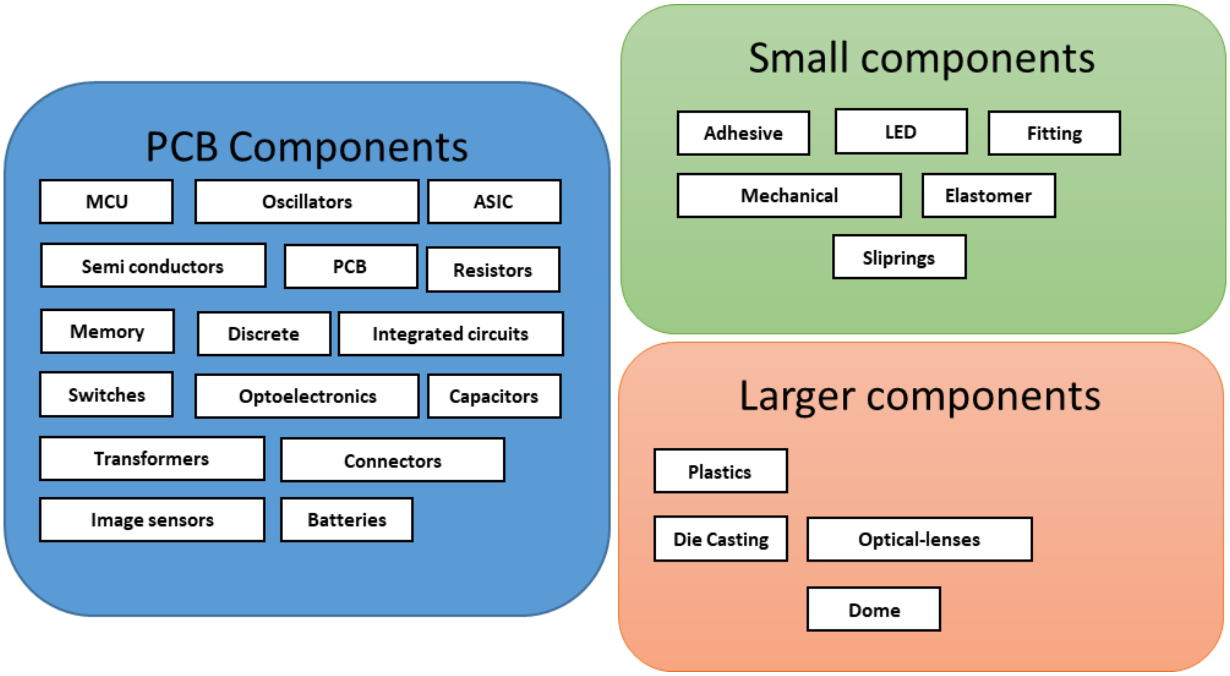

Figure 12: Component categories for Product B

Chosen components

The larger components contain seven categories for the more complex product A and four for product B. These were:

Plastics

Plastic components making the inner structure of the cameras. Often protecting the PCB and lens.

Figure 13: A plastic component

Die casting

Die casted metal components creating the mount and outer protection of the cameras.

Figure 14: A die-casted component

Optical lenses

The image capturing “camera”. Alongside the PCB makes up the core of the cameras.

Figure 15: A optic-lens component

Motors

The PTZ function in product A requires motors.

Figure 16: A motor component

Dome

The plastic dome covers protecting the optics.

Figure 17: A dome component

Fan and Thermal

Product A also contains a fan and a thermal cooling element to reduce heat buildup.

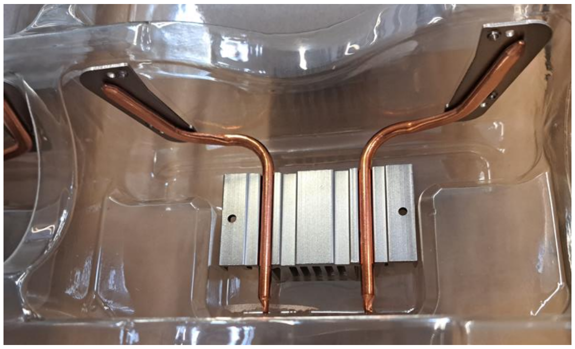

Figure 18: A thermal component

The next step was to identify the corresponding vendor and manufacturing location for each component type.

4.1.4 Supplier Map

After the relevant components for investigation were chosen the suppliers and origin for each category were identified and mapped in figure 19, 20 and 21 below. There is only one supplier for each packaging type in both products. The large majority of suppliers are located in China. Only the supplier of the die-casted components is located in Malaysia. However due to the nature of the large and heavy die-casted components Malaysia still makes up a significant portion of the packaging material used in both products. Both product A and B sources their plastic components and optical lenses from China but from separate suppliers.

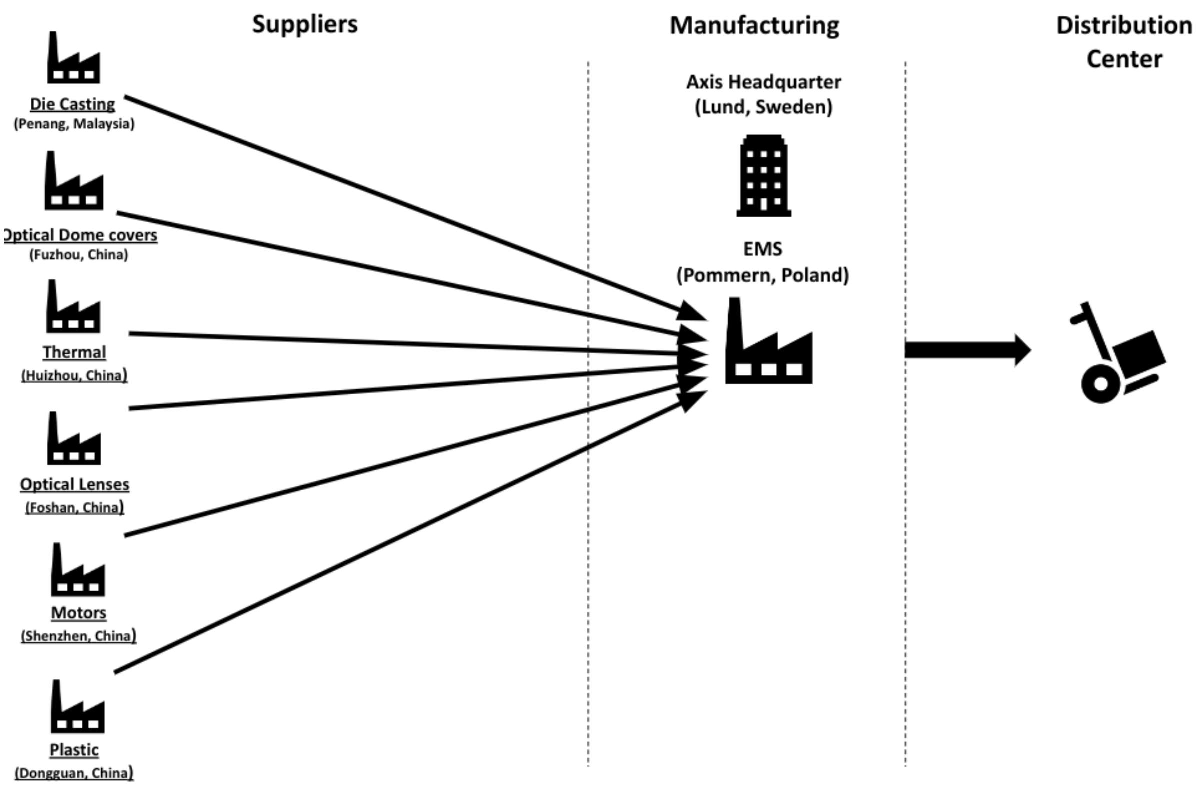

Figure 19: SC map for Product A

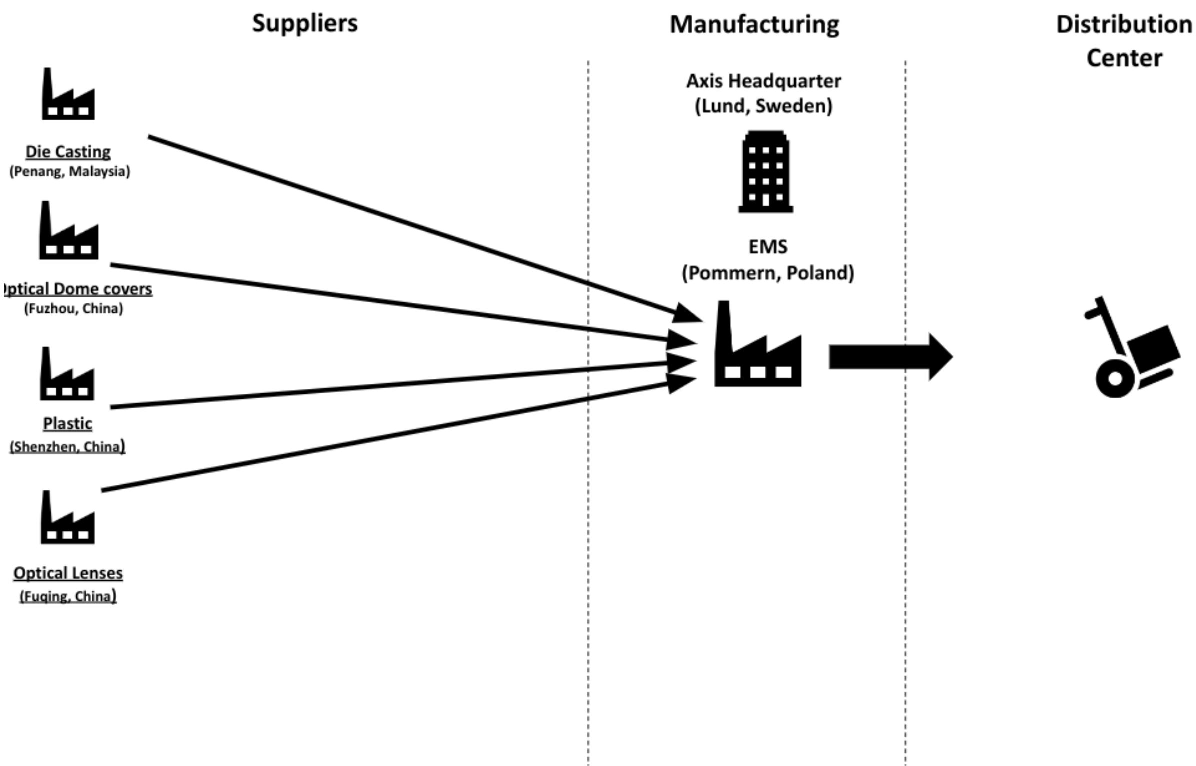

Figure 20: SC map for Product B

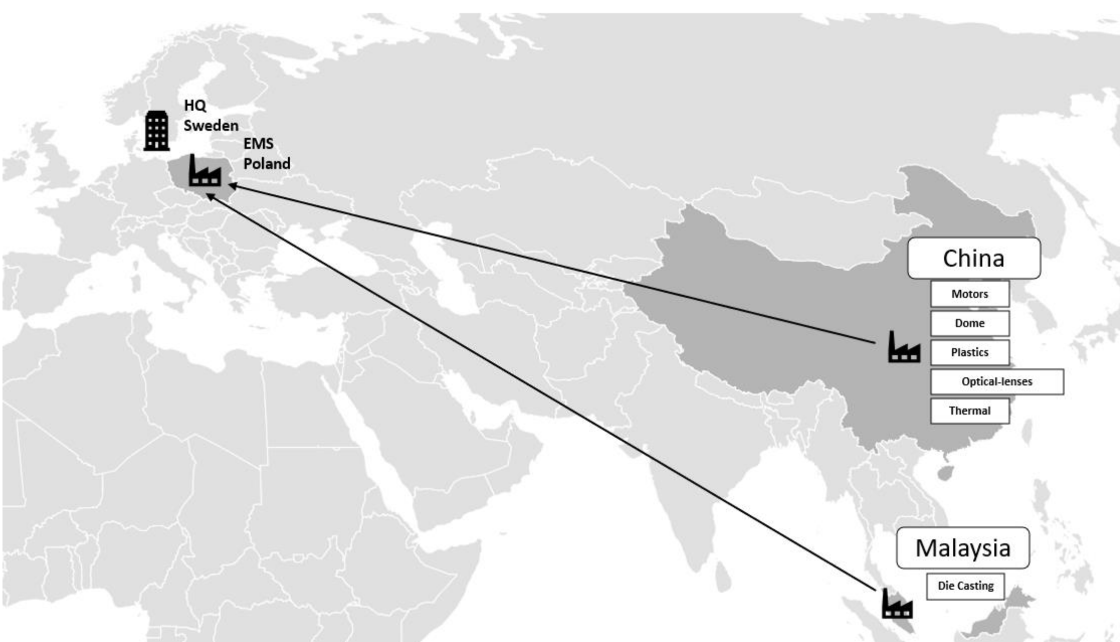

Figure 21: Location of supplier for each component category

4.2 phase two

Based on the information gathered at the EMS the packaging of the chosen components were mapped from inbound logistics to end-of-life. Firstly, a brief overview and explanation of the process map, followed by a more in-depth analysis on the handling of the different packaging levels and their material compositions.

4.2.1 The EMS

The electronic manufacturing service or EMS are third party services that manufacture electronic products. Axis has no inhouse manufacturing and relies on EMS for their production. The EMS manufactures the PCB and assembles the final products for Axis. The finished products are sent to Axis logistics center for final packaging and distribution. The EMS responsible for manufacturing the two investigated products are located in northern Poland and both products are sent directly to the distributing center upon completion.

Overview of the packaging handling at the EMS

This section will go through the process map in figure 22 below starting from the upper left corner. The components arrive at the EMS in tertiary or secondary packaging and are first handled by the logistics center where the components and packages are registered in the system and undergo an initial quality check. The packages are then transported to the warehouse where the products are stored in their tertiary packaging before use. When needed in production all necessary components for each product are collected and stored on a pallet in their secondary packaging. The pallet containing one of each component type is then moved to the inspection area and undergoes a detailed quality inspection. The components are then unpacked and sorted in trays on a roll container bound for production. At this stage most secondary packaging is discarded and sent to the recycling unit, but some secondary packages deemed ESD safe and stackable follow into production. Production is divided in two areas. The main production floor and the clean room. Since the products contain sensitive electronics and optics a clean room is needed to reduce contamination when sensitive components are assembled. In production the primary packages are removed from the components and discarded before the components are assembled into the products. All discarded packaging is shipped to the recycle area. The packaging material is then sorted and stored based on material and recyclability to later be transported to respective recycling facilities

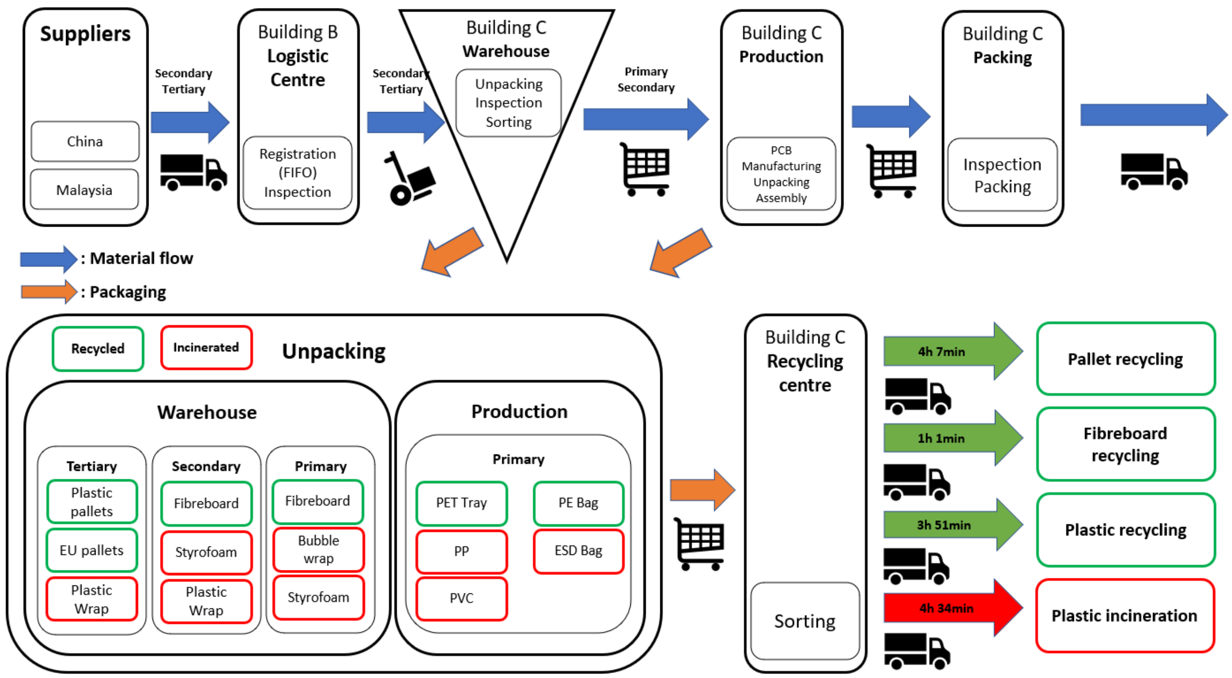

Figure 22: Flow of packaging material at the EMS

4.2.2 The Packaging System

To understand the different packaging used and at what level, this section will describe the three packaging levels and how they are handled at the EMS.

Primary packages:

During the visit to EMS Poland, a variety of plastic materials used for packaging were observed, including bubble wrap (made of recycled LDPE and PET), plastic covers (LDPE), trays (PET), Expanded Polystyrene (EPS), Electrostatic discharge (ESD) plastic used only for packing optical lenses, and Polypropylene (PP) as holding trays for electronic components. These packaging materials are sourced by components suppliers. PET is a thermoplastic polymer used for its film and molding properties and is recyclable by mechanical and chemical methods (F. Gao, 2004). However, label adhesives can cause discoloration and affect the mechanical properties of reprocessed PET. Although some handling issues were informed during the visit, the EMS Poland's Environmental, Health, and Safety (EHS) team confirmed that PET trays are completely sorted when leaving the plant for recycling. On the other hand, LDPE, a thermoplastic polymer used for plastic covers, is less recyclable than HDPE (F. Gao, 2004). The Bubble wrap, which is a combination of PET and LDPE, is not recyclable or biodegradable and is toxic as it releases carcinogenic emissions (N. Chopra & D. Satyan, 2022). However, recycled LDPE was used in the bubble wrap, and the EHS team was informed of its effective collection and incineration for energy recovery. Expanded Polystyrene (EPS), an inexpensive, hard plastic commonly used for the protection of delicate optical parts of a camera, is not recyclable, but is incinerated for energy recovery. EMS experts suggest avoiding EPS to improve waste recyclability in the value chain. Electrostatic discharge (ESD) plastics, which are commonly used to protect electronic components from electrostatic discharge, are cost-effective and easy to manufacture (R. D. Baldiris Navarro et al., 2017). They are sent for energy recovery as the separation of materials is not possible in the country of recycling. Polypropylene (PP), another commonly used thermoplastic polymer, is known for its low density, good heat and moisture resistance, and strong chemical resistance (H. Zhao et al., 2021). They are not recycled but incinerated due to its dark color. Fiberboard dividers are also used to hold certain components as dividers in the secondary package intact against shock and vibrations and they are completely recycled.

Secondary package:

Fiberboard is the major packaging material used in secondary packaging to hold multiple primary packages together. The fiberboard boxes are completely recycled by sending them to a paper company in Poland for producing recycled papers. The collection rate is well organized at the EMS, Poland. The secondary packages are handled in the warehouse area where repacking takes place as there is a risk of contamination in the production plant with paper particles. The fiberboard boxes are replaced with plastic trays inside the production plant and the plastic trays are being re-used multiple times. Some components contain dividers which are also fiberboard and so there is no special sorting and treatment required for recycling. Some components hold a plastic cover for extra protection or as fillers to keep the product intact. Plastic wraps are made of LDPE (Low-density Polyethylene) and sent for incineration in order to recover energy. Incineration was due to the scattered presence of plastic covers in the EMS. The other reason was the irregular presence of plastic covers in the package. Irregular package from the supplier without prior information to the EMS was observed during the visit.

Tertiary package:

EMS Poland uses both wooden and plastic pallets as their tertiary packaging material for component transportation, with both being reused in the manufacturing unit until they are no longer usable. The reusable pallets used within closed-loop systems are designed to be more robust by emphasizing higher deck coverage and hardwood leading-edge boards, although this could increase the weight and durability as well as the quantity and diversity of the materials used (Carrano & Thorn, 2014). The wooden pallets, which comprise about 90% of all pallets used, typically utilize mixed eastern oaks and southern yellow pine for their hardwood and softwood components, respectively (Bush & Araman, 2008). The EU standard wooden pallets used at the facility are 800 mm x 1200 mm x 144 mm with an average weight of 20-25 kg, and these pallets are reused until they are damaged (Deviatkin & Horttanainen, 2020). Non-EU wooden pallets are not reusable and are sold for revenue, while plastic pallets made of HDPE are also reused in the manufacturing plant. The environmental impact caused by these tertiary packaging materials is much lower compared to single-use plastic packaging due to their ability to be reused multiple times (Carrano & Thorn, 2014).

4.2.3 End-of-life of Packages:

The last step in phase two was mapping where each type of packaging material ended up after leaving the EMS.

The EMS Poland is in contact with three different recycling facilities in Poland depending upon the type of material. The packaging materials are either recycled or incinerated for energy recovery. According to the discussion with the EHS department experts at the EMS, the landfilling rate of the packaging material from the Axis products is none. At the EMS, there are no specific details on the waste management for Axis's products as that will increase the complexity of the process hence obtaining accurate weightage of waste output for the particular camera models could be difficult, but approximation will be discussed later in the analysis part.

The plastic wraps and plastic covers are sent to Stena Recycling Sp. z o.o., Kazimierza Wielkiego 23, Postal code: 67-400 Wschowa. Both materials are made of Low-Density Polyethylene (LDPE). According to the discussion with the EHS department experts at the EMS, the packages from LDPE are shredded and melted for new recycled materials production. A variety of components have plastic covers to be their primary package and so this material will constitute a major quantity of waste. The segregation happens at the recycling unit outside the plant and the waste collected in bulk is sent to the recycling plant for material recovery.

The Plastic pallets are recycled at Hemarpol Sp. z o.o., Fabryczna 2A, Postal code: 42-660 Kalety. The plastic pallets are re-used in the EMS for multiple purposes before being sent for recycling. The type of recycling is primary recycling for material recovery. According to the discussion with the EHS department experts, the pallets made of HDPE are shredded and melted for new material production mostly as granules. The excess pallets are also sent for recycling. But Transportation of plastic pallets from EMS to the recycling plant is not frequent as the life of the package is extended by reusing.

The Styrofoam and bubble wraps are sent to PREZERO STAROL Sp. z o.o., Kluczborska 29, Postal code: 41-503 Chorzów for energy recovery. Styrofoam is made of EPS and mainly used as primary packaging and also as fillers for protection. EPS is not recycled in Poland and thus the material is being incinerated for energy recovery. The bubble wraps are made of recycled LDPE and thus the material is being incinerated due to infrastructure constraints in Poland. According to the discussion with the EHS department experts at the EMS, the energy recovery rate from incineration is 7.7 GJ per ton of waste.

The fiberboards of all varieties are sent to Mondi Świecie S.A., Bydgoska 1, Postal code: 86-100 Świecie for recycling into the material. According to the discussion with the EHS department experts at EMS, the fiberboard is sent to a paper mill where the material is crushed and recycled into new paper material. Fiberboards are used as secondary packages for all materials and also as dividers for certain components, thus they produce large amounts of waste. The distance between the EMS and the recycling plant is not relatively long.

4.3 Phase three

4.3.1 The supplier's perspective

In phase one and two the study investigates and mapping "how" the current packaging system operates. The next step is to understand "why" the components are packaged the way they are. This information was gathered mainly from the questionnaire sent to the key suppliers, but also the interview with Axis engineers responsible for sourcing. Guides to both can be found in appendix A.

The five most relevant suppliers were sent questionnaires and four gave elaborated answers to the questions. The supplier questionnaire revealed that they have similar priorities regarding packaging. The most determining factors in their packaging strategy for Axis products were size, cosmetic level, strength, shipping distance and cost. Three out of the four suppliers confirmed that they consider sustainability an important part in their packaging strategy. Based on previously gathered information at the EMS two aspects of the supplier's packaging strategy was of specific interest to the study. These were:

- Why the frequent use of plastic covers around each component?
- What determines if the packaging consists of fiberboard grids, PET trays or Styrofoam?

Why single plastic covers?

Two answers were given to the frequent packaging of components in plastic covers. The main reason and which all suppliers answered was to reduce scratching on the components. Scratches does not mean that the components are functionally defective, but if the component is flagged by the purchaser to have cosmetic importance scratched components can be considered faulty.

The second reason given is connected to the sensitive electrical aspect of the products. The electrical components and the optical lenses are both sensitive to dust contamination and electrostatic discharges. A plastic cover protects the component until assembly from dust and other particles that can compromise the end product. The plastic covers can also be specified to be ESD safe to minimize risk of damaging sensitive electronics in production. Both factors are especially important for components assembled in the clean room.

PET trays, Fiberboard grids or Styrofoam?

When asked the suppliers what determines which of these packaging are used the following factors were mentioned.

Styrofoam is cost efficient and offers great protection. Especially for components such as the domes where the shape of the component makes it difficult to use any other alternative cost efficiently.

PET trays or **Fiberboard grids** are chosen case by case based on several factors. PET trays are more suitable for clean rooms. It is however more sensitive than fiberboard girds and can crack during transport. Fiberboard grids have the weakness of deforming in humid environments. In the end. Before any packaging strategy is chosen, all suppliers mentioned that the packaging has to go through comprehensive assessments and tests.

4.3.2 Packaging material calculations and rate of recycling

With packaging and waste management information from the EMS together with the previous packaging data, further analysis was made on the material used in the packaging system. In table 3 and 5 below the different packaging materials included in the packaging for product A and B are sorted by weight, percentage of total packaging weight and if they are recycled or not.

To calculate the amount of packaging material used for the products two things needed to be obtained. Determine what type of material the packaging is made of, and how much is used. With that the total amount in weight of each material used could be calculated.

Since the material information in the packaging documents varied some estimation needed to be made based on samples and pictures taken from the EMS.

The packaging dimensions were gathered from the packaging document (PLM) or measured at the EMS. Packaging with complicated geometry such as PET trays were subjected to approximations regarding its “flattened” dimensions. The weight calculated by first measured the weighing of a square or cubic centimeter of sampled material. It was then multiplied with its dimension to get an estimation of its total weight.

The fishbone diagrams below in figure 23 to 36 illustrate the material used in each component type's packaging.

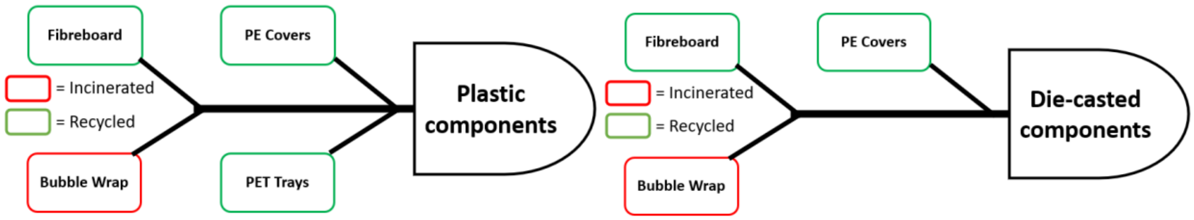

Figure 23: Material used in packaging of Plastic and Die-casted components

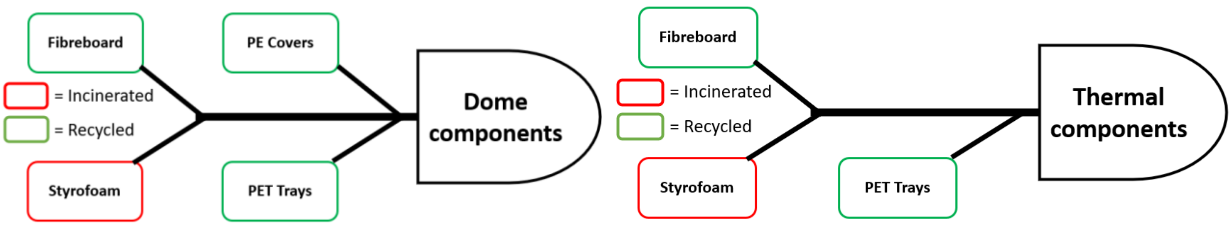

Figure 24: Material used in packaging of Dome and Thermal components

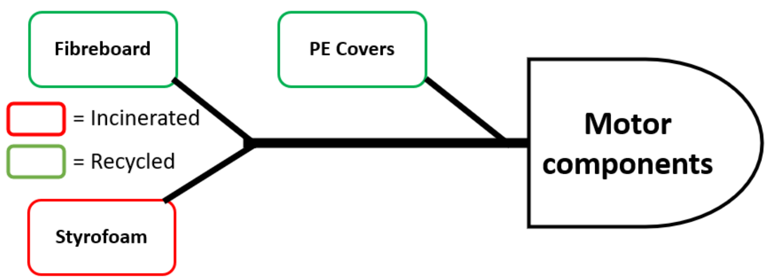

Figure 25: Material used in packaging of Motor components

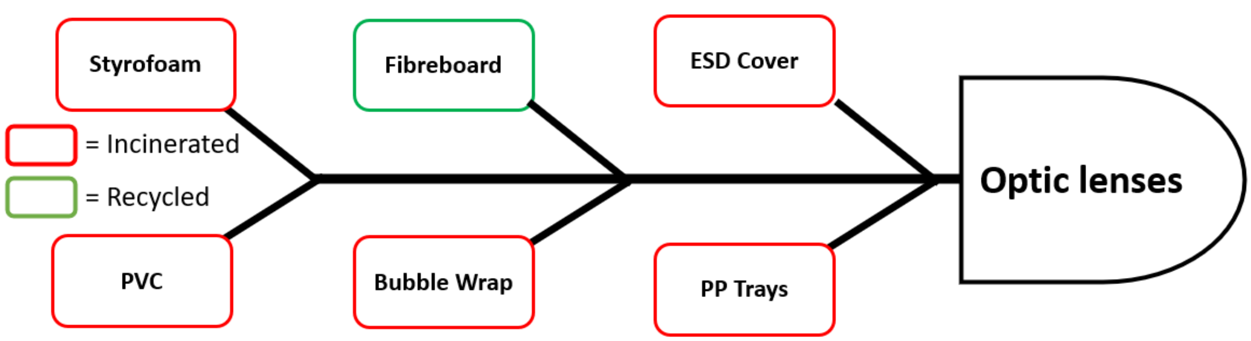

Figure 26: Material used in packaging of Optic-Lens components

Table 3: Packaging material used and recycle rate of one product A

Total Weight	Recycled	Incinerated
485g	74%	26%

Material	Weight (g)	Weight (%)	Recycled?
Fiberboard	314	65	Y
Bubble wrap	52	11	N
Polypropene (PP)	42	9	N
Low-density Polyethylene (LDPE)	33	7	Y
Expanded Polystyrene (EPS)	24	5	N
Polyethylene Terephthalate (PET)	13	3	Y
Polyvinyl chloride (PVC)	5	1	N
Anti-static bag(resin)	3	1	N

Table 4: Packaging weight and recycle rate for each component group in product A.

Component type	Weight (%)	Recycle rate (%)
Die-casting	48	81
Plastic	16	91
Optic-lens	16	6
Dome	8	76
Fan and Thermal	8	75
Motor	4	80

Table 5: Packaging material used and recycle rate of one product B

Total Weight	Recycled	Incinerated
175g	88%	12%

Material	Weight (g)	Weight (%)	Recycled?
Fiberboard	117	65	Y
Low-density Polyethylene (LDPE)	35	20	Y
Polypropene (PP)	12	7	N
Bubble wrap	7	4	N
Expanded Polystyrene (EPS)	2	1	N
Polyethylene Terephthalate (PET)	1	1	Y
Anti-static bag(resin)	>1	>1	N

Table 6: Packaging weight and recycle rate for each component group in product B.

Component type	Weight (%)	Recycle rate (%)
Die-casting	61	93
Plastic	22	97
Optic-lens	11	26
Dome	6	96

From table 3 and 5 above it can be observed that fiberboard makes up a clear majority of the total packaging in terms of weight around 65% for both products. Despite that most components are packaged with a plastic cover (LDPE) the thin film and low density makes the total weight low. Since components in product A use more bubble wrap the weight percentage of clear LDPE covers are much lower than for product B.

The polypropylene used for both products is in the packaging of the Optic-lenses. Due to the required level of protection the components cannot use PET, fiberboard or EPS. This can further be seen in table 4 and 6 above where the packaging for the Optic-lens only has a recycle rate of 6% and 26% respectively for product A and B.

The use of bubble wrap is mainly used for the heavy die-casted components. These components are sturdy and are not considered cosmetic, but they can tear and fragment the fiberboard if it is in direct contact. The bubble wrap acts both as a protective layer but also as a filler so that the components do not move around in the package. Since the die-casted components make up a large amount of the total packaging shown in table 4 and 6, the amount of bubble wrap used is significant. The Styrofoam (EPS) despite looking like a large part of the packaging for some components, especially the Domes, its weight percentage of the total packaging is low. As one of the preferred packaging at the EMS, PET trays are only used for a couple of components and with its low weight only makes up a fraction of the overall packaging weight. The ESD safe resin and PVC in the packaging of the Optic lens makes up one to two percent of the total packaging and as such the unrecyclable aspects of them makes little impact on the overall recycling rate.

4.3.3 Energy and carbon footprint

After determining the type and weight of the packaging material used for each product, the next step was to analyze how much energy and CO2-eq they represent. This information is a part of a life-cycle analysis and to investigate the packaging as environmental impact indicators.

To calculate the amount of energy required to manufacture each packaging type, Cumulative Energy Demand (CED) was used. With this the amount of energy required to manufacture the packaging used can be determined. To understand the global warming potential (GWP) of the packaging CO2-eq was used. As such the amount of CO2-eq released from cradle-to-gate for each packaging can be determined. Both the CED and CO2-eq rate can be seen below in Table X. The CED and CO2-eq rates were taken from various sources. For all plastic packaging except PP data from Patel (2003) and Pålsson (2018) were used. Data for PP were obtained from the American Chemistry Council (2021) and CO2-eq for bubble wrap from Hroncová, et al. (2015). Data used for the fiberboard were taken from Pålsson (2018) and Brogaard, et al. (2015).
In table X and X below the CED and CO2-eq for the packaging used in both products can be seen. CED for each packaging is calculated by multiplying the amount with the CED from table X. The CO2-eq is calculated the same way but using the CO2-eq rate.

Table 7: The CED and CO^2-eq rates for each packaging type.

Material	***CED** (MJ/kg)*	***CO^2-eq***
Bubble wrap	97	1.2
Low-density Polyethylene (LDPE)	93	1.2
Expanded Polystyrene (EPS)	90	1.9
Polypropene (PP)	76	1.6
Polyethylene Terephthalate (PET)	59	2.1
Polyvinyl chloride (PVC)	53	2.1
Fiberboard	22	0.9

Table 8: CED and CO^2-eq for packaging type and amount in product A

Material	***CED** (MJ)*	***CO^2-eq** (g)*
Fiberboard	6.9	296
Bubble wrap	5.1	63
Polypropene (PP)	3.2	67
Low-density Polyethylene (LDPE)	3.0	39
Expanded Polystyrene (EPS)	2.1	45
Polyethylene Terephthalate (PET)	0.8	27
Polyvinyl chloride (PVC)	0.2	9
Total amount	**21.4**	**546**

Table 9: CED and CO^2-eq for the packaging type and amount in product B

Material	**CED** (MJ)	**CO^2-eq** (g)
Fiberboard	2.6	110
Bubble wrap	0.7	8
Polypropene (PP)	0.9	19
Low-density Polyethylene (LDPE)	3.3	43
Expanded Polystyrene (EPS)	0.2	4
Polyethylene Terephthalate (PET)	0.1	3
Total amount	**7.7**	**187**

Fiberboard shows high CED and CO2-eq, but this is because it makes up the majority of the total packaging. By weight it is the lowest in both aspects. LDPE has a large impact on the total CED. Despite being only a third the weight of fiberboard in product B it has a higher total CED. PET and PVC have a lower CED but have a significantly higher CO2-eq than LDPE. PP lands in between in both categories. It should be taken into consideration that all the tables are based on new material and not recycled. Circularity will decrease the CED and CO2-eq by recovering or lowering the requirements of manufacture. The incinerated packaging from the EMS recovered on average 7,7 MJ per kg. The study does not include data on how recycling affects CED and CO2-eq, but it can be estimated to be more than incineration.

4.3.4 Packaging analysis

With understanding of the current packaging and the involved actors' capabilities and preferences a packaging analysis was conducted to evaluate the different packaging in use. By analyzing the packaging with a SWOT model and then combine the results given by the model into a scorecard for each packaging type.

The packaging analysis will focus on the seven identified primary packaging currently in use.

Four of the types of packaging contain several components. These are:

- PET trays
- Fiberboard dividers
- Styrofoam (EPS)
- Polypropene trays

The remaining three concerns packaging around single components. These are:

- Plastic covers
- Bubble wrap
- ESD bags

The only primary packaging not evaluated is the small amount of PVC packaging that is found in the Optic-lens packaging for product A. Due to the small amount used and specific use case a thorough analysis was not deemed necessary. The SWOT analysis will only focus on the primary packaging. The scorecard will include the tertiary and secondary packaging, but the study will not go into further analysis on them since they follow industry standard, and no alternative or downsides were identified.

SWOT

By applying the SWOT model on each package type key factors of each type were highlighted. These factors were separated into external and internal factors. The internal factors gave insight into how the different packaging function in the current system and were further analyzed and categorized into a scorecard in the next section. The external factors created the basis for further discussions on future risks and improvements. The EMS capabilities and handling were heavily weighted in the analysis, but the supplier's perspective was also considered. The results of the SWOT of each packaging type can be seen in Appendix B.

The external factors identified as opportunities can be connected to the 9R framework in chapter 3 and focus on the opportunity to increase circularity. These are:

- R2 Reduce: Smarter packaging with PET trays and better customized fiberboard divider can alleviate the need for bubble wrap and plastic covers on non-cosmetic components.
- R3 Reuse: Bubble wrap and plastic covers can be reused for packaging towards distributors.
- R8 Recycle: Bubble wrap can be recycled in the future if local recycling facilities expand their capabilities. Polypropene can be recycled but are currently not sorted separately for recycling.

The threats factors intensified were mainly regards to some improper collection and sorting of plastic at the EMS. Small plastic packaging such as covers are easily missed if sorted incorrectly in the warehouse or production. Axis has an initiative to remove as much plastic as possible from its supply chain and therefore threaten plastic packaging.

Scorecard

Scorecards are used to evaluate the different functionalities of the packaging levels to mark the areas of improvement. The scorecards will help in the improvement of packaging material that are oriented to specific functionalities. The scorecard has been diversified into four sub functional categories as effective that adds social and economic value, efficient that provides minimum use of materials and energy, cyclic that are recyclable and compostable and finally safe which determines the safety standards of the packaging material (Chopra & Satyan, 2022).

The scorecard is helpful for performing sustainability analysis to evaluate the overall performance of the packaging materials but in the case study, it has been mainly used to identify the cyclic efficiency of the packaging material to determine the circularity level and to compare the influence of circularity on the overall sustainability of the packaging.

For the case study, the three sub functional categories effective, efficient, and cyclic are selected. Safety is not considered as detailed analysis was not performed considering the focus of the study. In every sub functional category, the functionalities that are closely relevant to the packaging system are considered and the other functionalities are neglected. The scorecard was marked based on the internal factors of the SWOT analysis, the observation from the visit and information provided from three different actors of the supply chain: the suppliers, the EMS and Axis communications.

EFFECTIVE	EFFICIENT	CYCLIC

PRIMARY PACKAGE

Package vs Functionality	Reduce Product waste	Functionality	Reduce over protection	product package ratio	Logistics efficiency	Reduce Waste landfilling	Reusable	Recyclable	Average score
Bubble wrap	2	4	2	4	3	5	1	3	**3**
Plastic bags	3	3	2	4	4	4	1	4	**3.12**
Pet trays	4	5	5	5	5	5	1	5	4.37
EPS	2	4	3	4	4	5	1	3	**3.25**
ESD bags	2	4	5	5	4	5	1	3	3.62
PP trays	2	4	5	4	4	5	1	3	3.5
Fiberboard dividers	4	4	4	5	5	5	1	5	4.12

SECONDARY PACKAGE

Package vs Functionality	Reduce Product waste	Functionality	Reduce over protection	product package ratio	Logistics efficiency	Reduce Waste landfilling	Reusable	Recyclable	Average score
Cardboard box	4	5	4	4	5	5	1	5	4.12
Plastic films	4	5	4	4	4	4	1	3	3.62

TERTIARY PACKAGE

Package vs Functionality	Reduce Product waste	Functionality	Reduce over protection	product package ratio	Logistics efficiency	Reduce Waste landfilling	Reusable	Recyclable	Average score
EU wooden pallet	5	5	5	5	5	5	5	3	4.75
Non-EU wooden pallet	5	3	5	5	3	5	5	3	4.25
Plastic pallet	5	5	5	5	4	5	5	3	4.62

Figure 27: Scorecard for different levels of packaging

To summarize, the scorecard analysis determined the focus areas for improvement to be the primary package and thus the secondary and tertiary packages can be neglected. The scorecard is a five-scale analysis, 1 being the least and 5 being the most. Reusability is the functionality that scored the least for all the primary packaging as it is not done for any in the entire EMS except for the pallets. Recyclability rates are marked based on whether the material has been recycled as materials or energy. The recycled energy is marked as 3 and the recycled materials are marked as 5. The average score is calculated to understand the overall performance of the packages. The bubble wraps, plastic covers and EPS are possessing a relatively lower average score and they are marked for scope of improvement.

The scores to be discussed are mentioned in figure 27 above. Bubble wrap has the lowest score of all the primary packaging types. This is due to the incineration rate and the tendencies to be used on components that do not need that level of protection. Plastic covers have been marked with low scores due to the risk of overprotection to components and handling inefficiency preventing effective sorting for recycling. PET trays have the most favorable average score of the primary packaging and ranked high in most categories. Fiberboard dividers possess a good score since they are made of one material which facilitates efficient recycling in the respective country of waste management and also satisfies all the basic functionalities required from it. Styrofoam (EPS) rates low in the scorecard. The main factor for the low rating is due to not being recyclable and that it increases double handling. ESD covers scores quite low from it not being recyclable. It still serves a crucial role of protecting sensitive components from ESD and as such is almost unavoidable. Polypropene is currently not recycled at the EMS due to its dark color and as such is scored quite low. However together with the ESD covers creates the extra layer of protection needed for the sensitive optical components.

5. Discussion

Packaging is essential for the safe handling and transportation of electrical components in the supply chain. However, achieving circularity in packaging practices put forward challenges for organizations. This discussion presents findings from the analysis of the study on the packaging system of components for two complex electronic products, identifying both positive aspects and areas for improvement.

The results of the packaging data gathered from the PLM were sufficient to get an overall understanding of the component packaging used in the two investigated products. The PLM data combined with the visit at EMS conclusions can be made regarding the overall handling of packaging. If these components had more specific packaging data in the PLM the study could have had greater precision. With limited packaging data and hundreds of components the time it would require to investigate all smaller component packaging exceeds the time available at the EMS visit.

The weight calculations in the study are not precise. There was no information on weight or density in the packaging documents and we did not have the means to weigh each package at the EMS. The lack of specifications on the packaging material led to some estimations regarding its composition. As an example, we estimate that all the plastic covers were made out of pure LDPE, but in practice they could include softeners or other additives. However, the primary feature important to the study is if the material is recyclable or not. Extensive specifications were not deemed necessary.

To answer the first stated research question regarding how the industrial packaging system for components is structured, more information is required than is available to one actor. However, with the packaging information and handling presented in chapter 4.2 and 4.3 the general industrial packaging system can be observed. The lack of packaging information on some components, as well as the limited specifications on material used limits Axis ability to observe the complete packaging system. This results in that only during the times of problems due to packaging at the EMS, Axis takes note and intervenes. In order for Axis to gain deeper insight into packaging of components there needs to be an increase in structure and more detailed documentation on the packaging.

The analysis of EMS Poland's handling of packaging materials for electrical components reveals both positive potential and areas for improvement.

The primary packaging materials handled by EMS Poland for electrical components consist of a mixture of different plastic types, including PET, LDPE, EPS, ESD plastic, PP, and the fiberboard made of paper.

PET trays and LDPE plastic covers were found to be fully recyclable, promoting the potential for recycling. Tight fitting PET trays can also help remove the need for individual plastic covers.

If the EMS can identify outbound products that have the same dimensions and packaging requirements as incoming packaging, there could be possibilities to reuse (R3) packaging. Plastic covers and bubble wrap are two candidates for reuse.

Fiberboards are completely recyclable since it is a mono-material, but the use of fiberboard packaging raised concerns as it requires additional materials as fillers to protect the product. This practice leads to increased material usage and questions the sustainability of the fiberboard packaging. However, fiberboard has both the lowest CED and CO2-eq making it per weight the packaging with the least environmental impact. Exploring alternative solutions that minimize the need for fillers presents an opportunity for improvement in the packaging process. Even with the low CED and CO2-eq if it requires significantly more material using fiberboard even a “worse” material could have lower overall environmental impact.

Further investigation is needed to determine if there is a more sustainable solution than using PP trays and ESD bags for the optical components. Since the specific requirement needed to ensure the level of protection takes priority on such complex and expensive components. However, we do not know the total volume of PP handled at the EMS, and if there are a sufficient amount, they should consider expanding their capacity to recycle it.

The presence of non-recyclable materials like Bubble wrap and EPS in the packaging materials acts as a challenge due to the lack of recycling infrastructure at EMS Poland and their high CED and CO-eq rating. Consequently, EMS Poland circulates to incineration for waste management. While this approach minimizes waste, it still affects the circularity of the packaging materials when benchmarking the 9R Framework of circularity. And so, EMS Poland has significant opportunities for recycling if there is an infrastructure development in Poland to improve the recycling of bubble wrap. If the EMS also starts to recycle PP the with recycling of bubble wrap the total recycle rate can be increased for product A to 94% and B to 99%

During the visit to EMS Poland, experts identified an excessive use of bubble wraps and plastic covers, indicating an area for improvement. Addressing this issue can significantly reduce waste generation and enhance the sustainability of the packaging process. So, the refusal to use excessive materials like bubble wrap and LDPE bags for non-cosmetic components can help go up in the circularity chart.

The secondary packaging materials, primarily consisting of fiberboard boxes, were found to be fully recyclable. However, the inclusion of LDPE plastic covers for extra protection reduces the potential for recycling within the packaging system due its scattered presence in the manufacturing plant. The plastic is used to wrap the fiberboard boxes to protect the product against different moisture conditions throughout the supply chain. Improving the sorting system within the manufacturing plant can address this issue and improve the overall sustainability of the secondary packaging materials.

In terms of tertiary packaging materials, EMS Poland's handling of wooden and plastic pallets is proper and acceptable. The multiple reuses of these pallets minimize waste generation and contribute to the efficient use of resources within the packaging system.

To discuss further on the second research question, the recycling rates of the packaging material is above average and thus considered good. 74% of the component packaging for product A and 88% for product B are recycled. The rest is incinerated for energy recovery. Nothing ends up in landfill and as such everything is recovered in the form of energy or materials. As of now, the waste management actions contribute more towards the linear economy and less towards circular economy. But, as mentioned previously, there are still several areas to improve which can help to observe a shift from linear economy to circular to an extent by reducing, reusing and recycling different packaging materials along with better sorting and improved local recycling capabilities. However, the different locations of the other stakeholders, different sustainability and circularity perspectives will have a great influence in the supply chain preventing to be fully circular.

Additionally, there is a noticeable communication gap among the actors in the supply chain, hindering effective coordination and collaboration. Improving communication channels can lead to overall development of the packaging process. A clear example of this is that non cosmetic components are still packaged as if they were and that affects the overall circularity.

In the discussions with experts from Axis, it was evident that packaging is considered a lower priority compared to other factors such as cost, functionality, and capacity. Likewise, sustainability is found to have a lower priority in packaging when compared to aspects like protection and cost. This thesis helped identify significant gaps in the existing system, presenting opportunities for improvement and proposing necessary changes to establish a more coordinated and sustainable approach.

When conducting the study, no universal language regarding packaging was observed. Depending on the industry background of the person adding the packaging information different approaches were taken. As shown in figure 10 (chapter 4.1.2) some only use generic terms, but some use specified industry codes that are hard to identify.

To discuss the third research question, better communication between the different actors of the supply chain about the packaging materials specifications can improve the accuracy of the analysis by avoiding approximations and assumptions. Also, like mentioned above, refusing the excessive use of bubble wraps and LDPE bags can help to reduce the materials. Reusing those materials can also help in keeping the materials in a circular loop. The improved recycling facilities can also contribute to better recycling of materials by avoiding incineration. In order to increase circularity and reduce and reuse these materials the SC actors involved have to know where and how much of these packages are used. They also need to know why the specific packaging was used in the first place. In this way transparency and communication regarding the packaging is essential for future improvements.

Global industrial packaging is a long way from becoming circular. A relatively small company such as Axis has limited influence on the suppliers to drastically change the packaging and become fully circular. Together with the specific levels of protection on certain components true circularity is at the moment almost impossible.

6. Conclusion and Future recommendations

To conclude, the evidence examined and consideration of various perspectives has led to an overall understanding of the different packaging materials used for all included components in the two complex electronic products.

By mapping out the supply chain, it was evident that the components suppliers, the EMS and Axis communications are the three main actors involved in the process. The suppliers are located in different parts of Asia, and thus the packaging materials are sourced locally. The EMS is the manufacturing and assembly unit where the supplier's packaging is handled for waste management. Axis communication is the main actor of this supply chain where the information flow of packaging is considered. Plotting the supply chain map helped in understanding the influence of different actors and the impact of information flow in the circularity of packaging.

With an overall understanding of the supply chain mapping, it was convenient to move to the next step, the process flow map to derive the end-of-life of packaging materials. In the primary packages of all included components for the complex electronic products, the materials used were PET, LDPE, PP, ESD, Styrofoam and fiberboards. The PET and LDPE are fully recyclable and so the PET trays and Plastic covers made of LDPE are in the circular loop. Bubble wrap which is a combination of PET and LDPE is incinerated. PP, Styrofoam and ESD resin are also incinerated. The incineration of bubble wrap and PP is due to lack of infrastructure in the waste management plant. The overall recyclability rate of packaging materials for Products A and B is 74% and 88% respectively. The packaging system and waste management are more towards linear economy than the circular economy as the waste handling methods are only incineration and recycling. However, there is a possibility to increase the recycling rate by improving the waste management facility to accommodate materials for recycling that are incinerated at the moment. The materials considered for use are based on different functionalities of packaging of which some functionalities complement the circularity of packaging, and some affect it. So, to find a balance is very important. SWOT analysis of packaging materials with Packaging scorecard were performed considering different functionalities from various aspects like effectiveness, efficiency and cyclic to identify areas for improvement. To understand better, environmental impact indicators like CED and CO_2-eq were used to analyze the impact caused during the manufacturing of different packaging materials. Fiberboard has the lowest environmental impact by weight, but in terms of handling at the EMS and circularity PET trays can be the preferred packaging. It is up to Axis to determine with the help of the presented information what would be the preferred primary packaging for the components on a case-by-case basis.

For Axis our recommended next step is to first improve the accessibility of packaging information and establish a clear and more informative way of documenting packaging. Information such as more specific material data and weight of each component's packaging are vital to understand the level of circularity and environmental impact. With better information Axis could more easily apply similar methods as this study to evaluate all component packaging and identify areas of improvement.

An identified challenge is that the conditions for recycling are different around the world so the level of circularity for packaging depends on the location of the EMS. If packaging for products outside of Poland are investigated, the other EMS waste management capabilities need to be established. Another identified challenge is that no universal language regarding packaging was observed. As such miscommunication and lacking specification when sharing data could lead to incorrect conclusions.

The observation from the study is that the small and PCB components have a lesser impact on the overall packaging system, but it is not insignificant. Future research on the accumulated packaging of small electrical components and how it can become more circular would be an interesting study. Many electronic components were identified to be packaged on plastic reels which could be reused or recycled. A similar study would be interesting if conducted on a smartphone or similar smaller complex electronic products.

In this study there is a focus on the circular aspects of handling of packaging. This could be further narrowed down and studied in detail about different aspects of circularity. This could be for instance investigating how a specific packaging can become more reusable in the supply chain. Maybe by standardizing industrial packaging material and dimensions can increase the packaging reusability through the supply chain.

The communication and documentation available on the packaging of the components were identified in the study as lacking. A future study on how to improve the handling, documentation and communication of packaging information between the supply chain actors would be interesting.

The study could also be expanded to a more comprehensive investigation on the overall sustainability of the supply chain. For instance, by conducting a complete life cycle analysis on Axis supply chain.

To conclude, the investigated industrial packaging system is currently linear, but has a good recycling rate. There are some possibilities for the packaging to become more circular, but for Axis on a global scale to establish a fully circular packaging system is currently almost inconceivable.

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Appendix A (Interview Guides):

EMS interview guide:

INBOUND DATA COLLECTION

Material flow questions:

1. How are the inbound packages received (transport)?

2. In what form do the packages arrive (Tertiary, etc.)?

3. Does any repackaging/unpackaging occur before Warehouse?

4. How are the inbound packages stored in the Warehouse?

5. Does any repackaging/unpackaging occur in the Warehouse?

6. At which stages does unpacking occur?

7. How does the unpacking work at each stage?

8. What happened to the package straight after unpacking?
    - Primary
    - Secondary
    - Tertiary

9. Is there any part where packaging material is used/disposed of that has not been mentioned?

General packaging questions:

1. How often do parts arrive damaged due to transportation?

2. Is there a general feeling that some packages are overpacked?

Relation to supplier questions:

1. Is there a difference in the way parts are packaged depending on the supplier?
2. Is there a difference in the type of packaging material used depending on the supplier?
3. How often does a supplier change packaging?
4. Which supplier do you think overpacks?
5. Which supplier packaging do you think needs improvement?

OUTBOUND DATA COLLECTION

1. How do you recycle plastic?
2. What types of plastics are recycled as materials?
3. What types of plastics are incinerated?
4. Is every single plastic packaging material ending in the bin? If not, to what extent is it being collected in the bins?
5. How do you recycle paper?
6. Do you know the energy recovery rate from incineration?
7. Is every fiberboard packaging ending in the bin? If not, what is the collection rate?
8. How much of your packaging is expected to end up in landfills?
9. Do you have any treatment facilities for waste management at the EMS unit? If so, do you use the recovered energy in EMS? And what do you do with recycled material?
10. How efficient is waste management in Poland? What is the recycling rate of plastic and paper?
11. If there is an alteration in the package towards more sustainability, do you think the treatment facilities in the EMS or Poland can be flexible to adapt?

12. What are the types of tertiary packages received at Jaibel from the suppliers? And how are they handled?

13. What is the lifecycle of the tertiary package? Is it reused for other processes/products?

14. If tertiary packages are reused, for how many cycle times they are reused? If not reused, what is the end of life?

15. Is it possible to take pictures of the bins?

16. Is any packaging material of any component being retained in the finished assembled product that is sent to distributors?

17. Is there any package with reverse logistics (i.e., reusable package)? If so, specify the package and the supplier.

18. Do you weigh the amount of plastic packaging that is sent for recycling? If so, specify.

19. Do you weigh the amount of fiberboard packaging that is sent for recycling? If so, specify.

20. Do you have rules and regulations apart from EU regulations to follow regarding waste management? Be it expectations from Axis or Polish regulations.

Suppliers interview guide:

1. How is the level of protection determined for the component?
2. Is sustainability an important part of your packaging strategy?
3. What determines if a component needs an individual plastic (PE) bag?
4. Why is Styrofoam used for the Dome components instead of fiberboard or PET trays?
5. Would it be possible to change to fiberboard or PET trays? (why/who not)
6. What determines if the components are packaged in PET Tray, fiberboard grid, or lose?

Axis sourcing interview guide:

1. To what extent is packaging discussed with suppliers?
2. How important would you say the packaging is in the audit process?
3. How much influence has Axis had on supplier packaging?
4. Are the needs/wants of the EMS considered when discussing packaging?
5. Is sustainability/circularity discussed with suppliers?
6. Does Axis follow up/confirm that the stated packaging is followed?
7. If changes happen to the packaging, does Axis get informed?
8. Does Axis know of the capabilities of EMS waste management?

Appendix B

SWOT Analysis

PET Trays

Strength	Weakness
- Recyclable material - Less material handling in Warehouse unpacking - Easily stackable and so can provide practical volume and weight efficiency during transportation - Safe to move direct into production	- Limited in terms of the shape, weight and size of components it can sufficiently protect. - Prone to cracking from impact and vibration if unsupported
Opportunity	**Threat**
- Possibility to reduce the use of bubble wraps and individual plastic covers - Minimizing double handling	- Improper collection of PET trays in the correct bin at the Production plant

Fiberboard grids

Strength	**Weakness**
- Effective collection in the bin - Fully recyclable - Satisfies the goal of the company to use renewable materials more	- Double handling due to unpacking in the warehouse - More protective layer is required as the paper is highly prone to mechanical damage - Can deformation in humidity - Can be damaged by sharp and heavy components.
Opportunity	**Threats**
- Customization of grids to the actual shape of the component can reduce the use of additional protective layers.	- Not identified

Bubble wraps

Strength	**Weakness**
- High protection to keep the components intact to protect against shock and vibration	- No recycling facilities in Poland for bubble wraps and so high usage can reduce the circularity level to a great extent - Excessive usage leads to overpacking
Opportunity	**Threat**
- Re-usability of the materials at EMS for other processes or products can extend the shelf life of the material - Can be recycled in the future if Poland upgrades their recycling facilities - reusable	- Improper collection in the production plant

Plastic covers

Strength	**Weakness**
- Recyclable material - Extra protection for metal components to avoid package damage - Protects against scratches on cosmetic surfaces	- Excess usage leads to over protection
Opportunity	**Threat**
- Might be unnecessary on certain components and can be wholly removed - Reusable	- Improper collection in the production plant and high chances to miss connecting due to its small size and high volume

Styrofoam

Strength	Weakness
- Good protection - Moldable to fit complicated shaped components - Cost efficient	- Can not be recycled - Excess usage leads to over protection - Not environmental friendly - More space occupied inside a secondary package - Can create loose particles that can contaminate the end product during assembly
Opportunity	**Threat**
- Not identified	- Improper collection in the production plant

Polypropene Trays

Strength	**Weakness**
- Good protection - Less material handling in Warehouse unpacking - Easily stackable and so can provide practical volume and weight efficiency during transportation - Safe to move direct into production	- Can not be recycled in Poland
Opportunity	**Threat**
- Can be recycled	- To limited use for special treatment/recycling

ESD Bags

Strength	**Weakness**
- Can be used in clean room - Protects against ESD and particles - Protects against scratches	- Can not be recycled - Expensive compared to LDPE bags
Opportunity	**Threat**
- Not identified	- Not identified