Spare Parts Inventory Management

A Case Study at Axis Communications AB

AMIT AMULANI

MANOJ SRIDHARAN

Division of Production Management

Department of Mechanical Engineering Sciences

Faculty of Engineering, LTH

Lund University

Author Amit Amulani

Author Manoj Sridharan

Supervisor Anna Olofsson
Manager within Material Supply at Axis Communications

Supervisor Fredrik Olsson
Associate Professor at the Division of Production Management

Examiner Johan Marklund
Professor at the Division of Production Management

Master Thesis
Division of Production Management
Department of Mechanical Engineering Sciences
Faculty of Engineering at Lund University
SE-223 63 LUND
+46 222 72 00

Abstract

Title: Spare Parts Inventory Management - A Case Study at Axis Communications AB

Purpose: The purpose of the thesis was to explore the phenomenon of spare parts in the forward supply chain and identify the challenges, gaps, and opportunities to increase the overall efficiency of their spare parts inventory management practices.

Background: Organisations have recognized the need for balancing the supply and demand in inventory management to enhance the supply chain performance, cost and effectiveness. With excess supply resulting in capital tie-up and waste, and insufficient supply leading to stock-outs, decreased service levels and customer satisfaction. Having different product categories, including main products, accessories and spare parts plays unique roles, with spare parts particularly vital for the repair and maintenance in the after sales period which also has high uncertainty in its low demand. Today, Axis does not have a good strategy on dealing with spare parts in their forward supply chain and sometimes denote these as accessories because they sell these to customers. Therefore, a detailed study of relevant topics along with inventory frameworks was done to analyze and provide recommendations on how to deal with the spare parts to improve the overall efficiency in the supply chain.

Method: The research method of the study chosen is a single case study and some action research elements acting as a supplementary tool. An abductive approach has been used to have better flexibility in decision making with the available data and literature studied. The data gathered for this study is a mix of qualitative and quantitative from semi-structured interviews about the current working of the supply chain process of spare parts.

Findings: The findings from this case recommend a systematic approach to handle spare parts inventory within Axis's supply chains having a distinction between forward and reverse supply chain and the role of spare parts in providing customer support and in generating revenue. The product life cycle and segmentation analysis based on demand volume and revenue were identified as crucial steps. Through strategic planning, it is recommended to retain the high runners in the forward supply chain under few conditions and the remaining to the reverse supply chain considering the importance of service rather than sales of spare parts. Utilization of centralized hubs or an omnichannel approach in a reverse supply chain will improve the overall operational efficiency and reduce the obsolescence inventory. Our proposed solution aims to enhance inventory management effectively while focusing towards customer satisfaction but not losing revenue opportunities as well.

Keywords: Spare parts, forward and reverse supply chain, supply chain segmentation, product life cycle, supply chain strategy, inventory management

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Amit Amulani and Manoj Sridharan

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List of Abbreviations

BOM	Bill of Materials
CLC	Configuration Logistics Center
CV	Coefficient of Variation
DOA	Dead on Arrival
EMS	Electronic Manufacturing Services
EOQ	Economic Order Quantity
ERP	Enterprise Resource Planning
FSC	Forward Supply Chain
KPI	Key Performance Indicators
MRP	Materials Requirement Planning
MTO	Make-to-Order
MTS	Make-to-Stock
PLC	Product Life Cycle
PU	Product Unit
RMA	Return Material Authorization
ROP	Reorder Point
RSC	Reverse Supply Chain
S&OP	Sales and Operations Planning
SBU	Strategic Business Unit
SCM	Supply Chain Management
SKU	Stock Keeping Unit
SU	Sales Unit
TAT	Turnaround Time
WMS	Warehouse Management System

CHAPTER 1 - INTRODUCTION

This chapter aims to provide a brief outline to the reader with background information about the studied case company. It will also reflect on the problem formulation, research questions and limitations that are addressed. Finally, it concludes with the thesis outline which is explained in further chapters.

1.1 Background

For many years, companies have extensively focused on creating a balance between supply and demand. The reason for creating a balance is because the overall supply chain performance increases and organisations can concentrate on being cost-effective (Jacobs et al., 2011). Therefore, inventory management is important for an organisation's planning and control. It can assist in managing the uncertainties in demand, supply or cost factors and maintain a smooth flow in the supply chains. In the event of an excess supply in comparison with demand, companies will be forced to accumulate these vast quantities of stock which results in a significant amount of capital being tied up and often leads to an increase in obsolescence. Similarly, if the demand exceeds supply, then there becomes a shortage of products which in turn reduces the service level and the corresponding overall sales. As a result, inventory management is now regarded as one of the core competencies of supply chain management (SCM) to achieve a competitive edge (Axsäter, 2006).

According to ASCM (2022), inventories are meant to support customer services, production, and related operations. Thus, the goal of inventory management is to ensure different types of products are available at all locations and how many of them there are across the company's supply chain.

A supply chain in an organisation includes multiple processes with different types of products being handled with each product having different functionalities and requirements, so it is important to develop an appropriate supply chain structure for each product category (Bozarth and Handfield, 2019). In any organisation, the products are generally categorized into regular products, accessories, spare parts and other components. Each category is unique in terms of its use and functionality. Regular products, also known as main products for any company are sold directly to customers and contribute to most sales in the business. On the other hand, accessories are those components sold separately and play a supporting role in adding value to the main products. The contribution in generating revenues might be less but some of them could be highly critical regarding usage and cost. The purpose of spare parts can be distinctive for different industries. They could generate some revenues if sold directly, but the main aim lies behind providing services where customer satisfaction becomes key. Spare parts replace the original components so the product can continue functioning (Zhang et al., 2021). Providing spare parts to customers can help increase the customer repeat rate, therefore, they are of high value and can create a high impact in the supply chain.

Spare parts are mainly used in maintenance activities to keep the products active in operating conditions (Kennedy et al., 2002; Zhang et al., 2021). The non-availability of spare parts can create huge financial losses for organisations as they are highly responsible for after-sales services which is where organisations claim for warranties in their products. Therefore, an efficient flow of spare parts is required such that product downtime is reduced and customer satisfaction is improved (Zhang et al., 2021). Amniattalab et al. (2023) state that the demand for spare parts is driven by three main factors; the number of products used by customers, the number of products returned due to failure or maintenance and lastly the rate of discarded products. Compared to standard supply chains where demand forecasts for main products provide approximately accurate results, for spare parts it is usually not the case due to high variable demand (Zhou et al., 2024). The demand variability is high for spare parts because of high demand uncertainty. However, there are reasons for this. First, the product variety is more compared to the demand volume of an individual component. Second, demand forecasting is difficult due to intermittent (irregular) demand patterns. Third, the product life cycle is highly dependent on the main product (Zhang et al., 2021).

Therefore, there is a potential for improvement in the spare parts supply chains to create a balance between supply and demand. This could include improving the stock levels, using appropriate forecasting models, working on lead times or maybe placing them in the right areas. It is also necessary that the improvements or models suggested should be aligned with the organisation's strategic decisions and it should create a valuable purpose by helping them achieve their goals. Depending on how the organisation wants to manage the stocks and invest, the implementation of inventory management practices might look different (Schiro and Rubin, 2023).

1.2 Case Company

Axis Communications is a global industrial leader in video surveillance with a wide portfolio of network solutions in video surveillance, access control, intercom and audio systems along with an extensive range of training, tools and support (Axis Communications, 2024a). The company was founded by Mikael Karlsson, Martin Gren and Keith Bloodworth in 1984 with its headquarters in Lund, Sweden and has been a part of Canon Group since 2015. Axis employs more than 4000 people from 50+ countries with 62 sales offices and 33 Experience centers (Axis Communications, 2024b).

The business model of Axis Communications is built based on partnership, trust and mutual support bringing in experience, knowledge and innovative solutions from leading experts. They do not adhere to the conventional business model which means they do not engage directly with the end customers, instead, they work closely with long-term partners or distributors located all around the world who deliver solutions and support customers whenever in need (Axis Communications, 2024a). Axis ensures that the distributors have enough stocks with them in order to fulfill the demands of the end customers. Distributors tend to sell the products through system integrators or resellers to the end customers. These resellers or system integrators are located in 100+ countries and Axis assists the distributors in their sales network towards respective resellers (Axis Communications, 2024b). Axis also offers a stock rotation policy to its key distributors, which allows them to return their unsold products to Axis for a

100% refund. This policy encourages the distributors to maintain a greater inventory of the products without significant risk. They have three distinct business regions: Europe, Middle East and Africa (EMEA), Asia-Pacific (APAC) and Americas. Figure 1.1 represents the business model of Axis.

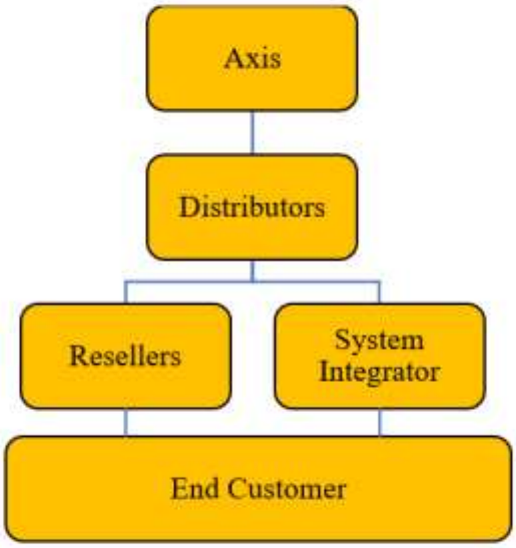

Figure 1.1: Axis Business Model (Created by authors)

1.3 Problem Formulation

Axis has a wide range of products in the supply chain. This includes their main products, accessories and spare parts. They have two different supply chains i.e. forward and reverse. Forward supply chain (FSC) aims to deliver products and solutions to customers thereby, generating revenues and profits. Reverse supply chain (RSC) takes care of repairs and replacements of the components which means after-sales services. For RSC, getting sales is not their primary goal but providing the best services is what they want to have so that customers are satisfied.

In the current context, Axis has a defined strategy for managing its inventory in both forward and reverse supply chains. However, there is a lack of a strategy for managing the spare parts in the FSC when sold to its distributors. The spare parts are kept in multiple Configuration and Logistics centers (CLC) based on specific requirements and they are unsure whether they require all of those or not. Orders are placed for spare parts based on the forecasts generated based on historical data and previous trends of similar products. A new forecasting software has been implemented which helps them to create forecasts using historical data. It is necessary to understand how the forecasts are created for spare parts and their impact on inventory decisions. Furthermore, they are in the phase of developing the ABC classification for all product categories based upon the demand volume and cost of products, but it is in the developing phase to categorize the high and low runners in managing the inventory of the supply chain.

1.4 Purpose

The purpose of this Master Thesis is to explore the phenomenon of spare parts in the forward supply chain in terms of their categorization and demand patterns. This study will investigate the current situation, challenges and gaps in their current management practices. Finally, the solutions proposed will drive a change and increase the overall efficiency in their future supply chain.

1.5 Research Questions

The research questions included in this master thesis aim to deliver the purpose of the work and guide the company to manage the spare parts in the forward supply chain in an efficient way. The purpose mainly includes the research questions.

RQ1: *How can a systematic approach for spare parts inventory management be established, considering how it is handled and looking at the demand pattern in their existing supply chain?*

In order to define a systematic approach to managing the flow of spare parts in Axis, it is necessary to comprehend the organisation's structure and its existing approach. The methodology involves appropriate research strategies involved which will follow a comprehensive literature review to understand the relevant approach to handle the spare parts inventory. Simultaneously, the semi-structured interviews will be conducted with the key stakeholders involved. This will follow the process of analyzing the data received from multiple sources including segmentation, product life cycle (PLC) and understanding the existing forecasts model. It is also important to understand the motivations behind these attributes so that an analysis concerning their usefulness and practicality can be performed.

RQ2: *How can the proposed solution help with the categorization and strategic planning decisions on spare parts in the existing and future supply chain?*

Once the current processes have been outlined and analysis on segmentation and PLC is performed, a comparison study with the theoretical studies will be done which will be relevant to the case and then suitable strategies are proposed that are useful to handle the spare parts in the existing and future supply chain based on the categorization. This would also take into account the restrictions Axis Communications has within all the regions.

RQ3: *With the proposed solution, what are the strategies required to drive a change in improving the spare part inventory decisions in the supply chain?*

Once the relevant approach is finalized, the strategies for its implementation will be proposed. After conducting the needs assessment, the proposed solution will be ready for its implementation process. The main attention would be to align the new approach with the current operational processes. The competencies will relate to the people and processes at Axis Communications and the findings will be used to guide the development of their global spare part inventory management initiative.

1.6 Focus and Delimitations

The focus of this study is to work with the inventory of spare parts in the FSC. Given the time frame of this thesis, the study is limited in terms of the depth of the analysis and the literature review. Today, Axis Communications has divided the supply chain with respect to the flow of components in forward and reverse supply chains and they keep many spare parts inventories in both of them. It is necessary to categorize the spare parts as the purpose is different for both supply chains. It is needed to address the advantages and challenges and make decisions on whether Axis should keep the spare parts in both supply chains or only with one considering their demand.

In order to support our decision-making, other focus areas needed would be on key performance indicators (KPI), understanding the enterprise resource planning (ERP) systems and other tools that are used currently in the case company. Axis strongly believes their forecasting models are used to predict their future demand which will determine the stock levels in their warehouses. The demands for regular products, accessories and spare parts are different and this study gives attention only to spare parts based on their demand patterns in the FSC.

Today, Axis does not focus on the segmentation of spare parts alone as they do for all the products taken as a whole. It is essential to have the segmentation to determine spare parts with high or low demand variability, have optimal ordering policies and maintain appropriate stock levels based upon the characteristics chosen. This will require a comprehensive understanding of the individual spare parts and classify them depending upon the demand and cost. With proper segmentation, the final area would be to study how the segmentation can help in having better service levels while making sure that it does not have a negative effect. It is also necessary to take the PLC of spare parts into consideration as they support multiple main products in the FSC.

1.7 Thesis Outline

Chapter 1 - Introduction

This chapter aims to deliver the background information of the master thesis on the case company and states the problem at hand for the given organisation. It also describes the purpose of the research objectives along with scope and delimitations.

Chapter 2 - Methodology

This chapter explains the procedure and the research methodology that has been used in this study. The methodology chosen is decided based on the comparative studies which align with the purpose and research objectives that support the goals and the available information and processes. To begin with, the research structure and strategy are comprehended, followed by in-depth research design and methods. Finally, it will conclude with a transparent walkthrough of the analysis and measures to ensure high research quality.

Chapter 3 - Literature Review

This chapter provides detailed research literature that serves the purpose of this master thesis related to spare parts inventory management with the case company. It introduces terminology, concepts, and frameworks that will be applied to execute the empirical study and analysis. The topics covered will set up the foundation for this thesis.

Chapter 4 - Empirical Findings at Axis

This chapter provides information about the supply chain structure of Axis Communications. This includes the current processes and the future directives related to the spare parts inventory. The information gathered will be primarily based on the interviews with the employees, observations from the warehouse visit and the data collected from all these areas.

Chapter 5 - Gap Analysis

This chapter performs a comparative analysis of the literature topics and the findings from the empirical data collected during this thesis. Each problem statement has been narrowed down into various small problems that are mentioned in Chapter 1. This analysis will provide more information on how the problems can be solved using theoretical frameworks to support the current situation of the case company.

Chapter 6 – Solution Proposal to Axis

This chapter provides the solution proposals and recommendations to the case company. The implementation process for their current and future supply chains is discussed in detail. It includes suggestions and practical insights that can solve the problem regardless of the barriers and challenges within the flow of products and the reasoning behind the current ways of working.

Chapter 7 - Conclusion

The conclusion chapter outlines the remarks, including a revisitation of the purpose of this study. It gives brief insights into how the research questions have been answered within the time frame given. Additionally, both the theoretical and practical contributions are provided as well as the recommendations to solve the problems in the given case along with the limitations and future work that can be done.

CHAPTER 2 - METHODOLOGY

The methodologies used throughout this study have been outlined in this chapter. The research structure briefly overviews the selected research approaches and the criteria established based on the problem identification and research objectives. The chosen methodologies have been described in detail which will later conclude the analysis and measures to ensure high research quality.

2.1 Research Structure

Saunders et al. (2019) mentioned in their book about the "Research Onion" that describes all the factors in general about choosing the appropriate research methods. Considering the degree of research and work to be carried out for this thesis, the relevant research methods mentioned in Figure 2.1 have been selected which are described in detail in the later sections in this chapter.

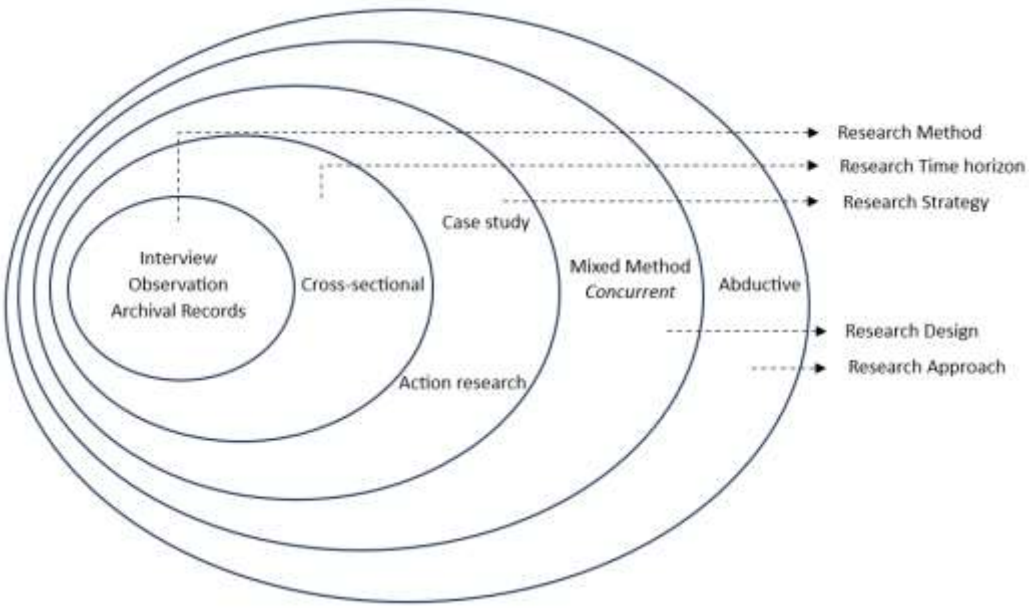

Figure 2.1: Research Onion (Saunders et al., 2019)

2.2 Research Approach

Research philosophy describes the development of knowledge for a system. This refers to knowledge gained from the study, which could include generating and describing new theories or addressing a specific problem. Every research project involves using an appropriate theory that describes the design of this research. The level to which the research focuses on theory development or testing has an impact on the project's research design. In the discipline of logistics research, there are two research approaches: inductive and deductive. The inductive approach is used to explore the phenomenon by first gathering empirical data that needs to be described in order to formulate a theory. It begins with facts and progresses to theory, requiring no prior theoretical knowledge of the subject. In contrast, the deductive approach necessitates a literature review to comprehend a formal theory before testing the assistance theory through analysis. It begins with logical conclusions derived from theory and given as propositions or hypotheses (Saunders et al., 2019).

In a typical business context, organisations struggle to settle on a single approach. To accomplish their goals, they sometimes link together both types of phenomena. This approach moves back and forth and combines both inductive and deductive methods and therefore is known as the abductive approach (Saunders et al., 2019; Olhager, 2023a). A well-developed abductive approach is associated with pragmatist philosophy which is relevant to our thesis. In our case, the phenomena has not been explored, although the relevant theories exist and have been employed previously. Therefore, both the research approaches mentioned in Figure 2.2 can be used simultaneously and as a result, in this study, abductive research is adopted. It also allows for greater flexibility in the development and analysis of ideas because literature studies and data collection can be conducted concurrently (Saunders et al., 2019).

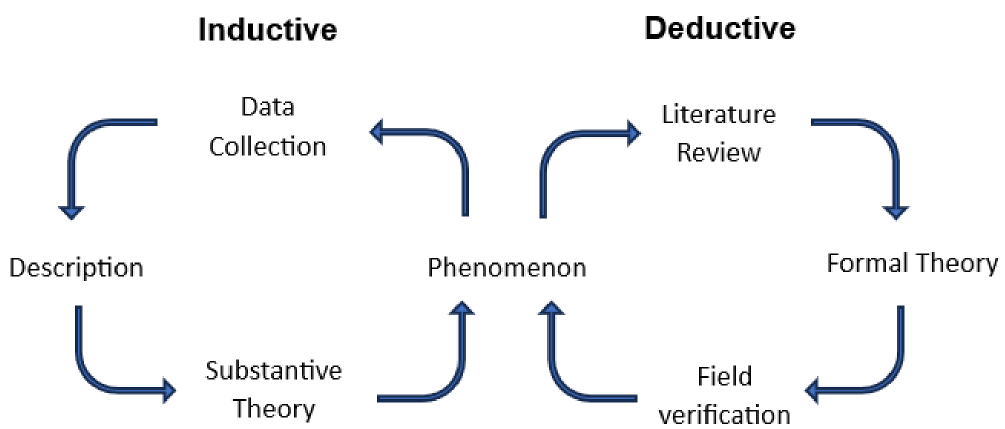

Figure 2.2: Adaption of Woodruff's (2003) diagram of the flow of abductive research (Olhager, 2023a)

2.3 Research Design

A research design offers a general framework for addressing the research issue and the subsequent strategies that will be selected. It contains the objectives derived from the research question, the literature articles that would be referred to, the sources from where the data will be collected and tested and how it has been analyzed. In a typical study, two types of research techniques are used: qualitative and quantitative methods. Qualitative studies focus on developing conceptual frameworks and defining relationships between variables using theoretical studies. The meanings are derived from words or images and not from numbers. Comparatively, quantitative research uses a variety of statistical and graphical techniques to examine the relationship between variables through numerical measurement and analysis. It also provides validation to the measured data (Saunders et al., 2019).

In practice, there are scenarios when both these methods integrate to validate the study or experimentation techniques. In such cases, mixed-method research is preferred. A mixed-method study is a subset of research techniques that encompasses the application of qualitative and quantitative techniques. Because mixed research methods allow for the testing of theoretical hypotheses and the development of a deeper understanding of the topic, they are consistent with the abductive approach. There are two main forms of mixed techniques: sequential and concurrent mixed methods. Concurrent mixed method research signifies that both quantitative and qualitative methods function separately within the data collection and theoretical analysis respectively for the same research topic. The combined findings from the two approaches undoubtedly offer a thorough answer to the study issue. Conversely, the sequential mixed method technique takes individual methods into successive phases i.e. one followed by another. The framework can be chosen based on the pertinent data gathered at each stage of the study and the highly targeted methodology (Saunders et al., 2019).

To conduct research studies, it is essential to understand its objective, what it implies and how it is of value to the research community. Every research conducted has a certain purpose and future scope. Saunders et al. (2019) mentioned four types of research studies i.e. exploratory, descriptive, explanatory and confirmatory. *Exploratory research* is conducted when prior knowledge about a topic is limited. It aims to provide initial insights, identify crucial variables, and offer a preliminary understanding of complex concepts. This method lacks a predefined model and aims to uncover unknown aspects of the phenomenon, providing researchers with the foundation to develop hypotheses and gain a deeper understanding of the subject. *Descriptive research* aims for a detailed portrayal of a phenomenon, highlighting its importance and revealing characteristics, behaviours, or attitudes in a specific group. Examining how this phenomenon is distributed within a population, such as studying traits in firms practicing supply chain integration, enhances our understanding of its significance. It is also called an extension of exploratory research or the forerunner of explanatory research. *Explanatory research* delves into causal relationships between variables to uncover why phenomena occur and how one variable impacts another. It seeks to identify, assess, and explain the extent and nature of cause-and-effect relationships, including the effects of specific changes on dependent variables and the underlying patterns of these relationships. *Confirmatory research*, as the name implies, is geared towards validating established theories, hypotheses, or models by empirically testing their adequacy, hypothesized linkages, and causal relationships among variables. Yin (2018) connected the same studies under the case study that is described in section 2.4.

Given the nature of the study, the phenomenon requires exploration because the overall understanding of this subject for the case company is limited. As a result, the authors have chosen to conduct exploratory research. However, the study also expects to highlight the importance and behaviour of the phenomenon in the supply chain such that the authors can reach some conclusions and outline suggestions for future research. The phenomenon by nature is already described in the field of research which means the theory exists. So, it is anticipated that the research study is aligned with the descriptive study as well. Therefore, the authors have concluded to use a mixture of two research investigations, comprising exploratory and descriptive research studies (Saunders et al., 2019). Additionally, the methodology selected leans toward a mixed study design in which both qualitative and quantitative analysis will be performed. While working independently, these two approaches support one another in providing more insight and helping to make effective judgments. Therefore, the concurrent mixed-method research is used. While designing your research, it is also essential to consider the time horizon which means total time to complete the study on the phenomenon. The cross-sectional time horizon has been selected due to the phenomenon analysis being conducted in the given amount of time. It also often relates to mixed-method research that uses both qualitative and quantitative data analysis (Saunders et al., 2019).

2.4 Research Strategy

A research strategy is a course of action that the researcher defines to achieve the goal by answering the research questions. Research strategies are linked to the previously described research philosophies, designs, and procedures. All of those are a part of the strategies based on the research objectives (Denzin and Lincoln, 2018). The choice of research strategy is guided by the research questions, research approach, objectives, resources, available time and the knowledge of that area (Saunders et al., 2019). It is therefore important to realize that the tactics with the choices are not always mutually exclusive. Yin (2018) mentioned the three conditions when choosing a method i.e. a) the form of research question posed b) the control a researcher has over actual behavioural events c) the degree of focus on contemporary as opposed to entirely historical events. Table 2.1 shows the conditions and the relevant strategy that could be adopted.

Table 2.1: Various research strategies for different situations (Yin, 2018)

Strategy	**Form of research questions**	**Requires control over behavioural events**	**Focuses on contemporary events**
Experiment	How, Why	Yes	Yes
Survey	Who, What, Where, How many, How much	No	Yes
Archival Analysis	Who, What, Where, How many, How much	No	Yes/No
History	How, Why	No	No
Case Study	How, Why	No	Yes

Keeping these situations in our thoughts, the focus shifted toward research questions and they were connected to “how” and “what” statements. In simple words, how is the current situation of the case company and the problems identified, how can literature studies and analysis performed help to solve the challenges and what strategies are required to implement to have an efficient supply chain. Additionally, the researchers do not have actual control over the events and the research is focused on contemporary events. So, there are three possible scenarios i.e. case study, survey and archival analysis (Schiro and Rubin, 2023).

Depending on what needs to be achieved from the study, the appropriate research strategy should be chosen (Schiro and Rubin, 2023). In certain circumstances, selecting the best strategy is challenging since there are several strategies that can be considered. Additionally, there are various situations when one research strategy cannot fulfill the research purpose and requires support from the other strategy. In such scenarios, a blend of two strategies can be used to achieve the goal where one method can share its elements with the parent strategy (Saunders et al., 2019).

A case study is a comprehensive analysis of a particular occurrence in a real-world context. By allowing the phenomena to be studied in their natural setting and permitting the development of pertinent ideas through actual observation, this method has a substantial impact on research (Saunders et al., 2019). The relevant case research should be examined in accordance with the research topic and its structure. The purpose of choosing case research can vary from initial exploration to more advanced theory testing or refinement (Yin, 2018). In the exploration stage, the aim is to formulate new ideas and develop research questions that are not studied or explored in the field. In the theory-building stage, the goal is to identify key variables and patterns that can impact the specific phenomenon. This stage also mentions the existence of these relationships. The theory testing stage is more aligned towards multiple case studies or if they include large sample sizes, for example, data received from multiple sources. It usually tests the theories with the empirical findings and predicts future outcomes. Furthermore, it is important to decide the number of case studies used in the study. Single case studies give an in-depth understanding and provide an opportunity to observe and analyze the phenomenon that few have considered or require exploration. Multiple case studies on the other hand focus on findings that can be replicated across cases (Saunders et al., 2019). Case studies usually commence to have an abductive approach where findings are tested and compared with theoretical studies (Schiro and Rubin, 2023).

Action research deals with a sequence of events and an approach to solving a problem. It involves two major goals i.e. to solve a problem and contribute to science. Coghlan and Brannick (2010) stated that it is research in action rather than research about action. This is because it addresses the challenges of organisational issues. The action research cycle consists of six stages which are shown in Figure 2.3. Before starting the first step, the context and purpose should be defined to give a concrete idea about the research. The first stage involves data collection from the relevant sources and this could include both qualitative and quantitative information. The second step involves data feedback where an action researcher gathers information and does the reporting to make it ready for analysis. The third step includes data analysis and is one of the critical aspects because it will reveal the gaps in the current study and the areas that require improvements. The fourth step is action planning which involves planning of action to create a change in the desired area. The fifth step is the implementation phase where the researcher looks to implement the action and is followed by an evaluation step (Coughlan and Coghlan, 2002). The process of action research is mostly iterative where continuous diagnosis at every stage is needed. Once the first research cycle is finished after evaluating the actions, the next cycle continues with diagnosing and constructing the issues and following the process again (Saunders et al., 2019).

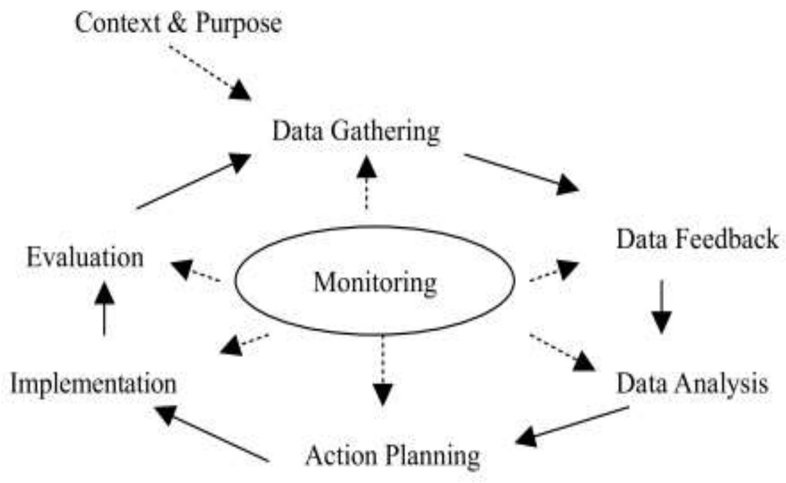

Figure 2.3: Action Research Cycle (Coughlan and Coghlan, 2002; Olhager, 2023b)

Since one case company will be thoroughly studied in this project, a single case study is the suggested research approach. A variety of information is collected to describe the situation in detail. The data includes qualitative and quantitative information which will help the authors in understanding the supply chain processes and organisational flow. Further, the analysis of the obtained data will help in investigating the issues with the case company and answering the research questions for this thesis. However, as mentioned in section 2.3, the authors in this thesis must assist the case company in making decisions based on the studied data. So, it is also aligned towards problem solving and research in action which means action research strategy is also favoured.

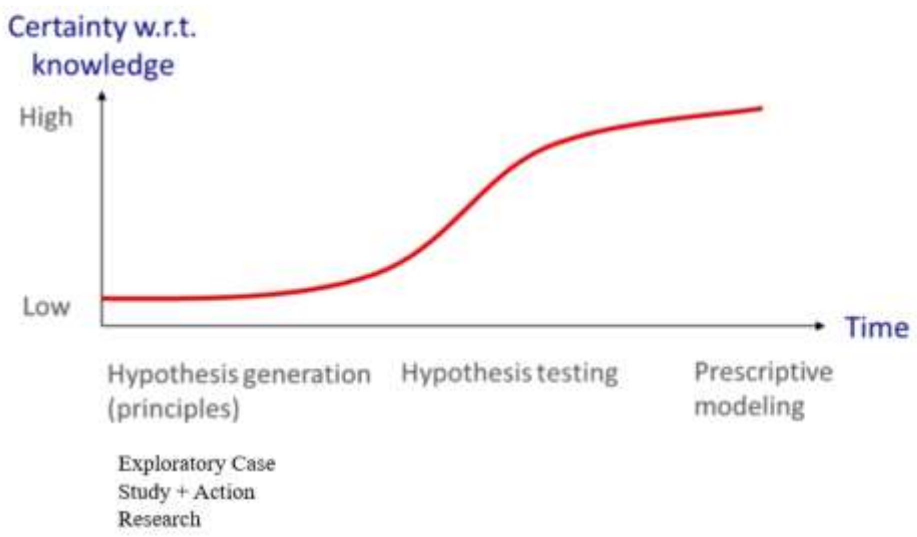

Figure 2.4: Maturity cycle of research (Malhotra and Grover, 1998; Olhager, 2023a)

Choosing an appropriate research phase could be an early hypothesis phase to a late hypothesis testing phase depending on the evolution of the phenomenon. This creates an increased understanding of knowledge on case company. If the subject is placed in the early stage, then the phenomena would be exploratory until it travels to the last stage meaning confirmatory study. This is known as the maturity cycle of research (Malhotra and Grover, 1998). Figure 2.4 represents the maturity cycle of research that signifies the appropriate research strategy selected for the case company.

After studying both approaches and connecting them with the research questions, it was concluded that this study will use a mix of two strategies, with action research serving as a supplementary tool for the case study. The choice is based on several considerations, such as the research's maturity, prior understanding of the subject, the availability of relevant data and resources, and the project's allotted time. Proper validation and triangulation of all the qualitative data in a case study will help to support the conclusions drawn from it. A detailed description of different data collection techniques is provided in section 2.5. Survey research was excluded due to the nature of the problem, lack of respondents and time constraints. Similarly, archival analysis had some data that could be used to support the analysis, but more focus is heavily on contemporary work (Yin, 2018).

	Single Case Designs	Multiple case designs
Holistic (Single unit of analysis)	**Type 1**	Type 3
Embedded (Multiple unit of analysis)	Type 2	Type 4

Figure 2.5: Basic types of design for case studies (Yin, 2018)

In addition to the case study's maturity and objective, decisions must be considered based on the number of cases included and the type of unit of analysis. When considering the case studies, it should be either single or multiple case studies. On the other hand, the type of analysis could be single or embedded depending on how many research designs are involved to support the case study. In our case, Axis Communications will be the case company as the study is focused on one company. In terms of units of analysis, this study uses a single unit of analysis as it analyses the inventory management of spare parts in depth to comprehend the significance of different factors. So, Type 1 (Yin, 2018) will be the ideal choice to conduct the study mentioned in Figure 2.5.

2.5 Research Methods

Multiple methods such as literature review, interviews, observations and archival data (Eisenhardt, 1989) were used to describe the case content, comprehend the problem statement and offer a recommended solution to research questions. Qualitative data is gathered to understand the working structure and various processes taking place which served as a foundation for addressing the research questions. Quantitative data on the other hand provides numerical information to perform analysis and provide suitable results to support the decision-making process. To gain an understanding of the management of spare parts in general and connected topics, a thorough literature review is required. To understand the case company specifically, the research methodology also included observations and interviews with employees in various organisational structures. Lastly, the utilization of archival data facilitated in acquisition of relevant historical and current data necessary to assess the current way of handling spare part inventory as well as to suggest a course of action against research questions. Additionally, the stability and reliability of the data acquired are increased using a combination of approaches also known as triangulation (Voss et al., 2002; Yin, 2018).

2.5.1 Literature Review

According to Eisenhardt and Graebner (2007), research should always start with a strong foundation of understanding the relevant literature. Literature review plays an important role in serving as a foundation to provide knowledge about guidelines, new ideas, practices, policies, etc. (Snyder, 2019). The major purpose was to gain an understanding of current study fields by recognizing interrelated links or trends, as well as positives and problems. Second, identify the appropriate topics and subjects to have a deeper understanding and have reliable information to help us construct theories for our thesis.

We have utilized a combination of research articles and books, but mostly research articles in our study. In addition to this, materials from our academic courses were also used. LUB search and Google Scholar were the search engines used to find relevant articles. The widely used and preferred search engine was LUB search rather than Google Scholar. Our strategy for searching articles was to brainstorm the popular keywords related to the necessary topics upon which data was required. Since the area of inventory is very broad, a single search strategy was not a feasible option to carry forward. There was an abundant amount of information and filtering the necessary information related to our study was difficult. Therefore, additional time was used to find the relevant literature using research papers, books and previous articles.

2.5.2 Interviews

Conducting interviews is a common method to gather information from an expert for a case study (Nicmanis, 2024). Interview is a very adaptable and versatile strategy by which rich data can be obtained regarding the experiences, memories and emotions of your participants through qualitative interviews. Since it is a responsive approach, there is a possibility of asking follow-up questions for deeper understanding. The information obtained from interviews is usually biased because most of the answers from the respondents come from their personal experiences.

Table 2.2: List of interviews conducted for the case company

Interview Role	Onsite/ Virtual	Date and Duration
S&OP Planner	Virtual	23rd January 2024, 30 minutes
EMS Supply Lead	Onsite	24th January 2024, 60 minutes
Experienced Purchaser	Onsite	25th January 2024, 60 minutes
Process Developer	Onsite	26th January 2024, 60 minutes
Reverse Supply Chain Director	Onsite	29th January 2024, 60 minutes
Experienced Purchaser	Onsite	31st January 2024, 75 minutes
Global Product Manager	Onsite	1st February 2024, 60 minutes
Material Supply Manager	Onsite	13th February 2024, 60 minutes
Supply Chain Transformation Manager	Virtual	15th February 2024, 60 minutes
Service Manager	Onsite	28th February 2024, 60 minutes
Experienced Purchaser	Virtual	28th February 2024, 60 minutes
Reverse Supply Chain Planner	Onsite	12th March 2024, 60 minutes
Team Lead Distribution	Virtual	18th March 2024, 45 minutes
Distribution Operations Account Manager	Virtual	25th March 2024, 60 minutes
Material Supply Manager	Onsite	3rd April 2024, 60 minutes
Process Developer	Onsite	9th April 2024, 60 minutes
Logistics Analyst	Onsite	15th April 2024, 45 minutes
S&OP Planner	Virtual	15th April 2024, 60 minutes
Experienced S&OP Planner	Onsite	26th April 2024, 45 minutes
Supply Chain Manager	Onsite	26th April 2024, 60 minutes

Semi-structured interviews are used for our study (Yin, 2018; Voss, 2002). Before the meeting with the responsible expert, the authors discussed and created a set of questions followed by some spontaneous questions in the discussion. Both the participants were actively involved in all interviews enabling more interactive sessions. Most of the interviews took place face to face which was an added benefit in observing how well the responder was reacting to the questions. In addition to the face-to-face interview, we had to conduct a few interviews online as well. Table 2.2 represents the list of participants who were interviewed from various functionalities and different hierarchical levels. A detailed interview guide discussing the questions asked to the experts is mentioned in the Appendix.

2.5.3 Observations

Empirical evidence gathered from observations can be an excellent source when conducting a case study, as well as for gaining a better understanding of the phenomenon under research (Yin 2018). There are two types of observations used in the data collection phase: participant observation and direct observation. A participant observation occurs when a participant takes part in a collaborative event to gain a better understanding. Direct observation includes scenarios such as factory tours, warehouse visits, and other physical activities. Direct observations are more valuable to the researcher and the case study process because they are designed to be analyzed in their natural setting. A list of observations used in this study can be found in Table 2.3.

Table 2.3: List of observations held throughout the thesis duration.

Employee Job Title	Region	Date and Duration	Location
Product Manager	Sweden	3rd April 2024, 60 minutes	Axis Experience Center
CLC Manager	Sweden	11th April 2024, 60 minutes	Warehouse tour

2.5.4 Archival Records

According to Yin (2018), documentation and archival records are two standard methods for collecting data for case studies. Archival data can mean financial records, minutes of meetings, service records, organisational records and other documents (Runeson and Höst, 2009; Yin, 2018). Some of the data might be precise to the requirement while others will be tailored specially to a topic area, hence the archival data is to be used carefully and might contain unwanted information.

Archival data is obtained in two ways in this project. Firstly, we went through the Axis information page and documents to gather the relevant details. Secondly, from the interview conducted with informants, various types of information including presentations and spreadsheets helped in making suitable decisions for answering our research questions.

2.6 Research Quality

A research study conducted should be of high quality so that its findings are reliable for the case company and to ensure that the goal is achieved. According to Yin (2018), enhancing the quality of research design involves being transparent about theoretical perspectives, clearly defining the case and phenomenon of interest, justifying the study design, and using multiple data sources for analysis. The four criteria mentioned below evaluate the quality of our thesis work: construct validity, internal validity, external validity and reliability (Yin, 2018; Voss et al., 2002).

2.6.1 Construct Validity

As per Yin (2018), construct validity is one of the crucial and difficult steps in a case study methodology. Selection of many measures to construct is easy, but selection of optimal measures specific to a case study can be hard. In this thesis project, the two measures are considered, firstly multiple sources of data (Literature, observation, interviews, archival data) and data triangulation to improve the reliability of obtained data. Secondly, we used many informants from different positions and hierarchical levels to validate the responses.

2.6.2 Internal Validity

Internal validity aims to establish causal relationships that support the study either directly or indirectly (Voss et al., 2002). It means a certain result can affect the other result, separated from false relationships. As the current focus of this research is to establish the right path for the given phenomenon, the current results require validation by reviewing results and conclusions with key people in the organisation.

2.6.3 External Validity

External validity refers to how the findings of the research can be applied to other focus areas or how generalizable the conclusions are to a similar population (Saunders et al., 2019). It also provides insight into whether the findings or the outcomes of the research can be applied to other populations or different settings. As the focus of research will be targeted to a specific focus area with unique characteristics, the generalizability is often limited.

2.6.4 Reliability

Reliability refers to the consistency and dependability of data collection ensuring that the research method produces comparable results multiple times indicating stability and consistency in the findings (Hall et al., 2018). It is crucial to determine how well the research can be replicated by other researchers, highlighting the robustness of the study. Establishing strong reliability is crucial because it demonstrates the findings are stable and have consistent results, regardless of factors like time, sample size and observer differences (Saunders et al., 2019).

CHAPTER 3 – LITERATURE REVIEW

This chapter represents the overall literature study that has been conducted to achieve the purpose of this master thesis. The topics covered will provide the basis for this study and identify the relevant topics that connect strongly to work on the research area and the research objectives. The relevant topics include Supply Chain Management, Supply Chain Strategy, Product Customization, Inventory Control, ABC Segmentation, ABC-XYZ Segmentation, Categorization of Spare Parts, Aspects of Demand, Key Performance Indicators, Organisational Structure.

Managing spare parts in an organisation is an important aspect of maintaining an efficient operation of a supply chain, particularly for companies that have two different supply chains. It is also essential to investigate the aspects of the manufacturing processes and customer attention towards repairs and replacements which comes under reverse flow. During the literature study, several topics had a strong connection with inventory management and spare parts in the supply chain. A general overview of direct and indirect factors that were relevant to this thesis project is described in Figure 3.1.

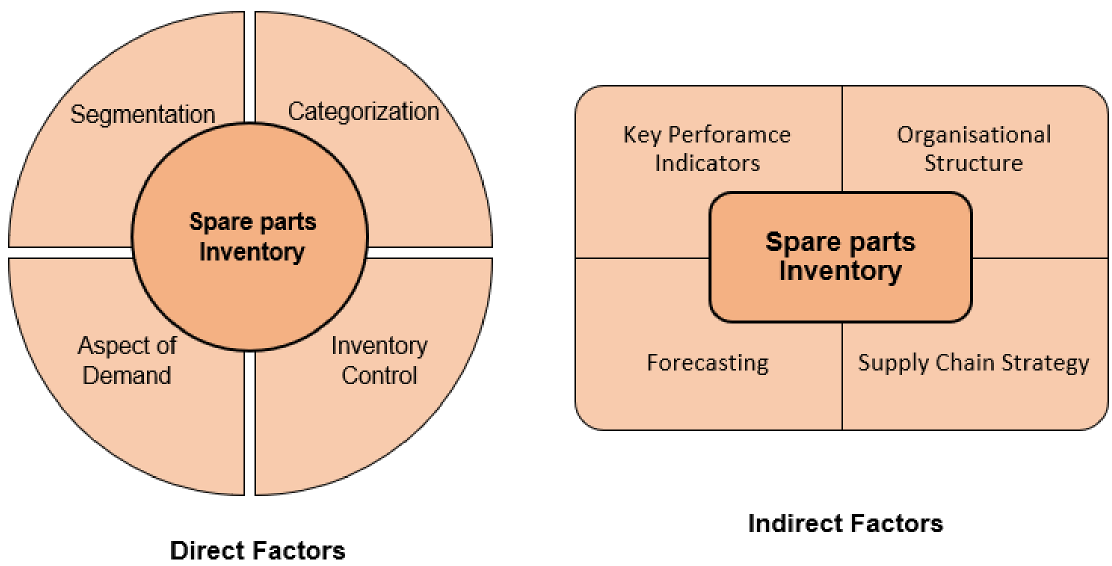

Figure 3.1: Relevant topics chosen that had a connection with spare parts inventory management (Created by authors)

3.1 Supply Chain Management

In a supply chain, several various enterprises including suppliers, distributors, manufacturers, and retailers collaborate along the entire value chain to convert raw materials into finished products and deliver them to customers (Ivanov et al., 2021). A multitude of definitions of supply chain management have been proposed over the years. Stock and Boyer (2009) in their article reviewed 173 definitions of supply chain management. In different industries, the term has various meanings and includes logistics, operations, purchasing and how the organisation works functionally both internal and external (Lambert, Garcia-Dastugue and Croxton, 2005).

Supply Chain Management (SCM) in product industries can be defined as

"The management of a network of relationships between the independent business units that consists of material suppliers, purchasers, logistics, marketing, production facilities, sales and systems interconnected within the value chain facilitating the supply of products and services from supplier to the end customer with the aim to be innovative, highly efficient, achieving customer satisfaction and maximize profits" (Stock and Boyer, 2009).

It requires all actors that participate in the supply chain actively in the process to meet the demand and achieve high service levels. The actors can be linked directly or indirectly based on their role and their contributions.

3.1.1 Forward and Reverse Supply Chain

According to Diriba (2023), there is no fixed definition of what is meant by a forward and reverse supply chain. Together, these processes ensure a comprehensive management of products throughout their lifecycle. The operational cultures and characteristics of the two supply chains are distinct, yet interdependent, exerting a significant influence on each other. The implementation of an effective FSC can result in a reduction in the number of returns for repair or replacement in the RSC. Similarly, an effective RSC in the after-sales market enhances customer satisfaction by addressing customer problems and issues, thereby boosting the company's reputation and reliability. Addressing such repairs can also facilitate the redesign and restructuring of product design and manufacturing processes, which in turn benefits the entire PLC.

FSC represents the fundamental operational structure of an organisation, encompassing a network of interconnected activities that span the entire supply chain, from the sourcing of raw materials to the delivery of finished products to end consumers. Figure 3.2 depicts a general flow of forward supply from the source to the destination of a product. It is a fundamental aspect of the supply chain that ensures products are delivered to consumers in a timely and appropriate manner. The various key departments included in FSC are sourcing, production, inventory management, and distribution. Aligning these departments together is essential for businesses in a timely fashion to minimize costs, reduce lead times, optimize inventory decisions, and meet customer demands on time. An effective forward supply chain enables companies to respond swiftly to changes in market demands and to adapt to any disruptions, thereby enabling them to capitalize on the opportunity to achieve maximum growth Stock and Boyer (2009).

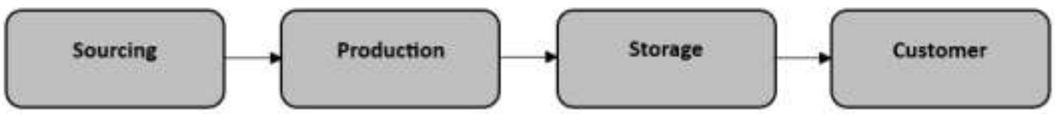

Figure 3.2: General flow of a product in the forward supply chain (Created by authors)

The reverse supply chain is a process that facilitates the flow of products from the end consumer to the original manufacturer, intending to recover the value of the product and minimize the environmental impact. The product value can be obtained through recovery, repair, recycling, or proper disposal. This may be for the purpose of replacement or repair. Blackburn et al. (2004) observed that the flow of products for both unplanned and planned returns poses challenges in storage, workspace availability and its corresponding accessory availability for many manufacturers, as organisations are challenged to design, plan and control RSCs and to make decisions regarding the profitability of product disposal. These decisions must consider the potential for reuse, refurbishment, salvage, or recycling. Additionally, the RSC is responsible for the repair or replacement of damaged parts which can be refurbished to be used again or scrapped. RSC in an organisation is the first contact from the customer whenever a fault is observed in products and the fault is to be resolved back to the customer in the shortest possible lead time, which in turn affects the actual demand for products in the FSC. It is important to implement an effective management strategy for spare parts inventories to ensure repairs and the timely availability of components. Figure 3.3 is the general flow of a component when the customer returns the product to the manufacturer either for repair or requesting a new replacement product. Furthermore, decisions regarding the disposal and recycling of irreparable items should be made with environmental responsibility in mind, to demonstrate a commitment to sustainability. A sustainable approach not only minimizes costs but also enhances the customer experience (Frei et al., 2020)

Figure 3.3: General flow of a product in the reverse supply chain (Created by authors)

3.1.2 Omnichannel Distribution

Omnichannel inventory management encompasses the coordination of inventory across multiple sales channels from a centralized warehouse (Kembro and Norrman, 2021). Making inventory decisions becomes particularly challenging in contexts characterized by high product variety and geographic dispersion across different regions. This complexity is compounded as the number of sales channels expands, potentially resulting in product unavailability in certain areas (Humphreys J., 2022). Achieving high levels of customer service and economic performance is a primary objective of omnichannel distribution. Key parameters considered in studying this distribution system include transportation and inventory costs, fulfillment operations such as picking and packing, and warehouse capacity (Millstein et al., 2021). Figure 3.4 illustrates a simple omnichannel distribution with a centralized hub that stores all the necessary inventory for the regional hubs.

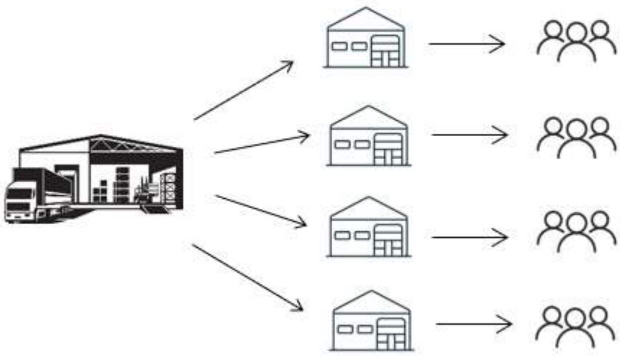

Figure 3.4: Omnichannel warehouse distribution model (Created by authors)

Limited capacity constraints often restrict retailers' ability to stock all products, whereas warehouses, although not constrained by storage capacity, must contend with delivery lead times due to the distance from suppliers. In response to diversifying customer consumption habits, many retailers have adopted multiple sales channels, making the omnichannel model increasingly prevalent (Li et al., 2023). Netessine and Rudi (2003) examine a customer-driven substitution problem within centralized inventory management, emphasizing the effectiveness of operations and expected profit function in the centralized setting.

To accommodate the diverse consumption habits of customers, many retailers have embraced the construction of multiple sales channels, with the omnichannel model rapidly gaining prominence in the market. Inventory management within omnichannel retailing has gathered significant attention from both practitioners and researchers over an extended period (Li et al., 2023). Numerous scholarly works have been dedicated to this topic. For example, Shi et al. (2018) conducted research on optimal ordering policies for omnichannel environments over two different scenarios which had a similar positive effect in better overall efficiencies. However, a crucial aspect often overlooked by researchers is the discussion of warehouse inventory. In many studies, warehouse inventory is assumed to be infinite for a single product. For instance, Gabor et al. (2022) investigated inventory control issues in omnichannel settings involving one warehouse and multiple stores. They devised a heuristic approximation solution by calculating inventory costs for a single warehouse and store while setting appropriate lead times. Nonetheless, their analysis focused solely on a single product and assumed infinite warehouse capacity, neglecting the lead time from suppliers to the warehouse. Another aspect could be the storage capacity of that warehouse. In practical scenarios, the capacity is limited and can result in backlog orders. Gayon et al. (2016) introduced a combinatorial algorithm to address the challenge of backlog or lost sales for the centralized warehouse.

The existing literature has predominantly focused on inventory control for individual products, assuming stores possess infinite storage capacity, with warehouses primarily tasked with meeting stores' demands. However, numerous real-world scenarios involve stores with limited capacity, necessitating consideration of lead times from warehouses to stores. Miao et al. (2022) addressed the multi-warehouse and multi-store inventory control problem, even though assuming infinite warehouse storage capacity while considering lead times. Subsequently, Li et al. (2023) expanded on this research by proposing some new models for having better channels of flow by encompassing various factors mentioned in Table 3.1. These factors have been important for the real case scenarios for any case company. They emphasized the need for stores to adjust ordering quantities to mitigate backlogs and lost sales, while advocating for warehouses to optimize capacity utilization to prevent shortages, balancing overall price and product volume.

Table 3.1: Research problems stated by Li et al., 2023

Problem	Omnichannel	Multi-products	Limited storage	Out of stock	Warehouse problem	Delivery lead time
	✔	✔	✔	✔	✔	✔

3.1.3 Multichannel Distribution

Multichannel fulfillment entails the strategy of listing and selling products across various channels, aiming to increase accessibility for customers in different regions. Each channel operates independently with its own inventory and management system, though large organisations may interconnect multiple channels across regions to facilitate internal product movement and enhance stock availability (Davenport A., 2023).

Although a long-standing strategy, the multichannel supply chain strategy continues to have significant impacts on contemporary business practices. This integrated approach enables consumers to benefit from synergies within the sales channel system and, when executed effectively, can enhance distribution efficiency. For organisations, customer satisfaction is a must and the focus is on quick responses with shorter lead times (Nawar et al., 2022). Figure 3.5 illustrates the multichannel distribution model where multiple hubs are used to meet the customer demands in corresponding regions.

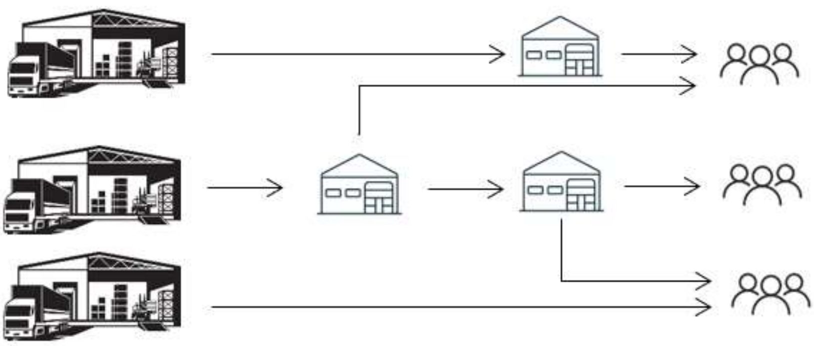

Figure 3.5: Multichannel warehouse distribution model (Created by authors)

The multi-channel approach typically involves the adoption of two or more channels providing a seamless customer experience across these channels. The focus lies on formulating strategies specific to each channel and meeting the respective customer demands on time across diverse channels. It revolves around offering customers a range of choices and expanding the number of channels available for interaction. However, certain channels may be preferred over others depending on customer preferences (Nawar et al., 2022).

3.1.4 Difference between Omnichannel and Multichannel Distribution

Omnichannel represents a fusion of customer satisfaction and internal operational management within a company, with a focus on orchestrating the supply chain to ensure seamless synchronization across all channels to meet customer needs. This transformation necessitates adapting the supply chain into an omnichannel model, ensuring a continuous flow of products across various channels through a unified supply chain approach. Consequently, omnichannel supply chains require robust yet flexible inventory management practices, often involving the establishment of regional distribution centers to supplement a central distribution channel (Nawar et al., 2022).

In contrast, multichannel supply chains offer customers multiple purchasing options, whether in-store or online, with each channel operating independently. This often results in organisational silos, where each channel functions independently on their respective departments, warehouses, and transportation infrastructure, leading to a fragmented approach to serving customers (Nawar et al., 2022).

Omnichannel represents an evolution of the multichannel supply chain paradigm, focusing on serving customers across diverse sales channels. Warehouse management plays a pivotal role in enabling business growth within an omnichannel environment. An omnichannel warehouse serves as a central hub capable of processing orders from various retail locations and channels, necessitating the adoption of advanced warehouse management system (WMS) software to enhance fulfillment capabilities (Nawar et al., 2022).

To maximize the overall supply chain efficiency and simultaneously meet customer expectations, companies must implement intelligent WMS dashboard systems, allowing for the assessment of key performance indicators (KPIs) and informed decision-making. Orders in an omnichannel supply chain originate from multiple platforms, including in-store, online, e-commerce, and customer service-assisted channels. While a single warehouse may struggle to efficiently handle all orders, transitioning all warehouses into an omnichannel system offers a viable solution (Nawar et al., 2022).

Leveraging advanced technology, omnichannel warehouses optimize shipping times, enhance collaboration between stores and e-commerce platforms, improve order accuracy through integration, and expand shipping options such as click-and-collect delivery. Embracing omnichannel warehousing is essential for companies seeking to adapt to the dynamic business landscape and meet evolving customer demands (Nawar et al., 2022).

3.1.5 Omnichannel Model

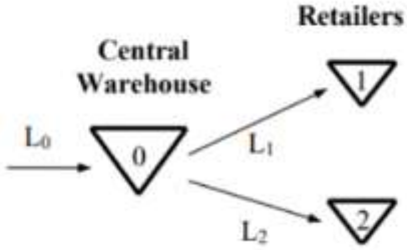

Figure 3.6: Omnichannel setting (Created by authors)

where,

L0 = lead time from supplier to central warehouse 0
L1 = transportation time to retailers 1
L2 = transportation time to retailers 2

Let us consider a multi-echelon distribution setting having a central warehouse and multiple retailers as mentioned in Figure 3.6. The retailers have certain demands from customers and based on that demand, the orders are given to the central warehouse. The central warehouse maintains the inventory by getting shipments from the manufacturing plant or outside suppliers. In the overall supply chain, the inventory decisions at any one location will affect the overall system and therefore it is necessary to continuously monitor the demand flow and the customer order rate.

An optimal solution to solve this problem is using the METRIC approach. It is a mathematical model used to determine base and depot stock levels for a group of items. The main purpose of this system is to optimize the performance of specified levels of system investment and the stock levels, redistribution of items for shipments and evaluating the overall cost of the system.

This approach will describe how this technique is applied including backorders and replenishments. It is appropriate to consider continuous review (S-1, S) policy for both central and regional warehouses. In this policy, as soon as the product is ordered, the same product will be backordered from the supplier. It is highly feasible if the demand volume with respect to lead time is low. Depending on how much demand comes from each regional warehouse, the central warehouse has to continuously look into the stock levels of the inventories. If any orders placed by the regional warehouse are not available with the central warehouse, then the lead time increases depending upon the excess time known as the waiting time taken to refill the stock by the central warehouse. In this case, the central warehouse does not keep stock in its inventory and using a cross-docking setup it will be shipped automatically to the regional warehouse. To optimize the inventory order-up-to-levels, the levels of central and regional warehouses have to be balanced and this will reduce the overall cost. Therefore, to create a balance, it is necessary to determine the upper and lower bounds of inventory levels for both warehouses as it will help to set a range of values that can be handled accordingly (Marklund and Rosling, 2012).

The optimization strategy is quite helpful in finding the optimal inventory levels of both areas. The central warehouse should maintain the stock levels according to the frequency of orders getting from regional warehouses. These have to maintain their stock according to customer demand. The overall system has to be maintained such that the overall cost of the distribution including the transportation costs is minimal.

3.2 Supply Chain Strategy

The concept of supply chain strategy encompasses the decisions made to shape the enduring capabilities and capacity of an organisation's supply chain management, with a focus on achieving strategic objectives. The strategic approach aims to secure a competitive edge through effective management of the supply chain, making it an integral aspect of the overall business plan. It is designed with a foundation of competitiveness in mind, including innovation, cost, quality, or service. (Hugo et al., 2011). It is directly linked to the power position, product strategy, marketing strategy, and consumer needs. In today's business landscape, both for-profit enterprises and non-profit organisations recognize the significance of robust supply chain methods. Non-profits, too, acknowledge the critical role of supply chain strategies in optimizing resource allocation and maintaining a proper flow. The performance of organisations hinges on the seamless alignment between competitive strategies and supply chain strategies (Chopra and Meindl, 2016). A strategic warehouse ensures price stability, prevents interruption to distribution and overall optimizes the supply chain creating a wide range of economic benefits. To increase efficiency and satisfy customer is changing demand, optimizing these all processes is a new wave (Nawar et al., 2022).

According to Simchi et al. (2003), it is essential for a supply chain strategy to align directly with and support the overarching business strategy. A successful business strategy begins with a clear vision and takes into account the various constraints and conditions within which the organisation operates. The effectiveness of a company's strategy for product and market expansion is heavily influenced by its approach to supply chain management. By integrating supply chain, product design, and market strategies, organisations can develop a more comprehensive framework for growth. This integrated approach not only enhances strategic direction but also contributes to advancing the understanding of the role and impact of supply chains and suppliers in driving product and market innovations. According to Sharifi et al. (2013), supply chain management is characterized as the strategic restructuring of processes within the networks of participating firms.

According to Cohen and Russel (2013), a supply chain strategy should be related to competitive and operations strategies. Depending upon the current supply chain, a clear strategy defined as “strategic fit” should be obtained by the organisations. Cohen and Russel (2013) mentioned four types of SCM strategies which are mentioned in Table 3.2.

Table 3.2: SCM strategies (Cohen and Russel, 2013)

Strategy	Advantages	Competitive Basis	SCM Contribution
Innovation	Unique brand or technology	Innovative and highly demanded products	Quick introduction of new products and innovation
Costs	Cost efficient organisation	Low prices in product segment	Efficient, lean SC organisation
Service/ response	Flexibility	Customer orientation	Agile SC is developed from the customer's point of view
Quality	High-quality products	Unique product properties	Quality control along the SC

Fisher (1997) recommends developing a suitable supply chain strategy based on the nature of the demand. Here, the demand for all products coming from end customers is being discussed. The attributes should be analyzed based on the PLC, product margins, forecasting errors, seasonal variations, availability with suppliers and lead times. Chopra and Meindl (2016) further emphasize the importance of considering demand uncertainty and implied demand uncertainty, which pertains to the unpredictability of customer demand and the uncertainty associated with the portion of demand that the supply chain aims to satisfy and attributes to customer sales.

The classification of products falls under two categories: functional or innovative based upon the demand patterns as mentioned by Fisher (1997). Functional products typically exhibit predictable demand and have long life cycles, providing supply chain planners with the advantage of streamlining the flow between supply and demand. Consequently, demand trends for functional products are more foreseeable due to the relatively stable supply and demand distribution. On the other hand, they contribute to low or decent profit margins because the demand is stable with fewer fluctuations so there is not much increase in sales. In contrast, innovative products face uncertain demand patterns and are prone to supply and demand fluctuations. These products often have shorter life cycles as they are designed to cater to evolving consumer preferences. To maintain competitiveness in the market, companies have to launch new products more frequently, presenting supply chain challenges due to unpredictable demand. Despite higher profit margins, managing the balance between supply and demand for innovative products is challenging, necessitating a focus on minimizing market mediation costs such as markdowns or lost sales resulting from supply excesses or shortages. Table 3.3 provides a summarized differentiation between functional and innovative products.

Table 3.3: Factors influencing functional and innovative demand (Fisher, 1997)

Aspects of demand	Functional (Predictable demand)	Innovative (Unpredictable demand)
Product Variety	low	high
Average stock out	1 % - 2 %	10 % - 40%
Average forecast error	10%	40% - 100 %
Product life cycle	more than 2 years	3 months to 1 year

To achieve strategic alignment, it is imperative to delineate roles across different stages of the supply chain and ensure an appropriate level of responsiveness. Developing the necessary capabilities to meet consumer demands necessitates the alignment of various functional strategies with the overarching supply chain strategy. This alignment should encompass all sub-strategies within the supply chain, including those pertaining to design, procurement, manufacturing, inventory management, and retailing. As a result, businesses in various places may operate within their boundaries and guarantee that their functional strategies complement the supply chain, all the while distributing resources equitably among the supply chain's participants to achieve the best outcome (Chopra and Meindl, 2016).

Once the reason behind the demand uncertainty is known, the next question arises on how a company should react and tackle those situations. Depending upon the customer requirements, lead times and supply chain capabilities, a suitable responsive strategy needs to be achieved (Chopra and Meindl, 2016). Once a new product comes into the market, the demand would be unstable until it gets some stability over a period and then the focus should move towards making the overall supply chain efficient by decreasing the cost of production, holding stock and setting suitable lead times.

In the case of functional products, a cost-efficient supply chain strategy is preferred (Chopra and Meindl, 2016). The supply chain is oriented towards being physically efficient since its primary purpose is to meet demand at the lowest possible cost considering stable demand. The primary focus is on reducing physical costs associated with supply chain operations such as production, assembly, and transportation (Fisher, 1997). However, if the customer response is chosen to be primost, then a market-responsive strategy would be appreciated. The demand would be unstable, so high initial investment is needed to have sufficient stocks and reduce lead times to avoid obsoletes in the inventory. This strategy is more aligned with innovative products that have uncertain demand and rely heavily on customer satisfaction. The main objective is to react quickly to changing consumer demand and so it leads to being market-responsive (Fisher, 1997).

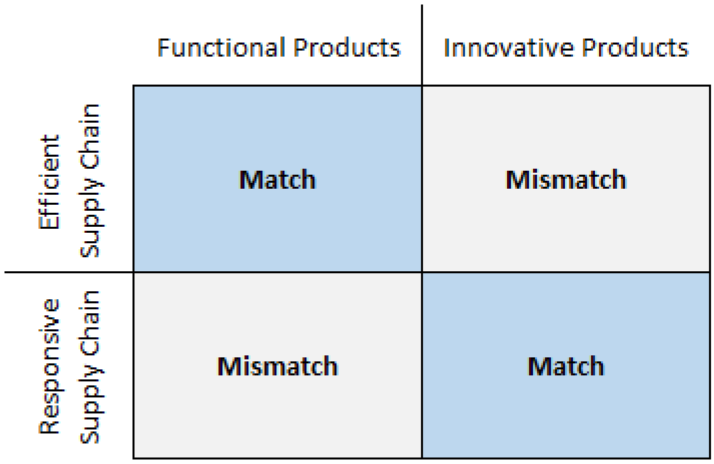

Figure 3.7: Matrix matching product supply chain (Fisher, 1997)

It is important to understand whether the demand pattern complies with the appropriate strategy which is either cost-efficient or market responsive. Using Fisher's (1997) framework, the correlation between product and supply chain strategy is shown in Figure 3.7. However, achieving both implied uncertainty and appropriate response to it is another challenge and requires trade-offs (Chopra and Meindl, 2016).

However, in practice, the execution of strategic changes is fraught with challenges. Many organisations devise divergent competitive and functional strategies, underscoring the critical importance of coordination among stakeholders. Factors such as the product life cycle (PLC), revenue or customer-based segmentation, demand fluctuations, and product diversity must be considered within the supply chain context. Merely adopting a singular strategy or adhering to a particular approach does not guarantee an optimized supply chain (Chopra and Meindl, 2016). Often few customers who contribute to high revenues are treated differently as they value the organisation more. Lead times play a vital role in meeting those demands. Therefore, product and client groups should be segmented and addressed independently based on the amount of uncertainty. By adopting such a nuanced approach, organisations can optimize responsiveness while minimizing resource wastage and associated costs in areas where functionality and efficiency are paramount (Schiro and Rubin, 2023).

3.3 Product Customization

Organisations can adopt tailored strategies based on the demand pattern and current sales of their products. This customization typically involves considering two distinct approaches: the pull and push processes. The selection of the appropriate process depends on product categorization and market demand, aiming to optimize both profit margins and customer satisfaction (Bozarth and Handfield, 2019).

In the pull process, execution commences in response to specific customer orders. So, the customer demand can be measured and is more certain. This approach is closely associated with the make-to-order (MTO) strategy. Conversely, the push process involves initiating execution in anticipation of customer orders. So, customer demand cannot be measured and requires forecasting methods to anticipate the demand. This method is aligned with the make-to-stock (MTS) strategy (Ivanov et al., 2021). Further examination of these strategies is warranted to elucidate their respective intricacies and implications.

3.3.1 Make-to-Order

Make-to-order (MTO) products encompass two distinct types, contingent upon demand variety and variability. Regarding demand variety, MTO products utilize standard components, but their final configuration is tailored to meet specific customer requirements, similar to assembly-to-order processes (Bozarth and Handfield, 2019). This approach not only involves the individual manufacture of final assemblies from standardized modules and components but also allows for additional customization based on customer requests (Ivanov et al., 2021). From a demand variability perspective, MTO is preferred when variability is significant or lead times in relation to demand are comparatively high. This indicates that customer demand for a product is significantly low. Consequently, maintaining inventory stocks becomes impractical for companies due to associated costs that can impact inventory holding costs and high obsolescence (Bozarth and Handfield, 2019).

3.3.2 Make-to-Stock

In contrast, make-to-stock (MTS) products lack customization, representing generic items produced or outsourced in high volumes and maintained in stock to promptly fulfill customer orders. Customers typically acquire these products "off the shelf," whether through in-store purchases or standard online orders (Ivanov et al., 2021). MTS offers advantages such as low unit production costs and optimal capacity utilization owing to economies of scale, coupled with flexibility in meeting demand fluctuations resulting from product standardization (Bozarth and Handfield, 2019). Emphasizing reduced lead times and heightened service levels becomes paramount in MTS strategies to enhance sales and maximize profit margins.

3.4 Inventory Control

A well-defined classification of inventory items based on multiple criteria will streamline operations by ensuring the optimal utilization of resources. Figure 3.8 represents the various commonly maintained inventory stocks. There are two main types of inventories: cycle stock and safety stock (Corbett, 2001). Cycle stock refers to the overall inventory of an organisation that is actively being used to fulfill customer orders and other sales. It is also continuously replenished in bulk or certain quantities as per the demand requirement as the existing products are either sold or used to keep production running smoothly. It is important to maintain an optimal level of cycle stock to prevent stockouts, which can result in the loss of sales or overstocking, which incurs unnecessary additional costs associated with the scrapping of excess inventory. In practical scenarios, the cycle stock will not be uniform as shown in Figure 3.8, it will have minor fluctuations depending on the product demand in the market. Safety stock is another additional inventory that a company should maintain to mitigate the risks of being unable to meet customer demand or experiencing delays in the supply chain (Corbett, 2001). The primary objective of maintaining safety stock is to provide a buffer for any possible uncertainties like fluctuations in demand, supply, production, quality issues and many more. The decision regarding how much safety stock is required depends upon several variables including the reliability of suppliers, safety lead time, seasonal fluctuations, demand patterns and shelf life of products (Bozarth and Handfield, 2019). In addition to these considerations, it is also advisable for companies to review their historical sales and inventory data to determine an average consumption rate.

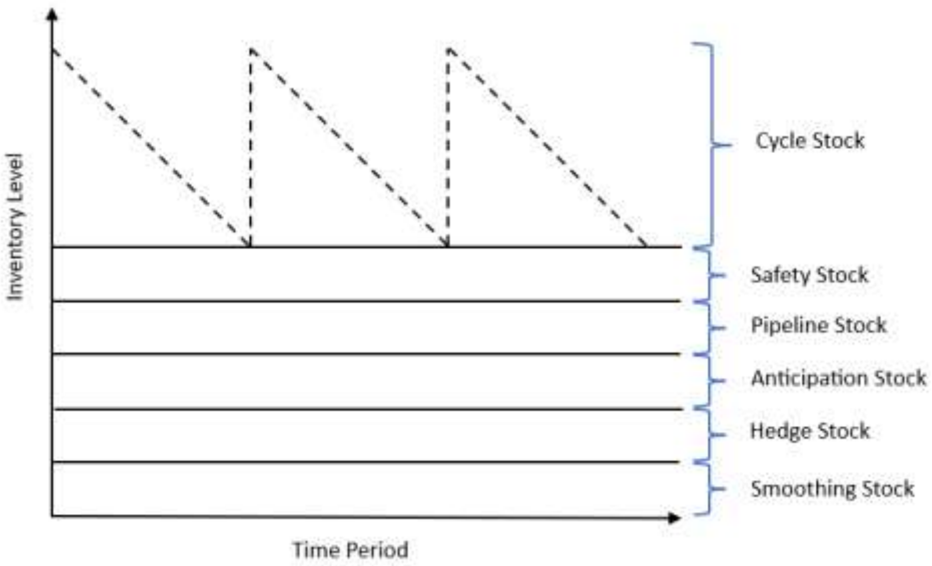

Figure 3.8: Inventory types (Bozarth and Handfield, 2019)

In order to optimize the supply chain inventory of a given product, it is necessary to consider several additional costs. According to Bozarth and Handfield, 2019, the inventory types include pipeline stock, anticipation stock, hedge stock and smoothing stock. Pipeline stock refers to the stocks that are in transit. This includes products that are currently manufactured by the supplier, products that are in the process of being shipped, and products that are ordered from the suppliers but have not yet been received. The maintenance of a pipeline inventory provides a clear visibility of incoming inventory. Anticipated stock is the additional inventory that a company retains to address an anticipated surge in demand for specific products. Such stock is typically maintained during seasonal peaks or in accordance with market trends and events. It can also be beneficial during periods of market price increases or supply shortages. Hedge stock is a buffer against unforeseen events, depending on the company's strategy and policies. Smoothing stock is the necessary inventory required to keep a production continuously running as per the production plan document.

The demand for any product is inherently uncertain, and thus the necessity for these stocks is necessary to address unforeseen situations. The factors that drive a company to hold inventory are known as inventory drivers (Bozarth and Handfield, 2019). Table 3.4 provides an overview of the various ways in which inventory drivers influence the different types of inventories.

Table 3.4: Inventory Drivers and their influence (Bozarth and Handfield, 2019)

Inventory Driver	Influence
Uncertainty in supply or demand	Safety Stock, Hedge inventory
Mismatch between customer demand and the most efficient production or shipment volume	Cycle stock
Mismatch between the customer's demand levels and production capacity	Smoothing inventory
Mismatch in the timing of customer demand and supply chain lead times	Anticipation stock, Pipeline stock

All organisations are subject to uncertainty in supply and demand, hence are obliged to maintain safety stock or hedge stock to satisfy customer demands. The implementation of a quality program or the utilization of a robust forecasting tool can assist in the reduction of these fluctuations (Raghuram et al., 2023). Another factor influencing inventory levels is the discrepancy between demand and production or shipment volumes. While the demand for a product may be for a single use, end customers often maintain a larger stockpile for future purposes (Axsäter, 2006). Similarly, a discrepancy between demand and production capacity may arise due to limitations in production. In such instances, the implementation of a smoothing inventory strategy can be beneficial. Finally, the discrepancy between demand and lead time for seasonal fluctuations in demand or the introduction of new product categories can be mitigated by maintaining a buffer stock or anticipation stock, which will reduce the lead time (Srivastava et al., 2023).

3.4.1 Periodic Review

In a periodic review system, inventory levels are checked at regular intervals, and replenishment orders are made to restore inventory to a predetermined level, denoted as ‘R’. Unlike in the continuous review system, the order quantity ‘Q’ is not fixed in this approach. This quantity helps to bring the inventory back to R as shown in Equation 1. Here, ‘I’ is the inventory level when the system is reviewed (Bozarth and Handfield, 2019; Simchi et al., 2003). For example, inventory levels may be reviewed monthly or weekly, and orders are placed accordingly. Since orders are placed at predetermined intervals, the fixed cost associated with placing an order becomes a sunk cost and can be disregarded (Simchi et al., 2003).

$$Q = R - I \tag{1}$$

3.4.2 Continuous Review

In a continuous review system, inventory levels for an item are continuously monitored and an order is triggered when the inventory level reaches a predetermined reorder point (Bozarth and

Handfield, 2019; Axsäter, 2006; Simchi et al., 2003). This point is determined based on various factors including supply and demand dynamics and the desired level of safety stock. The size of the replenishment order is determined by balancing holding and ordering costs. Specifically, the order quantity Q, remains fixed, resulting in the ordering of nQ units when the reorder point is reached, where n represents the number of batches (Bozarth and Handfield, 2019).

3.4.3 Reorder Point

In addition to determining the optimal order quantity, it is essential to comprehend the optimal time to place an order in the system, taking into account the lead time from the supplier. The most common method to calculate reorder points in the system is given in Equation 2. The demand rate 'd' and the lead time 'L' are considered to be constant (Bozarth and Handfield, 2019).

$$ROP = d \cdot L \tag{2}$$

However, in practice, the demand rate and lead times are rarely fixed. To achieve some balance, it is expected to keep the reorder point somewhat higher to allow for the unpredictability in demand and lead time trends. Therefore, the revised reorder point is calculated using the Equation 3 (Bozarth and Handfield, 2019).

$$ROP = d \cdot L + SS \tag{3}$$

Here, safety stock (SS) represents an additional quantity required to fulfill average demand during lead time. It supplements the reorder point to mitigate the overall variability caused by demand and lead time. Its inclusion extends the window for organisations to initiate orders, providing a buffer against fluctuations. It ensures that future orders will arrive before existing inventory runs out of stock (Bozarth and Handfield, 2019).

In practice, reorder points are subject to variability due to fluctuations in demand and lead times (Schiro and Rubin, 2023). While safety stock serves to mitigate this variability to some extent, it does not imply a static reorder point. Additionally, the concept of reorder points is closely intertwined with Material Requirements Planning (MRP), where material planning typically hinges on anticipated future orders. A detailed description of how MRP can affect the safety stocks and reorder points is given in section 3.4.6.

3.4.4 Economic Order Quantity

To ascertain the optimal quantity (Q) aimed at minimizing the total cost, one commonly employed formula is the Economic Order Quantity (EOQ). This formula, outlined in Equation 4, serves to strike a balance between the expenses associated with ordering replenishments and holding inventory. The model has few assumptions for instance, constant demand, continuous review policy, batch quantities are ordered at once, shortages and safety stocks are not included. Despite its simplicity, the EOQ has found extensive practical applications and continues to be widely utilized (Axsäter, 2006).

$$Q = \sqrt{\frac{2Ad}{h}} \tag{4}$$

where,

A = ordering costs
d = demand per time unit
h = inventory holding costs

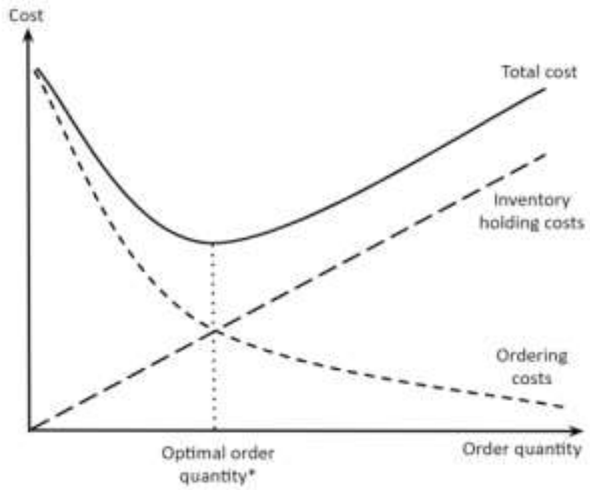

Figure 3.9: Total cost curve (Bozarth and Handfield, 2019)

The EOQ formula is instrumental in optimizing inventory management practices, offering a straightforward yet effective means of determining the most cost-efficient order quantity. Figure 3.9 shows how total annual cost (combining holding and ordering costs) reacts to order quantity values. At the optimal EOQ, it is observed that the overall costs are lowest (Bozarth and Handfield, 2019). The EOQ formula offers several advantages, primarily due to its simplicity and resilience against significant fluctuations in order quantities in terms of costs, as highlighted by Axsäter (2006). Furthermore, its integration into MRP calculations enhances managers' ability to plan their orders effectively.

EOQ also offers some limitations regarding ordering policies and demand variability. Estimating holding and ordering costs can often pose challenges, as they may vary over time and are subject to uncertainty. Additionally, demand rates frequently fluctuate throughout the year, further complicating the determination of the EOQ. Consequently, continuous revisions are often necessary to adapt and fine-tune the EOQ over time, ensuring that it remains aligned with evolving business dynamics and market conditions. This iterative approach allows organisations to optimize their inventory management practices and maintain cost-efficient operations despite the inherent uncertainties (Bozarth and Handfield, 2019). In practical scenarios, it is improbable that the assumption of no backordering remains valid. Typically, there are associated penalties or costs related to backorders, which should be factored to the calculation of optimal order quantity (Axsäter, 2006). Moreover, the assumption of constant costs overlooks the reality of quantity discounts often offered for larger batch orders (Ivanov et al., 2021). These considerations underscore the need for a nuanced approach to inventory management and order quantity determination (Bozarth and Handfield, 2019).

3.4.5 Quantity Discounts

A common practice in pricing policies involves the provision of significant quantity discounts, a tradition deeply entrenched in business operations. Consumers frequently seek such discounts when making bulk purchases from a particular brand (Dolan, 1987). Conversely, firms often extend quantity discounts as a means of price discrimination or to curtail operational costs, whether internal or within the broader system (Munson and Rosenblatt, 2009). Quantity discount arrangements are prevalent and anticipated across various levels of the distribution channel and within industrial markets (Dolan, 1987).

Within the context of EOQ calculations, one of the assumptions is keeping the price per unit fixed. This assumption is convenient for researchers as it facilitates a focused examination on minimizing annual total ordering and holding costs (Bozarth and Handfield, 2019). Certain firms enforce minimum order quantity requirements for any given order, effectively resembling quantity discounts where the undiscounted price approaches infinity. Thus, the majority of quantity discount papers are readily capable of incorporating such requirements (Munson and Rosenblatt, 2009).

When quantity discounts are implemented, our analytical approach necessitates adjustment to consider the total annual costs associated with ordering, holding, and acquiring an item (Bozarth and Handfield, 2019). This adjustment is exemplified in Equation 5.

$$Total\ holding, ordering, and\ item\ costs\ per\ year\ =\ (Q/2)H\ +\ (D/Q)S\ +\ D \cdot P \quad (5)$$

where,

Q = order quantity (EOQ value)
H = holding cost per unit
D = annual demand
S = ordering cost
P = price per unit

It is assumed that before offering any discounts, buyers determine their optimal order size using the EOQ. Dolan (1987) introduced an economic cost framework for sellers, suggesting that when considering the combined costs of buyers and sellers, total system costs can be reduced if buyers order quantities exceeding the EOQ. To incentivize larger order sizes and subsequently decrease seller costs, sellers must provide economic incentives to buyers. One effective approach is to offer significant quantity discounts that reduces costs for both buyers and sellers. Lal and Staelin (1984) proposed a quantity discount pricing strategy aimed at minimizing joint system costs by revising the buyer's optimal order size. Additionally, they outlined a mechanism for sellers to transfer a portion of the cost savings to buyers as desired (Dada and Srikanth, 1987).

3.4.6 Material Requirements Planning

Materials Requirements Planning (MRP) serves as a pivotal stage in production scheduling, wherein the master production schedule transforms into planned orders for requisite parts and components. Employing a dependent demand inventory approach, this process meticulously accounts for inventory items directly linked to the production of other items. MRP is based on three interrelated concepts: the bill of materials, backward scheduling, and the bill of material explosion (Bozarth and Handfield, 2019). By forecasting and considering lead times from suppliers, MRP facilitates efficient planning and control of manufacturing processes, thereby aligning with overarching business strategies and marketplace demands. A streamlined MRP system holds the potential to confer notable competitive advantages within the marketplace (Yeung et al., 1998). The effectiveness of MRP is contingent upon various factors, with forecast errors and safety stock management emerging as significant determinants. They are mentioned below.

1. Impact on Forecast accuracies

Forecast inaccuracies can precipitate inventory shortages, transportation inefficiencies, and disruptions along assembly lines (Yeung et al., 1998). Biggs and Campion (1982) investigated forecast errors and assessed system performance in terms of total stock out amounts, average inventory, purchase orders, and labor needs. The results also had an influence on total costs. Likewise, De Bodt and Wassenhove (1983) conducted simulations to assess different lot sizing methods within a unified MRP system model, analyzing their cost implications.

2. Impact on Safety Stocks

The incorporation of safety stocks and safety lead times presents another challenge in MRP implementation. Serving as a buffer between orders and existing inventory, safety stocks uphold high service levels and mitigate the risk of stockouts. Concurrently, safety lead times ensure the timely arrival of materials for production or warehousing activities (Yeung et al., 1998). While safety stocks play a pivotal role in averting inventory shortfalls, determining the optimal quantity is paramount to circumvent excessive holding costs and rescheduling expenses, as posited by Sridharan and LaForge (1989). Contrasting safety stock and safety lead times, Whybark and Williams (1976) concluded that quantity uncertainty aligns more closely with safety stocks, while time uncertainty favours the adoption of safety lead times to counter demand variability within MRP systems.

3. Impact on other factors

In addition to forecast inaccuracies and safety stock concerns, additional factors such as PLC and lot sizing can have a substantial impact on MRP planning, however they are closely related to the previously described parameters. The length of time a product is present within the supply chain depends on its current and forecasted demand levels. Excessive reliance on forecasts may culminate in surplus inventory, underscoring the imperative of accurately determining lot sizes with suppliers to mitigate excessive ordering costs and ensure timely inventory replenishment (Yeung et al., 1998).

MRP also comes with some of its drawbacks with its implementation on the existing systems with high investment cost and time (Bozarth and Handfield, 2019). Also, MRP is mainly data driven, any missing or inaccurate data will result in affecting its efficiency. This also requires frequent updating and regular monitoring.

3.5 ABC Segmentation

ABC segmentation is a common analytical approach employed by numerous scholars and researchers across a range of disciplines. The classical ABC analysis adheres to the Pareto principle, hence also known as Pareto analysis (Chen et al., 2008). Due to its straightforward implementation and notable efficacy in inventory management, this approach is frequently employed in practice (Douissa and Jabeur, 2016). ABC analysis represents a pivotal methodology employed in the management of inventory, with the principal objective of categorizing items according to their relative importance and value (Alfredsson and Eriksson, 2015). The primary objective of the analysis is to assist businesses in the effective prioritization of their inventory items by determining the most appropriate inventory policy for each category. The classification of criteria can be applied to a variety of parameters, including monetary value, availability of resources, variation in lead time, product value, part criticality, or new product introduction (Chen et al., 2008). The typical ABC segmentation is conducted with a particular emphasis on high-value products, with the objective of optimizing stock levels and reducing costs.

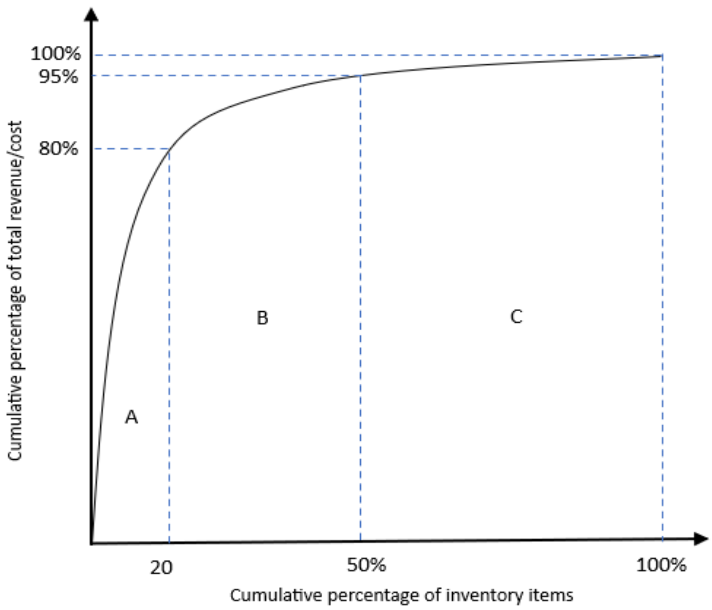

Figure 3.10: ABC analysis (Chen et al., 2008)

Figure 3.10 illustrates the ABC graph, which classify the total inventory into three categories: A, B, and C. Category A is considered as the most important, while category C is the least important. Category A represents the most essential segment and it could be related to cost, product volume or high runners. They represent a very low portion of the total number of products that have high value. The Pareto principle, also known as the 80-20 rule, states that 20% of products contribute to 80% of sales or revenue. Therefore, such products are placed in category A. Category B comprises products with a value higher than C items, but which are less critical than A items. Products which generate 15% revenue are placed in category B. Finally, category C comprises items with minimal value i.e. 5% of revenue is placed in category C (Douissa and Jabeur, 2016). The classification of items into these categories will facilitate the allocation of available resources in a more efficient manner, with a greater focus on the more critical products that offer a satisfactory return on investment. This contrasts with the current approach, which tends to prioritize less critical products. Furthermore, ABC segmentation facilitates the optimization of inventory levels and the reduction of excess stocks or stockouts (Alfredsson and Eriksson, 2015).

Although, ABC analysis has gained popularity and effectiveness from a theoretical perspective, it has proven challenging to apply in practical cases involving multiple criteria and maintaining all the advantages (Shivade and Sapkal, 2024). It primarily provides guidance for inventory management, contingent upon the criteria employed to categorize a product. It is possible that certain items may be categorized as belonging to either category B or category C due to a low demand for the product in question. However, these items may be of critical importance for the production of other items, and therefore decision-making should be approached with great care. Furthermore, it is essential to implement a continuous monitoring process to ensure that the products and their requirements are accurately identified and evaluated. This is because the category of products is subject to change over time.

3.6 ABC-XYZ Segmentation

Another classification used to categorize products is the ABC-XYZ classification, which is similar to the ABC segmentation. The XYZ component of this system is used to classify products according to their stability of demand and the extent of variation in demand (Yaremko et al., 2023). This method represents an effective tool for the analysis of the dynamics of the flow of goods or services, in conjunction with the optimal utilization of all available resources in order to achieve the desired end targets. The periodic implementation of ABC-XYZ analysis is of significant practical relevance in addressing the business supply chain issues that are encountered during daily operations, such as the scarcity of resources, the formulation of procurement and inventory management decisions (Bialas et al., 2020).

In the XYZ analysis, products are classified according to their fluctuations in demand or consumption. Class X represents products with minimal fluctuations, which can be easily forecasted. Class Y products exhibit greater fluctuations, typically resulting from shifts in trend, seasonal variation, or economic fluctuations. Class Z products, in contrast, exhibit highly irregular demand patterns (Scholz-Reiter et al., 2012).

Figure 3.11 represents the ABC-XYZ matrix with nine categories which allows for the categorization of products based on both their value and the variability of demand for the same product. Bialas et al. (2020) mentioned that the primary focus of all companies is generally on products placed in categories AX, AY, BX and BY. The reason is that the value is high and the demand variability is highly predictable with better stability. A well-defined strategy in these categories will benefit the company in terms of product availability and profitability. A secondary focus should be on the products in C which have low value and the Z category, which has high demand fluctuations. These products present significant management challenges, yet companies ignore and provide low importance to this (Stojanović and Regodić, 2017). This can be critical in disrupting the supply chain as an overall. Therefore, organisations should give more attention to these categories as well.

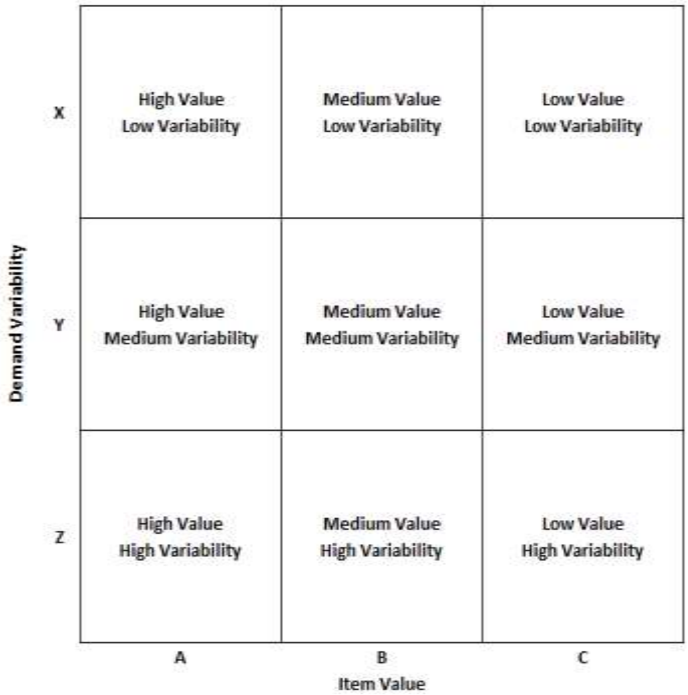

Figure 3.11: ABC-XYZ analysis (Scholz-Reiter et al., 2012)

where,

A = 80% of the total value of items
B = 80-95% of the total value of items
C = 95%-100% of the total value of items
X = CV < 0.5
Y = 0.5 < CV < 1
Z = CV > 1
CV = coefficient of variation

3.7 Categorization of Spare Parts in Supply Chain

In various industries, distinguishing between brands can be challenging, so companies are focusing more on customer satisfaction and loyalty. After-sales services are getting more attention because they help companies meet their goals by providing quick responses and high-quality support. Managing spare parts is crucial for these services, so efficient inventory control is important (Rego and Mesquita, 2015).

Spare parts need to be available at the right places in the supply chain to ensure good after-sales service and maintain the desired service level (Botter and Fortuin, 2000). However, managing spare parts inventory is complex due to factors like the large number of parts, unpredictable demand patterns, risk of parts becoming obsolete and the need for fast response times to avoid customer downtime. Managers have noted the lack of a comprehensive system view in spare parts management, weak supply chain relationships, inaccurate demand forecasts and challenges in maintaining effective inventory turnover (Bacchetti et al., 2016).

Additionally, the frequency of product innovation challenges organisations with managing demand for parts which do not have historical demand.

The organisation's spare parts division is struggling to forecast demand accurately because customer orders are unpredictable. This uncertainty has led to higher inventory costs than expected, as actual levels consistently surpass targets. Despite having more inventory, customer service levels have not improved, resulting in higher costs and poor service quality (Bacchetti et al., 2016).

Research on spare parts demand and inventory management has progressed quickly, with new findings being applied to software solutions due to their practical importance. Despite this, after-sales service and spare parts management for durable consumer products have often been neglected (Bacchetti et al., 2016). As pointed out by Boone et al. (2008), companies face challenges such as lacking a holistic view, weak supply chain relationships and imprecise demand forecasts. Boylan and Syntetos (2007) noted the diverse nature of spare parts for consumer products, which exhibit varying costs, service needs and demand patterns. Thus, categorizing spare parts can help in identifying service requirements across the different classes and making decisions regarding forecasting and stock levels.

A crucial operational concern in spare parts management is the categorization of relevant SKUs to streamline decision-making processes (Bacchetti et al., 2016). This becomes particularly critical when product managers are organizing spare parts within the supply chain. Williams (1984) discussed product categorization in his article, focusing on allocating demand forecasting for each group based on three main factors: mean lead time between demand, demand lumpiness and lead time variation. These factors enable classification of products as smooth, sporadic or slow-moving. Syntetos (2001) and Syntetos et al. (2005) categorized demand patterns into four types: intermittent, slow-moving, erratic, and lumpy. Spare parts exhibit high variability in terms of costs, service requirements and demand patterns (Boylan and Syntetos, 2007). Given the extensive inventory maintained by most manufacturing organisations (Cohen and Agrawal, 2006), categorizing spare parts stock keeping units (SKUs) is essential. This categorization helps determining service requirements for different classes of spare parts and aids in allocating appropriate forecasting methods and stock control policies. To optimize these aspects, categorizing products into smooth, sporadic, or slow-moving categories is required (Bacchetti et al., 2016).

The spare part inventories housed within a central warehouse are instrumental in enhancing service levels and mitigating operational costs. To achieve the targeted service levels and support maintenance or repair operations, the central warehouse must maintain a substantial stock of inventory. Additionally, the capital tied up in inventory increases rapidly, necessitating a focus on reducing inventory costs while maximizing service levels, thus becoming a notable area of study (Li and Kuo, 2008).

Many researchers focus on forecasting models with spare parts that could be helpful to improve the service levels and reduce the inventory levels. However, in practice working in organisations, forecasting for spare parts is still a challenge and requires more attention based on how the spare parts are treated in their supply chain. The conventional approaches to forecast the demand for spare parts includes manager's judgement simply based on their knowledge and experience, analog approach (Applebaum, 1966), time series analysis and regression model (Li and Kuo, 2008). Bacchetti and Saccani (2012) mentioned the gap between research and practice in spare parts forecasting where managers act a lot by adjusting the forecasts manually. Guajardo et al. (2015) studied the inventory management practices for an energy company and mentioned the same about manual forecasting. Although, many organisations are working on making the processes automated in future, the focus is towards selecting appropriate demand models and inventory control parameters. Syntetos et al. (2009) took the case study of consumer electronics manufacturers and used ABC classification based on demand value. Later, they used differentiated forecasting tools for managing inventory according to the classification. This had a positive effect on their service levels and significantly reduced inventory costs.

3.8 Aspects of Demand

A comprehensive study on demand trend for various products within a supply chain can provide insight into the productivity of an organisation and is a crucial element in the development of an effective supply chain (Fisher, 1997). The demand aspect is studied in a variety of ways, which can influence the decision-making process.

3.8.1 Product Variety

As Fisher (1997) describes, product variety is a crucial element to be considered when constructing the entire supply chain. It enables a company to meet customer needs without the necessity of maintaining an excessive safety stock. Product variety represents a pivotal element of an organisation's product mix strategy, which is contingent upon a multitude of variables, including the number of consumers, competitors, value, market conditions and other factors. The greater the variety of products, the greater the potential to attract customers with diverse preferences. However, this can also have a negative impact on production efficiency and related costs as well as on the management of the supply chain for the product (Christopher and Towill, 2000). Two main lines of inquiry emerge from the literature on product variety. The first examines how product variety strategies are used to improve sales, market share and customer satisfaction. The second focuses on the operational complexities when a new product has been introduced (Sweeney et al., 2022).

3.8.2 Volume

The total demand and the region of demand for a particular product allow the organisation to tailor their strategy according to the targeted market which in turn determines the strategy to be used in designing the supply chain (Fisher, 1997). The volume of product demand is a key factor in an organisation since the volume determines the necessity for flexibility or the potential to forecast and in segmenting the products (Christopher and Towill, 2000). The total demand for a product namely the volume of product sold, is receiving considerable attention in numerous academic works as this is one of the key criteria for aligning the organisation with its business objectives.

3.8.3 Variability

The variability of a product has a direct impact on the day-to-day activities of an organisation as it is linked with inventory, operational and sales performance (Sweeney et al., 2022). The product variety may occasionally exert a detrimental influence on inventory turnover, yet this effect can be mitigated as demand variability declines. The products are classified as either MTS or MTO with the former being those with a CV below a certain threshold, and the latter being those with a CV above this threshold (Chopra and Meindl, 2016). In order to calculate the CV, it is necessary to consider the mean of the demand 'μ' and the standard deviation 'σ'. The equation for calculating CV is mentioned in Equation 6.

$$CV = \sigma \,/\mu \tag{6}$$

As stated by Scholz-Reiter et al. (2012), a CV of less than 0.52 can be considered low variability. Typically, 20% of the total items will have a CV below 0.52, while the remaining items will exhibit high variability. A graph can be constructed with average demand and demand variability on either axis. Figure 3.12 illustrates the classification system based on the total volume of demand and the fluctuations in demand, where quadrant 1 (Q1) represents low demand and low variability, quadrant 2 (Q2) implies high demand and low variability, quadrant 3 (Q3) indicates high demand and high variability, and quadrant 4 (Q4) shows low demand and high variability (D'Alessandro and Baveja, 2000).

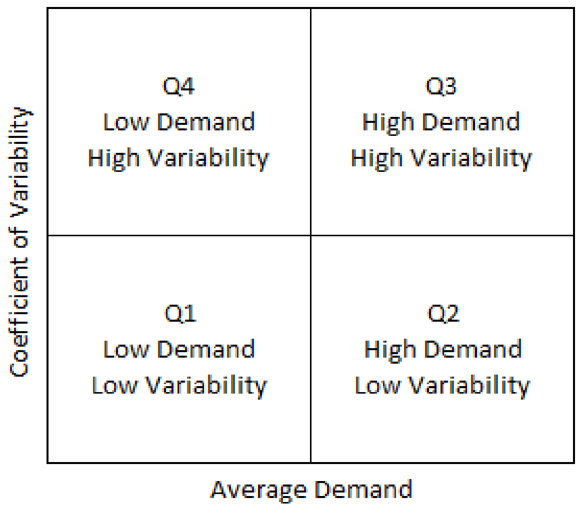

Figure 3.12: Coefficient of variation classification (D'Alessandro and Baveja, 2000)

3.8.4 Product Life Cycle

A framework used to trace the life of a product from its inception to its ultimate disposal. This circumscribes the period during which a product is introduced to consumers in the market and subsequently removed from the inventory. This framework is employed by management and marketing teams to determine factors such as advertising, expansion, price points and redesign (Udokporo et al., 2021).

Mohammadi et al. (2023) propose that the PLC comprises four distinct stages: introduction, growth, maturity and decline. In the introduction stage, the customers are initially exposed to the recently launched product. The investment costs are high in this stage as advertising for brand growth and marketing costs are additional. These costs play a key role in optimizing the product effect and positioning in the market (Sharma, 2013). Organisations can predict how consumers will respond to the product and based on this, design the supply chain for the future of this product. In the growth stage, the product will begin to gain greater popularity, leading to an increase in demand and revenue. At some point, sales will become stable and reach a saturation point, marking the maturity stage. The competition with rival companies will be at its most intense as new and improved products will begin to enter the market (Mohammadi et al., 2023). Finally, the decline stage is reached when demand for the product begins to decline due to the product becoming outdated or a change in market trend. The company must then decide whether to revamp the product, introduce a next-generation model or retire the product (Sharma, 2013). Figure 3.13 illustrates the various stages a product it goes through in its entire life starting from the introduction of the product in the market for consumers to the scrapping of the product.

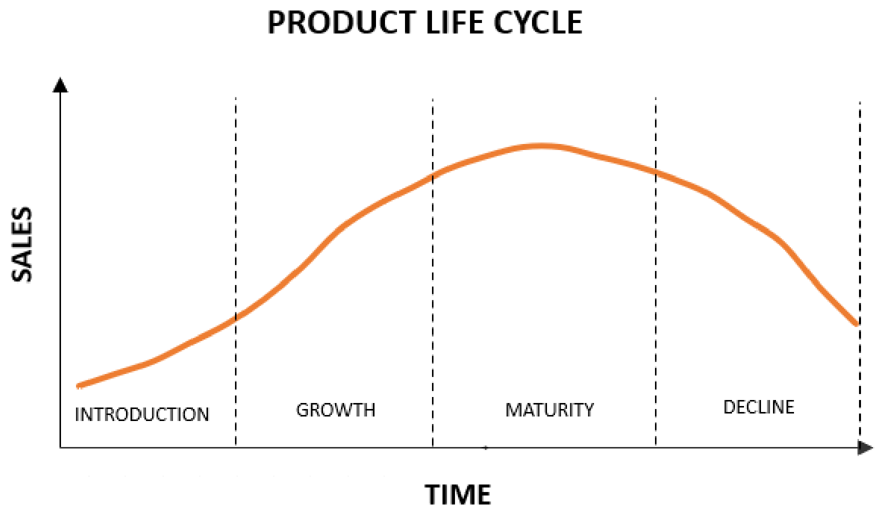

Figure 3.13: General product life cycle (Mohammadi et al., 2023)

By understanding the various stages and their implications, companies can anticipate the market's trends, identify opportunities for innovation and allocate resources effectively, thereby assisting in decision-making about product pricing and promotion (Udokporo et al., 2021). The various stages of a product's life cycle determine the way it should be adapted to the market. A successful product launch should result in a significant increase in demand and popularity, leading to a decline in demand for older products from the market and a reduction in the costs associated with marketing and advertising. A well-defined PLC can serve an organisation in implementing strategic actions, enabling decision-makers to allocate staff, resources and budget to specific areas of innovation (Udokporo et al., 2021).

3.9 Key Performance Indicators

Key Performance Indicators (KPIs) are quantifiable metrics employed by most organisations to monitor progress toward specific business objectives. It serves as a tool for setting up goals, monitoring achievements and identifying areas of improvement from a long-term perspective (Yurtay et al., 2023). As Beer et al. (2022) describe, performance measurements entail a multitude of processes commencing with the collection of requisite data, the analysis of data pertaining to the organisation, its processes, activities and the communication between individuals utilizing measuring instruments which may range from highly standardized, quantitative performance indicators to context-specific qualitative case studies. The establishment of a defined list of KPIs and the subsequent analysis of these continuously provides an overview of the business's performance, thereby assisting the management in making crucial decisions regarding the working nature of current operations or the implementation of a strategy change. The optimal approach is to incorporate each element of the KPI within the framework of SMART criteria (specific, measurable, achievable, relevant and time-bound). The KPIs can be established at the organisational level as well as the individual level, thereby ensuring alignment with the end business goal. It is recommended that individual KPIs focus on the success of organisational KPIs rather than individual performance.

Table 3.5: Represents the various KPIs used in inventory handling

KPI	Reference	Description
Inventory Days of Supply	(Chae, 2009; Yurtay et al., 2023)	The length of time a product is available in a company’s inventory is based on the current sales pattern. A higher value indicates a longer period up to which the demand can be fulfilled.
Inventory Obsolescence	(Shepherd and Günter, 2006; Chae, 2009)	The number of products that have reached the end of their useful life, are no longer in demand by customers, or are no longer fit for purpose. This phenomenon can be attributed to the introduction of similar products, market conditions, consumer expectations, or forecasting errors.
Inventory Stockout rate	(Shepherd and Günter, 2006,Beer et al. (2022)	The inability to deliver products within the agreed time frame due to a lack of available stocks. A high stockout rate is indicative of a lack of capacity within the organisation to meet customer demands.
Average Inventory Value	(Shepherd and Günter, 2006; Yurtay et al., 2023)	The average value or quantity of inventory held by an organisation over a specific period of time. This metric is useful in making decisions about production planning, potential overstocking and stock outs.

Logistics Cost	(Yurtay et al., 2023)	All costs incurred in the physical transportation of goods, from the sourcing of raw materials to the delivery of the finished product to the consumer. The ability to exert control over these costs will result in enhanced profitability and operational efficiency.
Supply Lead Time	(Shepherd and Günter, 2006; Chae, 2009)	The time elapsed between the supplier's receipt of the order and the delivery of the goods to the buyer company. It is of great importance for the company to be able to plan its productions and meet the demands of its customers.
Demand Lead Time	(Beer et al., 2022; Chae, 2009)	The time elapsed between the completion of the manufacturing process and the delivery of the finished product to the customer.
Forecast Accuracy	(Shepherd and Günter, 2006; Chae, 2009)	A measure of the degree of accuracy of a predicted demand forecast in comparison to the actual sales or demand of a product.
Service Level	(Shepherd and Günter, 2006; Yurtay et al., 2023)	The measurement of how an organisation is performing in a certain sector. The proportion of customer orders that can be fulfilled with the available on-hand inventory to align their inventory strategies with customer expectations.
Repair Rate/ Replacement Rate	(Shepherd and Günter, 2006, Yurtay et al., 2023)	The number of post-sale products that are returned for repair or replacement. A low repair or replacement rate is indicative of the longevity and reliability of the product over an extended period.
Purchase Order Cycle Time	(Shepherd and Günter, 2006; Chae, 2009)	The average time taken to process a customer order is defined as the interval between the receipt of a purchase requisition and the release of the order to the supplier, inclusive of all necessary negotiations, approvals, and other related activities.
Shipping Accuracy	(Shepherd and Günter, 2006, Yurtay et al., 2023)	The degree of congruence between the customer orders and the actual delivery of the ordered items. The extent to which a company can fulfill orders correctly, ensuring the delivery of the correct product, in the correct quantity and accordance with other delivery requirements.

As Chae (2009) posits, there exists a significant discrepancy between the planning and execution of planning. The identification of these gaps and the subsequent correction of any potential problems is facilitated by the role of KPIs. An effective inventory management system is of high importance for the success and profitability of any organisation that deals with physical goods. To ensure an optimal inventory level, effective operations and higher customer satisfaction, organisations tend to monitor and analyze KPIs related to the inventory aspects. KPIs furnish the organisation with invaluable insights into pivotal aspects of inventory control, thereby enabling data-driven decision-making to optimize the process and reduce overall costs. Table 3.5 refers to the commonly used KPIs, as derived from a study of various articles and books on the subject.

3.10 Organisational Structure

An organisational structure facilitates the company in organising its personnel, roles and responsibilities in order to achieve its objectives. A well-developed framework defines the reporting relationships and information flows within the organisation (Steiger et al., 2014). The fundamental objective of the structure is to reinforce the organisation's overarching vision and serve as a foundation for the coordination of work, communication of information and the formulation of decisions in order to achieve the ultimate objective (Van Weele, 2014).

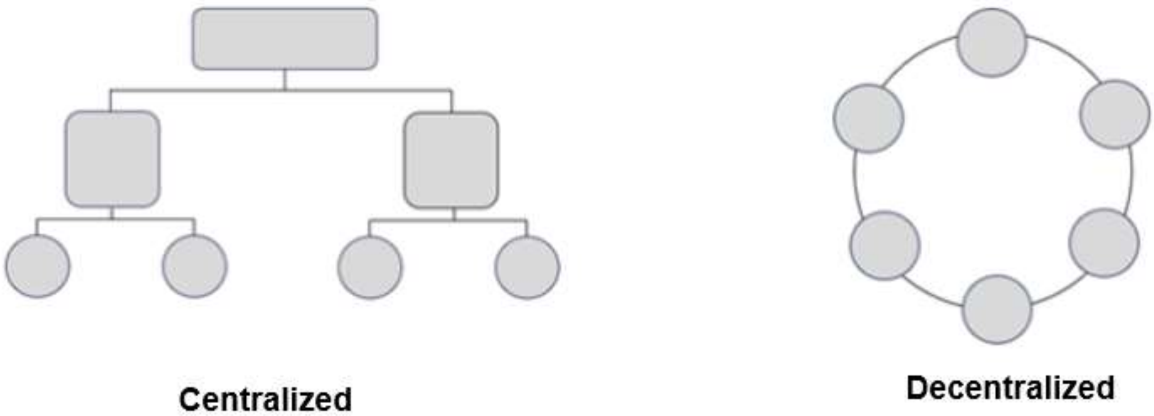

Figure 3.14: Centralized and decentralized organisation structure (Created by authors)

Every organisation will have a different organisation structure depending on their business and the type of materials being handled. Figure 3.14 illustrates a common classification of organisational structure based on the business needs and requirements of centralized and decentralized structures. A centralized organisational structure is defined as a top-down approach, wherein the higher-ranking personnel is accorded greater authority and power than those at the lower echelons of management. The decisions made by the senior executives are conveyed to the lower-level employees, who are then responsible for implementing them. In contrast, the decentralized structure affords managers greater autonomy in decision-making, with collective decision-making becoming the norm rather than a top-level decision. There has been a growing trend towards centralization in supply chain management, driven by the perceived benefits of standardization and the transfer of expertise in knowledge (Van Weele, 2014). Some organisations tend to have a blend of both centralized and decentralized depending on their structure also known as a hybrid structure where some groups are grouped together and decisions are taken collectively enhancing more flexibility and agility (Albert, 2023). This hybrid organisation offers a flexible and balanced approach combining the strengths of both centralized and decentralized.

CHAPTER 4 - EMPIRICAL FINDINGS AT AXIS

This chapter presents the empirical findings regarding the current working processes of the case company. It includes the structure of the supply chain and the management practices of spare parts. Here, the strong focus is on spare parts although the characteristics of the main products help to support the analysis. The information gathered is primarily based on the interviews with the employees at the case company and the observations from the warehouse visit.

4.1 Axis Current Supply Chain Setup

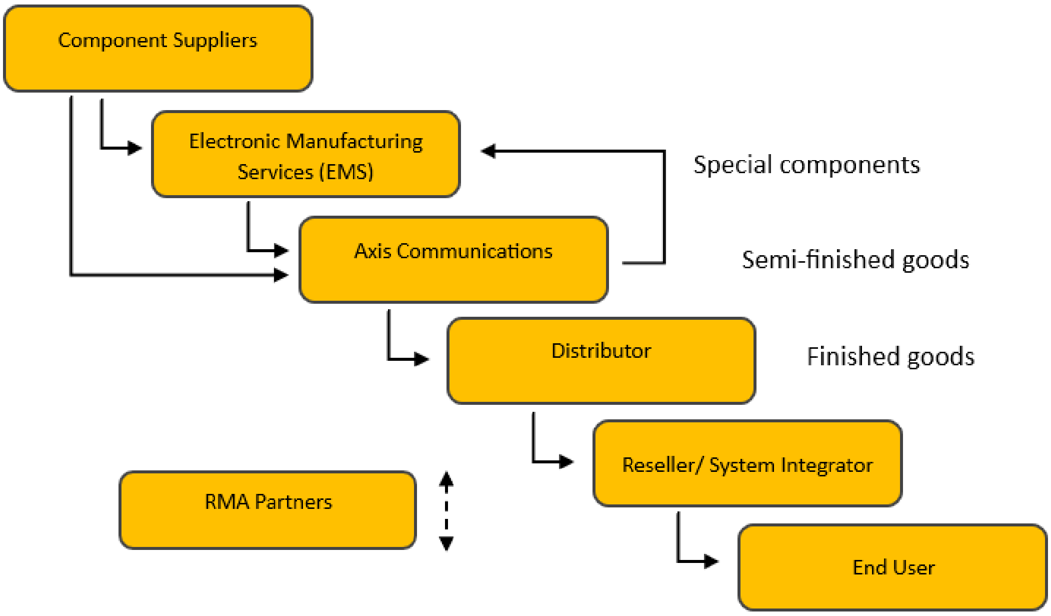

Figure 4.1: Axis global supply chain (Created by authors)

Axis, with its extensive global reach across three distinct regions namely EMEA, Americas and APAC, has an effective and efficient supply chain to ensure the timely delivery of parts to the end customers. It is of equal importance to provide customers with satisfactory after-sales services to enhance customer satisfaction if a product receives any fault. Figure 4.1 describes the global supply chain of Axis Communications. Axis outsources the manufactured products from electronic manufacturing services (EMS). Axis has currently partnered with four EMSs, two of them located in Europe, one in South America and one in Asia. They have many component suppliers who provide raw materials and individual components to EMS as well as some components (accessories and spare parts) directly to the Axis warehouse. Once the products arrive at Axis; quality checks are done to ensure there are no defective products before keeping them in the warehouse. Based upon the forecasted demand, the goods are shipped to distributors to ensure they keep stock of Axis products. The distributors receive these products for selling to customers through resellers or system integrators. The RMA partners take care of after-sales services wherein the issues from the customer end are resolved. Consequently, the supply chain is divided into two distinct categories: forward supply chain (FSC) and reverse supply chain (RSC). Both supply chains are explained in detail in the sections 4.1.1 and 4.1.2 respectively.

4.1.1 Axis Forward Supply Chain

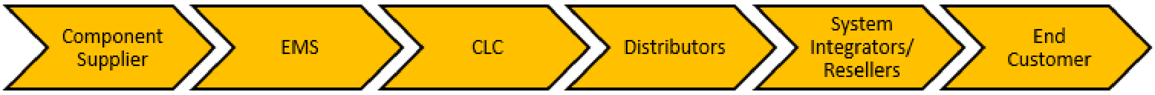

Figure 4.2: Forward supply chain flow at Axis (Created by authors)

The FSC in Axis is a series of interconnected processes, beginning with procurement followed by manufacturing and concluding with distribution to end customers. Figure 4.2 represents the forward supply chain of Axis. The FSC at Axis is built upon trust with its strategic supply chain partners. They act in the decision-making and coordinating entity to ensure the components are received in the desired lead time. They procure all the individual components for their main products from their trusted long-term partners or suppliers. They are responsible for providing components to their manufacturing partners known as EMS. The physical manufacturing of products is entirely outsourced to EMS partners, with Axis not bearing any responsibility for manufacturing with its partners. However, Axis is responsible for the design and the process of manufacturing. Axis determines 90% of suppliers from whom EMS partners are responsible for sourcing the material. There are a few strategic components in which Axis holds stock in-house to secure high availability. In addition to manufacturing, the EMS is also responsible for assembling the individual components to make a product unit (PU). The EMS is distributed globally in accordance with the requirements and market demand for the most effective way of meeting customer needs. The EMS sites are responsible for all aspects of production planning and scheduling for the manufacturing of Axis-specific products and timely delivery to Axis.

The Configuration and Logistics Center (CLC) serves as an intermediary between the EMS sites, strategic suppliers and distributors. The incoming goods from the EMS or suppliers often arrive in bulk quantities and in various packaging formats. The CLC receives these PUs, stores it in its warehouse and then packs again forming a sales unit (SU) which is then sold to the distributor. This configuration is done based on the customer's requirements. The CLC typically maintains two types of inventories: finished goods intended for sale to distributors and components procured from strategic suppliers. In certain instances, Axis incorporates multiple supplementary components alongside the principal component, with the objective of enhancing the product's usability and thereby increasing the value of the main product. One of the primary motivations behind Axis's utilization of a distribution system is to establish long-term relationships and to guarantee that distributors will favour Axis products. The distributors act as stock keepers and have a fixed lead time and service level set for most product categories. A shorter lead time would benefit the distributors by reducing their inventory requirements. It is the responsibility of the distributors to maintain an adequate supply of finished products that are sold to the end customer via resellers or system integrators.

4.1.2 Axis Reverse Supply Chain

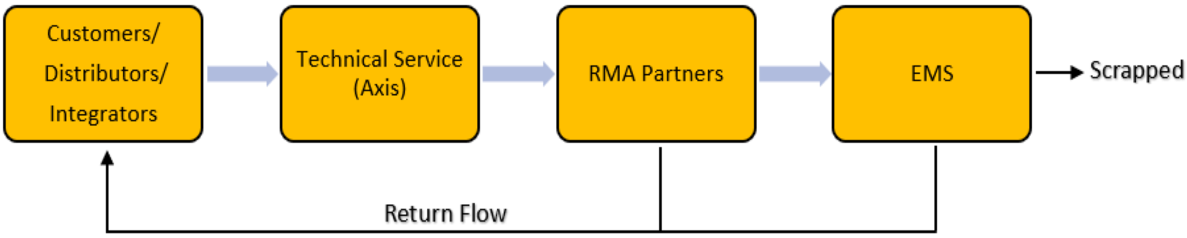

Figure 4.3: Reverse supply chain flow at Axis (Created by authors)

The reverse supply chain represents a crucial aspect of modern business operations, particularly in the context of sustainability, customer satisfaction, and resource optimization. Figure 4.3 represents the reverse supply chain flow where product return flow (damaged or defective products) is observed. Axis also employs a comparable business model with customer satisfaction and operational efficiency as its primary focuses. Similarly to the FSC, the RSC also comprises key strategic partners, also known as return material authorization (RMA) partners, located across the globe. It is notable that not all products are available worldwide. Some items are designed with specific regional requirements in mind, with RMA partners being selected based on their geographical proximity and expertise in the relevant product area. Axis offers five distinct service types. The first is the standard repair procedure, whereby the customer sends the product to the RMA partner. The partner is responsible for repairing the product locally, if possible, and returning it to the customer. Should the repair be deemed unfeasible, the item will be shipped to the original manufacturer for assessment. Depending on the condition of the product, the manufacturer may either attempt to repair it or scrap the product entirely. Second, if the customer requests a replacement for a product that has been damaged, a refurbished product is sent to the customer, who then sends the repaired product once the refurbished unit has been received. Third, when the customer reports that the product is dead on arrival (DOA), a new product is sent out as a replacement. Nevertheless, the right to authorize a DOA can only be exercised within a limited period from the date of purchase of product. Fourth, the company offers peripheral services that do not need the customer to return the product back to Axis for repair. This service is typically provided for a spare part or an accessory where the repair costs are typically higher than the original part cost. Fifth, there are also out-of-warranty services, which are subject to additional charges. These services are provided for repairs that are carried out even though the product is outside the specified warranty period.

In the event of a product malfunction, end customers may contact Axis for repair or replacement via two channels. Firstly, the customer should contact the technical services team who will analyze the condition of the camera based on the information provided. Secondly, the distributor or integrator should contact the technical service on behalf of the end customer. The technical services team will then provide guidance to the customer on the subsequent steps to be taken in order to rectify the issue as soon as possible. In most cases, the responsibility for repairing the damaged component falls upon the RMA partner, provided that the warranty is applicable. Otherwise, the repair can be carried out at an additional cost. If the RMA partner is unable to repair the item, it will be forwarded to the original manufacturer, mostly EMS, who will attempt to repair the item. If the product remains irreparable, it will be recycled or scrapped. The customer will be given a new or refurbished product based on the availability if the product is still in the warranty or out of warranty.

4.2 Spare Parts Flow in Axis Supply Chain

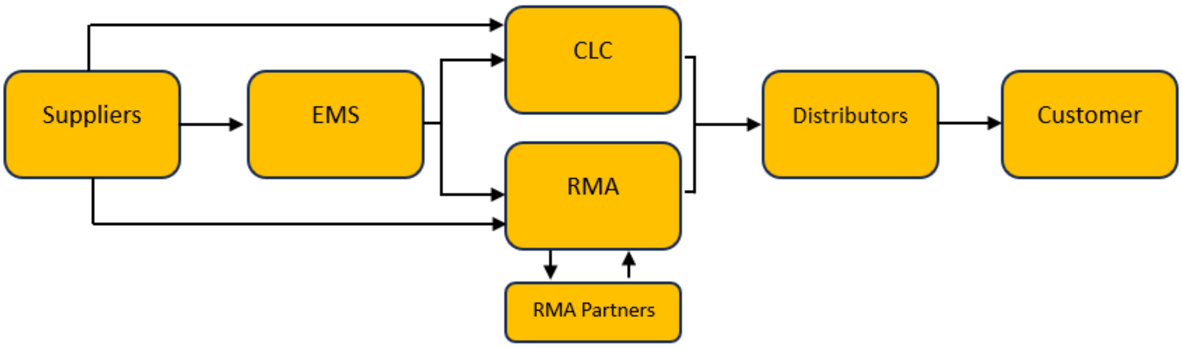

Figure 4.4: Flow of spare parts in Axis supply chain (Created by authors)

The product flow of spare parts is remarkably similar to the normal flow of other products as well. The spare parts are majorly manufactured by the suppliers with most of the spare part having only one supplier and very few parts which are manufactured by the EMS as well. The spare parts from the suppliers are sent to EMS for any manufacturing purposes to form a product unit. Apart from that the suppliers directly ship the spare parts to the CLCs or the RMAs. From a centralized RMA the parts are further distributed to its RMA partners for the repair or replacement requests for respective regions. The CLC sells to the end customers through its distributors for generating revenues and RMA also provides services through the distributors through the technical services to have a positive customer satisfaction. Lateral shipment can occur in rare cases between the CLCs and RMA in case of any shortage of any component. Figure 4.4 shows the flow of spare parts within the Axis supply chain.

Spare parts in Axis are acted as both functional and innovative, depending on the main products to which they are assigned. It is notable that one main product can be assembled with multiple spare parts, provided that the spare part serves its purpose. So, depending upon the customer requests, the final product is assembled and delivered from EMS to the CLC. One spare part can be used in multiple products, which provides flexibility in terms of the number of spare parts required. Moreover, this assembly is primarily conducted in the EMS, which implies that spare parts in the FSC are utilized as accessories for direct sales purposes.

4.2.1 Categorization of Spare Parts in Axis Supply Chain

The Axis supply chain portfolio encompasses a vast array of products. The first category encompasses core products such as cameras, speakers, audio systems and so forth. The second category encompasses all the accessories that enhance the functionality of the aforementioned products, thereby enhancing their value proposition and appeal to customers. The third category, known as spare parts, is utilized primarily for servicing and replacement purposes. Currently, the spare parts are present in both FSC and RSC. In FSC, the aim is to sell and generate additional revenue for specific high-performing products. It usually happens due to demands from distributors as the end customers request them. Though, it is generating revenues, the profit margins are not high compared to other products. Similarly, spare parts present in the RSC inventory look to the service perspective, which includes repairs and replacements. Here, the request of spare parts arises for replacing the defective component or if customers reach out to technical services for direct purchase. So, both supply chains function differently for the same category.

Although, we observed that approximately half of the spare parts in the forward and reverse supply chains are identical, the focus of this thesis project is to examine the spare parts in the FSC and assess their utility. The data pertaining to the spare parts was therefore collected from the demand planning team in the FSC for the purpose of analysis.

4.3 Product Customization

Axis receives a diverse range of products in its inbound flow from both EMS and the suppliers. Most spare parts are sourced directly from suppliers, while a smaller number are procured from EMSs. Some strategic parts are received from the supplier that are significant and are meant to be always kept in stock. Once the company receives PU in the CLCs, they pack and store it to make a SU which are subsequently shipped to the distributors for sale. Some products are packaged and shipped with other components that are necessary for the main product to function effectively in accordance with the customer's specifications. It is also the case that spare parts or accessories are referred to as sales units. In the Axis supply chain, product customization occurs at the end phase, whereby additional accessories are incorporated with the main product to form a new SU. Each principal product is accompanied by a specific set of accessories, and the SUs vary according to the accessories that are incorporated into the principal product. Some SUs are designated as both accessories and spare parts. In the FSC, some of the SU is designated as an accessory, whereas RSC designates the same SU as a spare part. This distinction can be attributed to the differing perspectives of the FSC and RSC. The FSC views the supply chain from the perspective of sales, whereas the RSC considers it from the perspective of service.

The way each SU is treated as a spare part varies depending on whether it is sold as a single part or as a kit. In the case of a kit, specific products are combined to form a single SU, which is then manufactured (i.e. pick, pack and ship) in the CLCs. This can be described as a combination of small parts that are assembled to create a SU of spare part. It is usually based on the request from the distributors and therefore Axis follows MTO policy. Spare parts sold as a single component from the CLCs are typically MTS and purchased from other suppliers. From the suppliers, the spare parts purchased directly follow MTS. This process occurs for all components that have a supplier in EMEA or APAC, as the market share is highest in the America region and demand is consistently high in comparison to other regions. In the case of spare parts, they are typically shipped with the main products and lead times are not a significant issue in this sector.

4.4 Product Life Cycle Perspective

It is important to gain understanding of the PLC of all products currently in the active market. This is essential for the effective planning of an organisation's entire supply chain. Axis maintains an inventory of all spare parts based on a forecast that is calculated primarily based on historical sales data. Figure 4.5 illustrates the PLC for the principal product and its associated spare parts. The graph is drawn in accordance with the interviews, data received from Axis and is inspired by Zhang et al. (2021).

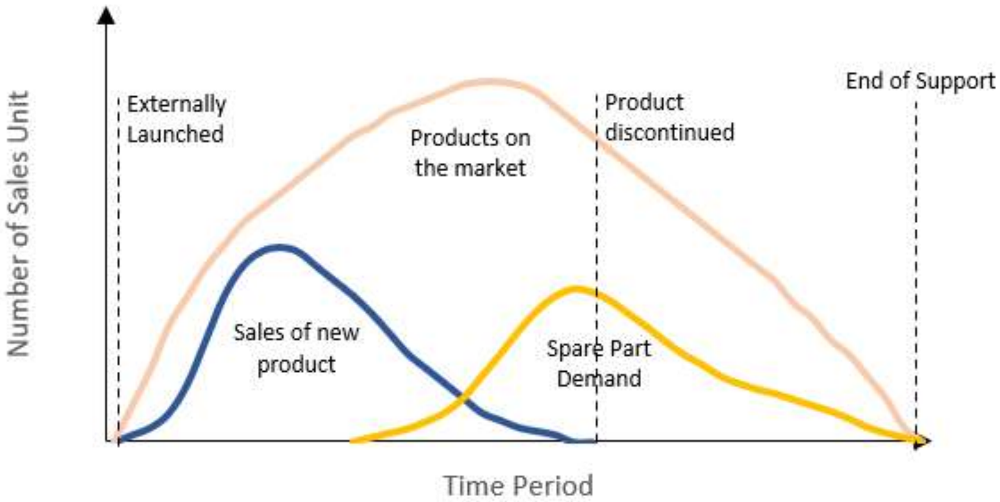

Figure 4.5: PLC of main product and spare parts (Created by authors)

The various product categories exhibit distinct product life cycles. It is challenging to predict the PLC until the products have been launched onto the market and the customers' responses have been observed. Axis categorizes each product into four distinct product life cycles: internally launched, externally launched, product discontinued and end of support. The products are initially launched internally within the organisation, allowing for the planning and procurement of all related accessories and spare parts. This allows the product to be released into the market with the necessary components in place. The subsequent stage is the externally launched phase, during which the products are made available to customers through distributors. The demand for spare parts will be minimal in the initial stages of the product launch, but will subsequently increase over time, typically within a year. The third stage is that of product discontinuation. At this stage, products in stock are sold to customers and manufacturing of the product ceases as demand for the product declines or a new product is launched. Finally, the end-of-support stage, during which Axis will no longer be able to guarantee any support for the product including repairs or spare parts as the product is no longer covered by warranty. Should any components remain available, Axis will provide support to customers on a fee-for-service basis. Upon the discontinuation of a product, the majority of accessories and spare parts in the CLC inventory are transferred to the RMA inventory. This is due to the minimal demand for these accessories, and in the event of any repairs being required, they can be provided until the end of the support period. Upon the discontinuation of a product, the price list for that product will be removed, and distributors will no longer be able to place orders.

4.5 Forecasting

In the FSC, Axis employs a systematic approach to analyzing demand forecasts, which is integrated with the demand planning process of the S&OP framework. The forecasting conducted by the demand planners comprises historical sales and additional customer projects that are expected to materialize in the future. An advanced planning software is utilized that leverages historical data and quantitative techniques for forecasts. Additionally, finance and product managers play a pivotal role in sharing their inputs on upcoming sales in important projects. The final demand forecasts extend over a time horizon of 1.5 to 2 years. However, each month, an overview is conducted on the products to ascertain whether the forecasts require adjustment considering the previous month's sales. Some part of the work is still done manually in making minor adjustments each month with the demand forecasts. In the case of spare parts, the forecast accuracy is low because of high fluctuations in its demand. Moreover, there is a need for further manual work and expertise from the management team, particularly in relation to spare parts, to improve inventory decisions. Furthermore, not all spare parts are forecasted, as most of them exhibit volatile demand and as a reason, the practice of using forecasting software is still not fully successful. Whenever a request is received from a distributor, it is entered manually into the system in the form of documents to generate adjusted statistical forecast. In accordance with the lead time agreed with the suppliers, forecasts are revised until that period and orders are placed accordingly, unless a new major project is in the pipeline, which also requires additional ordering. This approach ensures that minor fluctuations in the forecasts can be self-corrected, but significant changes can affect the overall forecasts' accuracy. Demand forecasts are generated for each of the three regions separately.

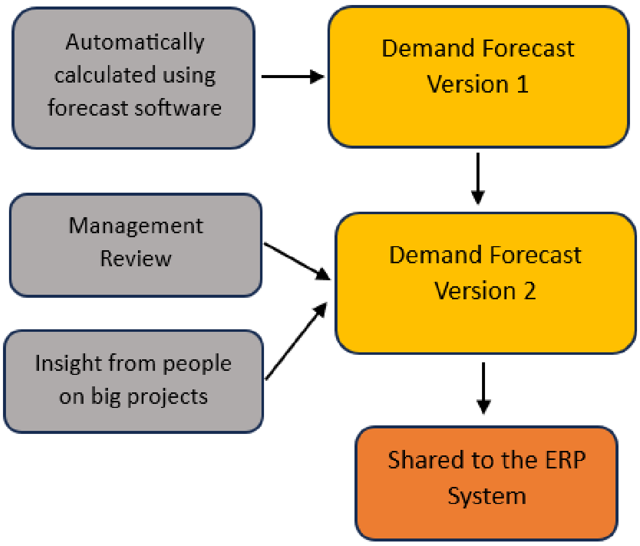

Figure 4.6: Current demand forecasting setup (Created by authors)

The demand planning process at Axis is illustrated in Figure 4.6. Based on historical sales and sales trends in the current market, the forecasting software determines the forecast for the product by implementing a suitable forecasting model. This forecast is then subjected to further review by the management team or the demand planners who are responsible for making minor adjustments manually and for adding additional changes to the software. These include changes in major projects or new projects that are to be implemented. The software recalculates the revised forecast in accordance with the amendments made and generates a final forecast for the product, which is then fed into the ERP system for the ordering of materials in accordance with the forecast.

In the reverse supply chain, there is no demand planning software that creates demand forecasts. Instead, demand planners perform this task manually. In this supply chain, the majority of products are accessories and spare parts. The spare parts available in this supply chain is close to half of the products present in the forward chain. However, they have a multitude of various parts which they have categorized as spare parts and only available in this supply chain. Additionally, they typically maintain a smaller inventory of spare parts, which they do not intend to sell. Instead, they focus on repairs and replacements.

4.6 Inventory Control

Axis has established an inventory policy and structure for its entire product range, which encompasses the main product, accessories and spare parts. However, when viewed from the perspective of individual products, it is evident that there is no distinct plan or strategy in place for the spare parts alone. Moreover, Axis has not devoted significant attention to the spare parts in the FSC, given that the revenue generated from selling the spare parts is relatively low in comparison to the main product. Nevertheless, every inventory within an organisation is of significant importance for the organisation in order to have an efficient and smooth supply chain running. The presence of spare parts in both supply chains results in higher value being generated through sales in the FSC and the provision of services to customers as soon as possible, thereby improving customer satisfaction.

The forecast, which is calculated by the forecasting software, is then fed into the ERP system. This forecast is used by the material planners to place orders with suppliers and EMS. The orders are placed for the MTS products that have been forecast. Figure 4.7 represents the inventory plot parameters used by Axis (Bozarth and Handfield, 2019). They currently maintain two distinct levels of inventory for its spare parts: cycle stock and safety/safety lead time stock. Cycle stocks are those stocks which are replenished in batches into the inventory, based on the type of product. A distinction is made between MTS and MTO orders. MTO orders are those which will eventually be shipped to the distributors within a fleeting period of time. Most of the spare parts are MTS components, and purchase orders are placed for these products whenever the stock level falls below the safety lead time stock. The safety lead time stock is the minimum stock that should be maintained in the inventory for the specified lead time of a particular product to fulfill customer demand. The reorder point is equivalent to the safety stock or safety lead time stock, at which point the ERP system prompts the purchaser to initiate a purchase. Axis does not use any other inventory types because they keep enough safety stock as a backup which is used until the same products are delivered from the supplier. They haven’t explored the other types of stock levels mentioned by Bozarth and Handfield (2019) and consider all of them in the form of safety stock/lead time. It was also observed that most of the spare parts had safety lead time and the reason being low demand in the FSC. Most spare parts are interrelated with the principal products and are launched in conjunction with the principal product. MRP assists in identifying the requisite number of units to be ordered, although it is not linked to the main products. The MRP for spare parts is created separately within the system. In the event of dealing with other suppliers, the minimum order quantities are set by the suppliers.

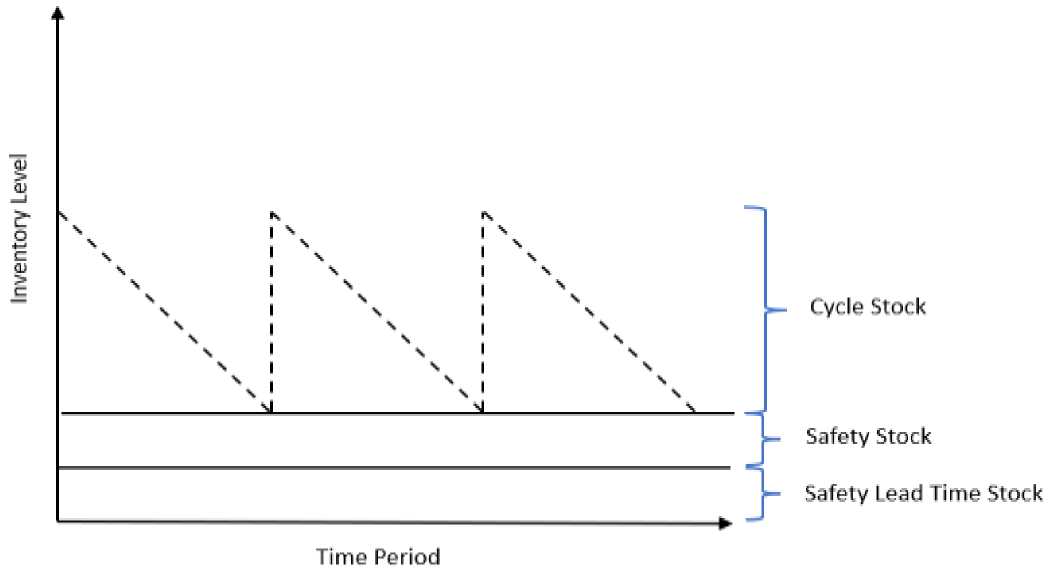

Figure 4.7: Inventory types used by Axis (Created by authors)

In the reverse supply chain, spare parts are retained for the purpose of repairs and replacements. Forecasts of demand are made for both supply chains, and separate inventories are maintained. The ordering process for the RMA is also distinct from that in the CLCs, despite the potential for the same supplier to be involved in both. The most crucial factor identified is the lead time and the quality of the service. Once a purchase has been made, customers are typically granted a warranty period within which they can request free services. During this period, customers may request replacement spare parts. It is the responsibility of the demand planners and purchasers to ensure that sufficient inventories of spare parts are held in stock for all partners.

4.6.1 Volatility and Demand uncertainties

The demand for different product categories exhibits distinct fluctuations. Axis encounters the greatest uncertainty in the demand for spare parts in its supply chain. Spare parts are employed for the repair or maintenance of the principal product. As the probability of the principal product malfunctioning is challenging to ascertain, forecasting the same with any model is a difficult undertaking. Consequently, a significant degree of manual intervention is required in forecasting to ensure the formulation of accurate inventory decisions regarding spare parts. Moreover, in comparison to the sales of the main product, the demand for spare parts is comparatively less significant. In general, fluctuations in demand tend to increase as the volume of sales decreases over time. Following the launch of the principal product in the market, demand for spare parts typically emerges approximately one to two years later. Consequently, distributors maintain minimal or no stock of these spare parts, which are provided to them in accordance with the agreed lead time.

4.6.2 Lead time

Axis offers its customers a lead time of 10 business days to its distributors for most of its products, both high-volume and low-volume items. The lead time variabilities through the Axis supply chain are considerably longer than those towards customers, which constrains the company's ability to offer MTO service. In contrast to the principal products, the demand for spare parts in the FSC is relatively low. This allows Axis to maintain an adequate inventory in the CLCs to a certain degree. The expeditious delivery times offered by Axis to customer's result in the company operating in accordance with the established forecasts.

4.6.3 Volume

The volume of spare parts in both supply chains is relatively low in comparison to regular products. Both the forward and reverse supply chains contain a disparate array of spare parts, with some items being exclusive to one chain or the other. In the category of spare parts present in both supply chains, the volume of spare parts required for repair work in the RSC is less than the actual sales conducted in the FSC. A small proportion of the total spare parts contributes to most sales in the FSC spare part category.

4.7 Service Level

Service levels can be evaluated from two different perspectives, one from the supplier's perspective and another from the customer's perspective. From the perspective of the supplier, the service level is not employed as a performance measurement term and the only parameter set was to oversee whether the necessary product has reached or not. The primary objective is to ensure the timely delivery of materials whenever is required and a check on to meet the requisite quality standards. It is also noteworthy that for most of the products and spare parts, they have a single supplier for each. It is therefore important to acquire positive relationships with suppliers ensuring the delivery of high-quality materials. Nevertheless, they employ other metrics to assess the performance of suppliers, which are closely aligned with the service level parameter.

From the customer perspective, there is a service level set for the main products which are in the market but for the spare parts there is no service levels set because of its high uncertainty in demand and even if a service level is set, it would be difficult to achieve it. Since the FSC does not differentiate between a spare part as well as a main product, depending upon the product categorization, which is explained in the next section, the service levels are set. So, some of the spare parts which are high runners have service levels while others do not. Even though many customer requirements can be fulfilled with on time supply.

4.8 Product Segmentation

Axis employs an ABC segmentation approach in the FSC, in accordance with prevailing theories. All main products, accessories and spare parts are of a uniform nature, regardless of their specific type. Axis has performed a supply chain segmentation for those products which have a fixed price list and are active in the market. The primary factors influencing characterization are revenue, the total demand over a period as well as demand variability.

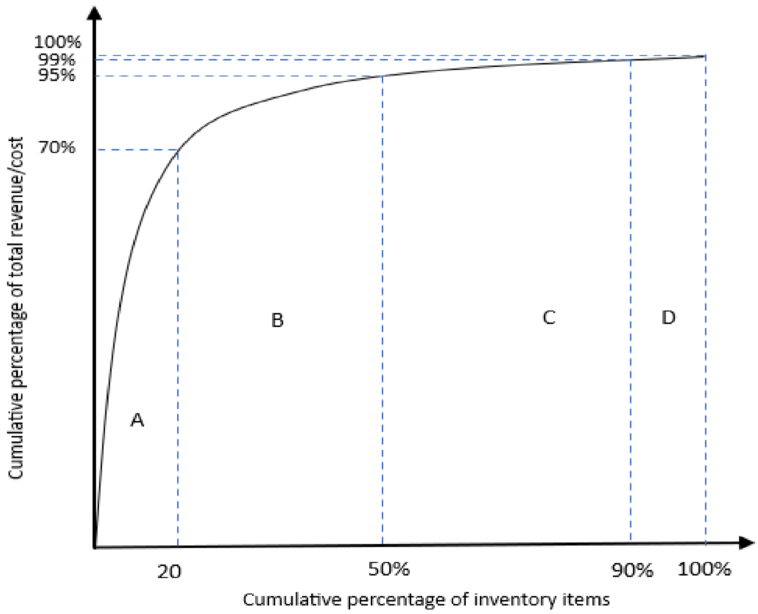

Figure 4.8: ABC analysis (Created by authors)

In the forward supply chain, the ABC segmentation methodology allows Axis to categorize its products according to two parameters: firstly, the revenue generated by the products and secondly, the total demand for the products over a given period. The products have been categorized according to the above parameters, resulting in the following categories: A, B, C and D as shown in Figure 4.8 (Chen et al., 2008). Category A includes products with the highest demand or revenue, while Category D includes those with the lowest demand or revenue. Category E represents products that have not been sold in the last five months as shown in Table 4.1. The introduction of additional categorization categories will facilitate a deeper understanding of the market trends associated with the products in question. This, in turn, will assist in the formulation of more effective ordering and stocking policies. In addition to the ABC categorization mentioned above, recently launched products are categorized as new product introduction (NPI), which requires analysis and determination of their optimal storage location.

Spare parts are generally classified in category D. The reason for classifying these products is that they do not contribute significantly to sales and have an unstable demand, which is relatively low compared to the main product. In addition, not all spare parts are included in this category. The main reason given was that the company has never prioritized the inclusion of all spare parts in the segmentation, as some are used as accessories and not all spare parts generate sales. Further, the analysis has not focused towards utilizing the CLC inventories and identifying high or low runners that could manage inventory levels.

Table 4.1: Percentage of revenue contributing to each segment.

Segment	Revenue/ Sales quantity	Uncertainty State of Revenue/ Sales
A	70%	Stable
B	25%	Mixed
C	4%	Volatile
D	1%	Volatile
E	No sales for last five months	

4.9 Key Performance Indicators

Axis has set various KPIs to measure its progress against the implemented action plan, helping them to identify and improve their supply chain. There are five main KPIs currently in use at Axis, which are aligned with their financial scorecard. Table 4.2 shows the different KPIs used.

Table 4.2: KPIs currently used in Axis supply chain.

KPI	Explanation
Service Level	Percentage of order lines delivered within standard lead time
Delivery Precision	Percentage of order lines delivered on or promised date
Supply Chain Quality	Percentage of order lines delivered correctly
TAT Return	Percentage of RMA units shipped within 7 calendar days
Supply chain cost	Cost per shipped unit in CLC and RMA partners

The service level represents the number of each individual order line that is delivered to the distributors within the agreed standard lead time agreed upon. Since the business model of Axis works on the trust with its partners, service level is a critical KPI to be regularly monitored. Delivery precision is similar to the service level KPI, but this deals with the inbound materials from its suppliers either the strategic components or the final PU. Supply chain quality KPI is to ensure that the right product with the right quantities as per the orders received is being delivered to the customers. TAT return stands for the turnaround time from the reverse supply chain which is essential to have a high customer satisfaction rate which will indirectly affect the brand and demand for all future products. Lastly, the supply chain cost KPI which is the average unit cost of all products per shipment. It is calculated separately for both the forward and reverse supply chains.

The KPIs are further broken down into smaller segments based on the exact needs of each department in the supply chain and each KPIs will have different target levels to be achieved, with some departments already achieving the target already and some lagging behind. There can be many factors that can influence the KPIs from achieving the set target levels and having a continuous review of the KPIs help in identifying the root cause of the problem. The KPIs should be intricately linked so that a comprehensive evaluation of the organisation's operations can be made.

4.10 Organisational Structure

Axis has various departments categorized within its comprehensive supply chain network, each with a distinct set of responsibilities and roles. It is challenging to implement a unified, centralized or decentralized organisational structure within the context of Axis business model. A hybrid organisational structure is therefore a more flexible structure that can adapt constantly to the business needs. The fostering of cross-functional collaboration within a hybrid organisational structure enables teams from diverse backgrounds to work together, thereby facilitating the generation of innovative solutions. Given that Axis has categorized its market segment into three main regions and offers a very wide portfolio of products and services, the decision-making process will vary for each of these products in its corresponding regions. It is of the essential to ensure that the organisational structure is sufficiently flexible to meet the end business goal, given that the requirements and market trends are subject to constant fluctuation.

CHAPTER 5 - GAP ANALYSIS

This chapter includes the gap analysis that is compared to the literature for the case company. The gaps are identified in the current supply chain strategy for spare parts in supply chain. The elements of action research including context and purpose, data collection, data analysis and action planning helped to support the analysis and developing solution proposal for the case company. The segmentation provides insights on both sales and service perspective. The theoretical models applied in this chapter provided a base in finding the solution.

5.1 Categorization of Spare Parts in Supply Chain

The supply chain of spare parts is highly disoriented, especially the way it is looked at by different departments, where it should be placed and how it needs to be handled. The use of spare parts is currently observed in both forward and reverse supply chains. In the FSC, spare parts help in completing a SU i.e. combination with the main product (typically cameras) and are used as accessories for selling it directly through distributors. Axis usually sells these spare parts because they get requests from the distributors and so they get some revenues as well. However, distributors never keep stock of the spare parts due to low demand, but they do keep some stocks for the accessories which puts another question for the authors whether these accessories are the same spare parts. Moreover, Axis keeps the spare parts only in the CLC and wherever the demand arises for spare parts, the distributors will request Axis and it will be shipped to the distributor within the agreed lead time. In the RSC, spare parts are kept for replacements under warranty when they request from technical services. The RMA partners are only allowed to sell those when the warranty period is over for the requested component. Interestingly, not all spare parts are kept with the RMA, only the necessary spare parts listed in the bill of material (BOM) list which is created when the product is launched for the specific main product is kept. Some of the components are called spare parts and accessories causing a confusion in the supply chain, hence a proper categorization is needed to sort which all products fall in spare parts and which comes under accessories.

5.1.1 Difference between Spare Parts and Accessories

In FSC, some of the spare parts and accessories are mostly categorized altogether even though, the purpose and use of both are different. Though the products are categorized as spare parts, they also sell these as an accessory to generate revenue because some of these spare parts have consistent demand from distributors which signifies that Axis does not have issues if they sell these products from CLC this hasn't been a strong focus anytime. However, the same product is called a spare part when it is given as complementary with the main product to make a PU for the customer. The reason to do this is because it becomes easy for customers to replace or add these with the main product.

In the RSC, the difference between the spare part and accessory is unclear. They both have the individual characteristics here but for Axis, this often creates confusion between the two especially with the employees. The reason this confusion has not been stated or looked deeply is because Axis mainly looks towards the part description and part number. They are not highly affected towards handling the inventories separately but instead focus on having enough inventories in stock to service customers.

Therefore, in terms of differentiation, the role of accessories and spare parts should be different. Based on theoretical perspective, the role of both components is different. Even if Axis doesn't investigate it deeply, the overall supply chain is getting complex and this creates more obsolescence because the same category is procured independently within two supply chains.

5.2 Supply Chain Alignment

According to Meindl and Chopra (2016), a company's competitive strategy should be defined in relation to their competitors that sets them apart and gives them a competitive advantage. However, it is also important to look at the factors such as organisational capabilities, costs and customer requirements. The aim should be to provide best services and offer good customer experiences with their product quality. Axis is aligned to these strategies within their supply chain as they value their customers a lot. Axis has a wide portfolio of products but having different strategies for one category for example, spare parts can be challenging to manage the inventories. If the functionality of spare parts is properly defined, then it will have better visibility in the suitable supply chain. Depending upon the product category, the suitable supply chain strategy needs to be achieved. In the case of spare parts, there is no unique strategy which exists although the strategy set for all product categories aligns very well with the business goals. A separate strategy on the spare parts can be more efficient as the demand for the spare parts is generally lumpy and can be tailored according to how the strategy for other components are. Based on the literature studies and the current case situation, the supply chain strategy for spare parts could be established based on the gaps identified, mentioned in section 5.3.

5.3 Supply Chain Strategy of Spare Parts

In this thesis project, the focus is mainly towards developing a suitable strategy on how spare parts should be handled in the supply chain. The aim is to make certain decisions on where they should be located and what will be the effect if the recommendations are followed. Currently, Axis has spare parts in both CLC and RMA, not necessary that all spare parts are present in RMA. Axis is highly flexible on the suggestions offered and they wanted to create this change to optimize and have better control over their spare parts inventory levels. Further, analysis done so far in this thesis will give a correct picture on how the authors have looked to this study.

As presented in the theoretical framework, there have been numerous and varied frameworks of supply chain segmentation proposed since Fisher (1997) asked the question "What is the right supply chain for your product? Different authors have considered different aspects though they all seem to agree that "One size does not fit at all". The problem lies behind how much spare parts should be kept in the CLC and even if done so, do they contribute significant margins on sales? Should Axis focus more on the sales perspective or service perspective? To develop a suitable strategy for spare parts, it is necessary to classify the purpose of each component and where it is of use and the importance of the spare part. In general, it is believed that spare parts are used for after-sales services and they are used for repairing or as a replacement of individual components of the main component which relates to the main product. Therefore, the importance should be driven towards the RMA partners as the customers always tend towards that chain for any support regarding the product. Another reason this is useful is because RMA partners mostly deal with repairs and replacements which are solely connected with small accessories and spare parts.

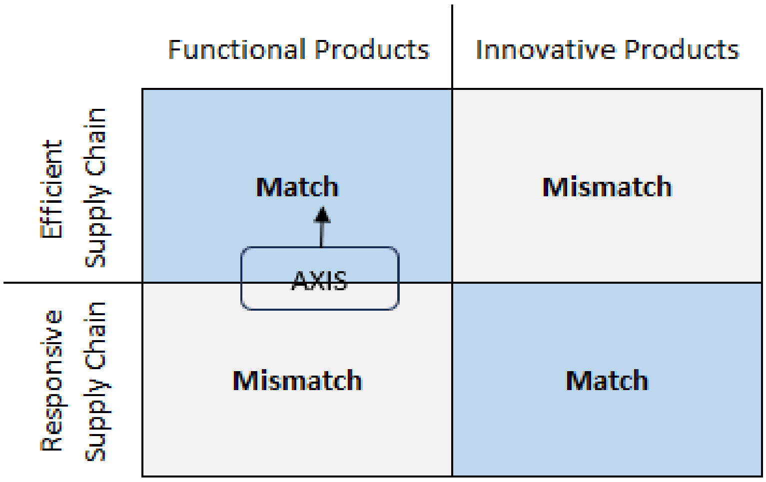

Figure 5.1: Placement of spare parts in Axis supply chain (Fisher, 1997)

At present, Axis does not have a clear strategy for spare parts in the supply chain. From the Fisher (1997) framework, it is observed that most of the spare parts lie in the functional category. However, with new products coming, the corresponding spare parts are also launched. This means that a proper supply chain strategy is required that could enhance the decision-making process. As spare parts in FSC are kept with the aim of generating revenues and demand coming from distributors is making it responsive towards end customers, a suitable match with the supply chain is missing. Based on the interviews and discussions held, Axis wants to shift this approach to develop an efficient supply chain for spare parts which supports our theory and analysis and can be seen in Figure 5.1.

When choosing the right fit supply chain, spare parts can be categorized as functional products because the volume is not huge and demand with respect to lead time is low, which gives Axis more leverage in restocking their inventories in the reverse supply chain. However, some of the spare parts also contribute to high volume and high cost on which Axis capitalizes to generate some extra revenue and does not want to lose these spare parts on providing only services. However, if the product is still under warranty Axis is committed to giving the services for free through the reverse supply chain. For this reason, some spare parts are necessary to keep in both CLC and RMA to have a balance between sales and services. In order to understand this trade-off a segmented action research approach was used and has been mentioned below.

5.3.1 Context and Purpose

During the start of this thesis, the research questions were unclear to the authors because managing the spare parts inventory could be significant in exploring many areas. Furthermore, the potential areas identified were related to spare parts segmentation, forecasting, service levels and inventory levels. Therefore, the first task was to narrow down the scope based on the time available, define a context and purpose on what should be achieved and then work on the areas which were highly important. The data collection mentioned in section 5.3.2 gave certain ideas on focusing these areas.

5.3.2 Data Collection

For gathering the relevant information on spare parts that are available in both CLC and RMA, the two conventional methods were used to explore the current inventories in the supply chain in Axis. As mentioned in Chapter 2, the two types of methods used are qualitative and quantitative data to understand and carry out the necessary analysis to provide a suitable recommendation.

Qualitative data is helpful in understanding how Axis organisation works in general and how the supply chain is aligned with the business goals. The data also helped in identifying how the supply chain is currently designed and the flow of all spare parts in the forward and reverse supply chain. The qualitative data gave us the perspective of how the organisation is structured in different departments in a supply chain. To get the information from the employees relevant to our thesis, we had continuous meetings with our manager to get the list of specialized people that can be contacted for the questions and discussions. The list of people and their designation can be seen in Chapter 2. A semi-structured interview was chosen for the interviewers followed by some questionnaires related to the discussion. Eventually, few of the responses gathered were conflicting since some interviewers had different opinions on the same questions asked and so multiple discussion rounds happened with those interviewers to get better understanding and clarify the doubts. The information obtained was scattered but gave us enough information to proceed ahead with the analysis and understanding on how Axis deals with the spare parts in their supply chain. However, in some cases, the responses were not feasible as the interviewers found it difficult to respond to those queries. This let us confirm the information with our manager.

Quantitative data was necessary to ensure that the analysis done by the authors supports the theory and the justifications made in order to help Axis in the decision-making process. First, the list of spare parts was collected from the planners which are currently being handled in the forward supply chain which also contained the historical demand for each spare part for the last 6, 12 and 36 months along with the forecast accuracy of all spare parts in each region. Similarly, the list of spare parts in the reverse supply chain was also obtained. However, the demand for spare parts in the last few years was not available collectively for all regions since there are a lot of RMA partners across the globe handling different product categories according to the local market and having a list of everything in one list was not beneficial for Axis. Second, the ERP system helped us in extracting valuable information like safety stock, future forecasts etc. for the spare parts. Although, some information was found to be incorrect and a few data points were also missing. This information was then used in the form of questionnaires and asked to the interviewers. Third, we focused on the supply chain segmentation of Axis products. So, an example of a similar analysis which is currently in process was shared with us which provided an idea on how to proceed with the segmentation of spare parts. Fourth, the price list of spare parts for which Axis sells to its distributors was obtained to conduct our segmentation process. The price list data of spare parts kept in the RMA was insufficient and looked a bit confusing because they were fluctuating in each region while some of the products had no fixed price list.

5.3.3 Assumptions

Historically, spare parts as a product category have not been the primary focus of Axis and therefore the categorization for the product plays a significant role based on how they will act in the supply chain. The assumptions in this thesis were made where the data was insufficient, or the necessary information was not available. Some of these assumptions are mentioned below.

1. The thesis project was mainly focused on handling the spare parts inventory in the CLCs and its importance in the forward supply chain. The spare parts given by the demand planning team were considered. However, there were many spare parts that were inactive or discontinued in the ERP system meaning that those had no future customer orders (i.e. no future demand forecasts). Therefore, the active spare parts in the ERP system were considered for the analysis.
2. The spare parts complete data from the RSC team was not available and the document shared with us only had a few spare parts which were common with the FSC spare parts list. Therefore, it was hard to make any comments on those spare parts and the analysis would not have delivered any feasible results. Therefore, it was not considered.
3. While doing ABC segmentation based on revenue, the price list given in their ERP system was taken into consideration. However, a few of the spare parts had no price list mentioned. We could not gather those, and it was decided to skip those products in the classification. Surprisingly, those products had incredibly low annual demand and their three-year history showed that the demand is quite minimal. Therefore, it did not have much effect on the results.
4. While doing ABC segmentation, the demand for spare parts is considered annually. This gives leverage to consider demand on a yearly basis as the demand volume for most of the components is quite low.
5. During the segmentation, PLC played a vital role in segregating the active spare parts in the FSC. The spare parts that were in the stage internally announced and externally launched were only considered. Products reaching the discontinue stage had no future demand forecasts, so they were excluded from the discussion. Some of the internally announced components had no incoming forecasts, these products were not taken into segmentation but once they begin with a certain demand they need to be added.
6. While calculating revenue for a spare part, the formula used is mentioned in Equation 6. Other factors including the holding costs, shipment costs from supplier and customer etc are not considered. We even tried to investigate the transportation costs but given

the information, it was very difficult to use it in calculating the spare part value in the supply chain. So, it was decided to skip it.

$$Revenue = Price \cdot Demand \tag{6}$$

5.3.4 Data Analysis

The data collected gave several insights on both perspectives i.e. qualitative and quantitative. The quantitative information gave an understanding of the spare parts inventory i.e. their annual demand in both supply chains, no. of quantities kept and the key spare parts that support maximum main products. Initially, the common spare parts inventory in both supply chains was also found out to see if both supply chains had all the spare parts available or not and if not, then those questions were raised. It was observed that nearly 40% of spare parts were overlapping which means many spare parts are not available with RMA and are only kept in CLC as a purpose of selling them. This means that the end purpose of keeping spare parts in both supply chains is not the same. The segmentation of the spare parts was conducted with respect to service perspective based on demand volume and sales perspective based on revenue generated. Detailed spare parts segmentation is explained in section 5.4. In their FSC, the data collected from the ERP system shows that most of the spare parts are MTO and close to 45% of the spare parts in the FSC mentioned in the system are not active which means they are discontinued. Such useless information in the ERP system shows that system cleanup is also required to have better visibility of the products. Further, it was also observed that 13% of products were newly launched products which had no future forecasted demand as they still did not enter the market. These will become active in the near future considering the fact that the associated main product is still in the pilot stage or is soon to be launched.

From a qualitative perspective, the discussions with interviewers gave us a thorough understanding of how the spare parts are treated in the FSC. It was observed that there is a lack of differentiation between spare parts and accessories and Axis usually keeps these components because they have customer demand from their distributors though, it is not high. On a few occasions, it was difficult to look for the responses but in the end the alignment of thought with a couple of discussions was achieved with the interviewers.

Table 5.1 represents the possible scenarios for keeping spare parts in the suitable supply chain. It takes all important aspects into account its advantages and disadvantages that could be either useful or not for Axis. It depends on them, how they want to look forward with spare parts in the supply chain. However, with discussions on generating revenues versus customer satisfaction, Axis mentions that they will prefer to value customer satisfaction more than thinking about sales. With regards to RSC, the use case is focused on providing services and the inventory is managed based on the requests they get from their technical services team. The lead time to service customers is usually 10 business days if the replacement is made. For repairs, it depends on how critical the product is damaged as it also goes for repair and tests.

Table 5.1: Possible cases to keep spare parts in the Axis supply chain

RMA (RSC)	CLC (FSC)	RMA and CLC (Both)
Focus is on providing service more than sales.	Focus is on providing sales more than service.	Focus is on providing sales and service.
Possibility of getting revenue for post-warranty demand requests from end customer.	More revenue can be generated but the warranty claim would be a challenge.	Some revenue can be generated by keeping high value and high demand products in CLC.
Ease in handling the inventory since, the spare part is with RMA for the entire PLC.	RMA must request CLC every time when a repair requirement arises.	Less interdependency since both inventories hold sufficient spare parts.
Customer requests can be resolved in less time. Service levels can be improved.	Lead times remain the same as it will follow a conventional route through distributors. Service levels need to be set accordingly.	Service levels must be set accordingly in both supply chains.
Risk of obsolescence will be reduced.	Risk of obsolescence will be more compared to RMA.	High risk of obsolescence since both keep spare parts.

5.3.5 Action Planning

According to Zhang et al. (2021), spare parts inventory management is always challenging depending on its purpose, PLC, inventory stockouts, service levels and proper forecasting in every industry. The current focus in Axis to deal with spare parts is towards after-sales services where customer satisfaction is important. Therefore, the importance of the reverse supply chain has been looked at as it strongly aligns with the purpose. From the theoretical definition, spare parts are always used as a replacement for the damaged components and the purpose of selling them does not contribute to the revenues and it makes the supply chain more complex which is why the use of omnichannel networks comes into the picture. Section 6.5 deals with the advantage of using omnichannel distribution and how Axis can use this to keep their spare parts in the supply chain.

5.4 Spare Parts Segmentation for Axis

Many aspects can be considered when constructing an appropriate supply chain segmentation framework and the aspects most relevant are dependent on the specific state and necessity of an organisation. Considering the current supply chain structure of Axis for spare parts, two aspects have been considered for analysis i.e. demand for spare parts for the last 12 months and the related unit cost associated with it. Considering the theoretical aspects which are used to segment the inventory and the data available, ABC segmentation was found to be the most suitable framework and an analysis model for spare parts alone was developed with the purpose of helping achieve the right recommended decisions for Axis providing a better clarity on segmenting the products.

The ABC segmentation is done taking two different perspectives for the forward supply chain. First, segmentation from the sales perspective where the revenue obtained from each spare part is analyzed. Revenue for each spare part is calculated by the multiplication of unit cost and the demand for 12 months. The calculation for revenue generated from spare parts was argued by Hu et al. (2018), who stated that many companies classify products into ABC classification based on one single criterion i.e. annual cost of the spare part calculated by multiplying demand volume and unit spare part cost. The unit cost of all spare parts that are currently in the price list is considered where the unit cost represents the cost at which Axis sells to its distributors and no other additional costs are included. Some spare parts have been neglected for the sales perspective analysis because of the non-availability of unit cost even though the product has a future forecast. Second, segmentation from the service perspective is carried out where the demand for the last 12 months has been considered. It strongly focuses on components having a high volume of demand. From the service perspective the factor of cost is not considered and has no influence on how high the unit cost of different spare parts is. The reason for taking both perspectives is to give an overview to Axis on what is important to achieve in order to have spare parts as a different category in the supply chain.

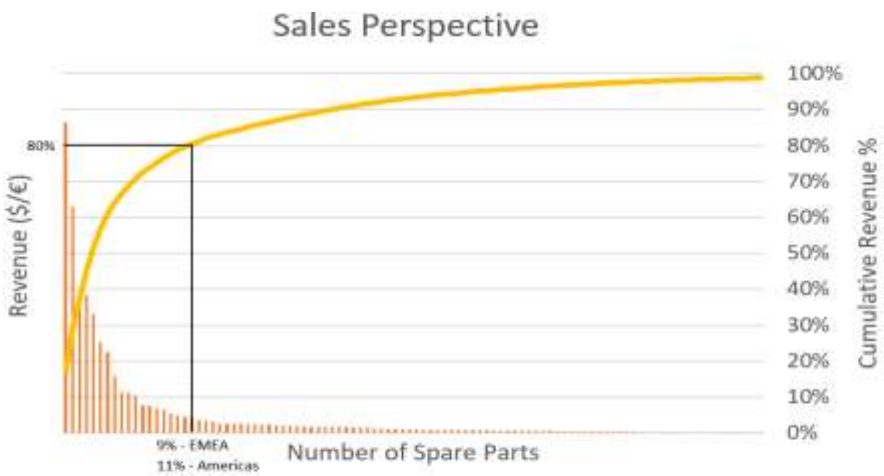

Figure 5.2: ABC segmentation based on sales perspective

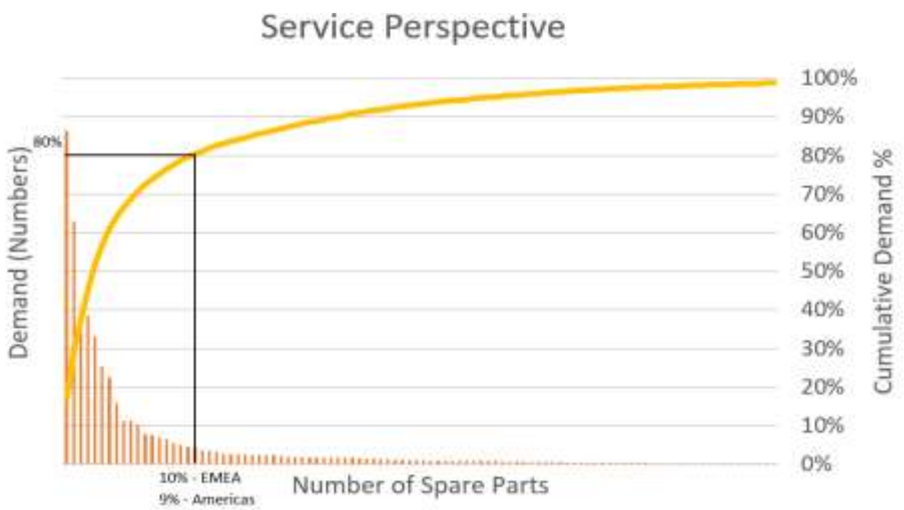

Figure 5.3: ABC segmentation based on service perspective

Figure 5.2 shows graphs for sales and Figure 5.3 represents service perspective with the horizontal axis having a number of spare parts and the vertical axis having revenue and demand volume for sales and service perspective respectively. Hence, different analyses for revenue and demand volume perspectives have been carried out for the EMEA and Americas region. Even though Axis has a market in the APAC region, analysis has not been conducted in that region since the market share in the APAC region is very low and sufficient data was not available. From revenue perspective, the analysis found that 9% of spare part volume for the EMEA region and 11% of spare part volume for the Americas regions contribute to 80% of the total revenue generated. In the case of service perspective, 10% of spare parts for the EMEA region and 9% of spare parts for the Americas region contribute to 80% of the total demand. As Chen et al. (2008) state that Pareto rules are always about 80/20 and considering that aspect of 80% of revenue or demand from both perspectives, it is visible that only 9 - 11% of products contribute to both 80% of revenue and demand generated in the forward supply chain and are segmented in the A category. The contribution of some of the common product categories is listed in Table 5.2. The product category means the number of spare parts that come under the given category. For instance, one dome category might contain different types of domes. Usually, one category has 2-3 spare parts that contribute most to the demand volume and sales, not necessarily same all the time.

Table 5.2: Demand volume contribution of common product categories in both regions

Product Category	**Americas Contribution (%)**	**EMEA Contribution (%)**
Category P	20	8
Category Q	26	30
Category S	12	7
Category T	2	8
Category U	12	5
Total	**72**	**58**

Additionally, from the analysis, some of the product categories had both high demand volume and revenues in their region. This means that those products are high runners and contribute to revenues as well. Further, when looking at both regions, some of the common spare parts categories are also observed and mentioned in Table 5.3.

Table 5.3: Demand and Revenue contribution in both regions for common product categories

Product Category	**Americas**		**EMEA**	
	Demand Contribution (%)	**Revenue Contribution (%)**	**Demand Contribution (%)**	**Revenue Contribution (%)**
Category P	17	24	7	9
Category Q	26	18	30	16
Category R	5	9	3	4
Category S	12	9	7	4
Category T	2	4	8	16
Total	**62**	**64**	**55**	**49**

5.5 Key Performance Indicators

From the literature review, there were many KPIs that were used to monitor the progress and status of all the inventory in an organisation. According to Yurtay et al., (2023), KPI serves as a valuable tool in setting up the organisational goals and identifying areas of improvement from a long-term perspective. Currently, Axis has mainly five key KPIs which help to track the materials and maintain a positive impact on its customers. The KPIs mentioned give an overall perspective of the organisation performing at a higher level to achieve their goals. However, the active KPIs lack detail and can be difficult to identify the root cause of problems. A KPI on stock levels will be beneficial in controlling the amount of inventory held, which can further reduce stock-outs or excess stock. Grouping the stock levels with the present KPI will create more visibility for the purchasers and the ordering process can be smoother. As the product is discontinued or reaches the end of support, most components are to be shifted out of the forward supply chain inventory thereby increasing the scrap percentage of product as only a minimal quantity is being shifted to RMA. Keeping track of how it is scraped can also help in backtracking because excess material has been purchased and kept in stock. There is no proper KPI for forecasting accuracy, as this will help in choosing the right model for spare parts since the demand for spare parts is always lumpy with high uncertainty. Having better in-depth visibility will enable Axis to have a clear picture and scope to improve the supply chain.

CHAPTER 6 – SOLUTION PROPOSAL TO AXIS

This chapter explains the proposed solution and recommendations after conducting the analysis on the case company, based on gaps identified. The implementation process for their current and future supply chains is discussed in detail. It includes suggestions and practical insights that can solve the problem regardless of the barriers and challenges within the flow of products and the reasoning behind the current ways of working.

6.1 Spare Parts in Axis Supply Chain

The primary objective is to develop a proper definition of what a spare part is and its importance in the Axis supply chain which can be followed by the product managers when categorizing between accessories and spare parts. The definition has been created by the authors and mentioned below.

Definition: *"Spare Parts are components used for substituting the damaged part of a given product. The principal objective behind maintaining an inventory of spare parts lies within the after-sales services in a supply chain, wherein end customers seek replacements for irreparable components. The demand for spare parts emerges when the demand for the primary product reaches its maturity phase. Once the main product is discontinued, the demand for spare parts persists".*

Spare parts are highly critical components in the forward and reverse supply chain. It is necessary to have a proper categorization of spare parts in the supply chain by the product management team. Before classifying a component whether it is a spare part or an accessory, it is important to understand its functionality and its use with the main product. The functionality of spare parts relates to the after-sales services, thereby looking for revenues in these does not contribute to the overall sales in comparison to the main product. In addition, the complexity of the supply chain increases, which creates problems with demand forecasting due to the high uncertainty of spare parts. As discussed earlier a lot of manual adjustment is required to adjust the forecast which can affect the accuracy of the forecast which eventually can lead to obsolete inventory or stock outs thereby affecting customer satisfaction and loss of capital.

6.2 Segmentation of Spare Parts

Based on ABC analysis explained in section 5.4, the spare parts in the forward supply chain have been categorized into A, B and C based on the demand volume for the last year. The products with an average demand above 250 units/year in the Americas region and 150 units/year in the EMEA region will be categorized as A category. The average demand for all active products was close to 250 units/year and 150 units/year respectively and this is one of the main reasons to choose and there was a sudden dip in demand pattern observed between all the spare parts. In the Americas region, the components with more than 40 units/year annual demand and less than 250 units/year can be categorized in the B category and the remaining in the C category. Similarly, in the EMEA region, the components with more than 20 units/year annual demand and less than 150 units/year can be categorized in the B category and the remaining in the C category. The products which are categorized in category A contribute to close to 80% of the total spare part demand in respective regions. A summarized view of the ABC segmentation has been depicted in Table 6.1.

Table 6.1: ABC segmentation based on PLC perspective

Demand in Americas (Units/ Year)	Demand in EMEA (Units/ Year)	Category
More than 250	More than 150	A
In Between 40 and 250	In Between 20 and 150	B
Less than 40	Less than 20	C

Until the spare parts have a demand of over 250 units in a year in the Americas region and more than 150 in the EMEA region, the spare parts will be kept in the FSC inventory i.e., CLC and when it falls below that demand value, it is to be shifted to the reverse supply chain inventory RMA. When the products reach category C, decisions on whether the products are still necessary to be kept in the supply chain are to be taken as it has become the low runner and might have reached the product discontinuation stage. However, these decisions are taken based on the PLC perspective which is mentioned ahead in section 6.4.

6.3 Categorize Spare Parts and Accessories

In the current Axis supply chain, certain products are called accessories as well as spare parts. Based on the ABC segmentation in section 6.2, this confusion can be eliminated by declaring category A as an accessory as they have high demands which can provide additional revenue. These will be maintained in the CLCs. B and C categories will be treated as spare parts and they will continue to be supported through RMA. The BOM list for the main product will contain the components to be maintained in CLCs and RMAs. This process should also look at the PLC perspective that is explained in section 6.4.

In the future, when the new products are launched, the corresponding accessories and spare parts will have to be separated in the supply chain. If a product is categorized as a spare part, it should be moved to RMA and these products will not be shifted to CLCs. CLCs will only have components that are defined as accessories that can be sold through distributors to generate revenue. Figure 6.1 shows the future scenario of the supply chain for new products.

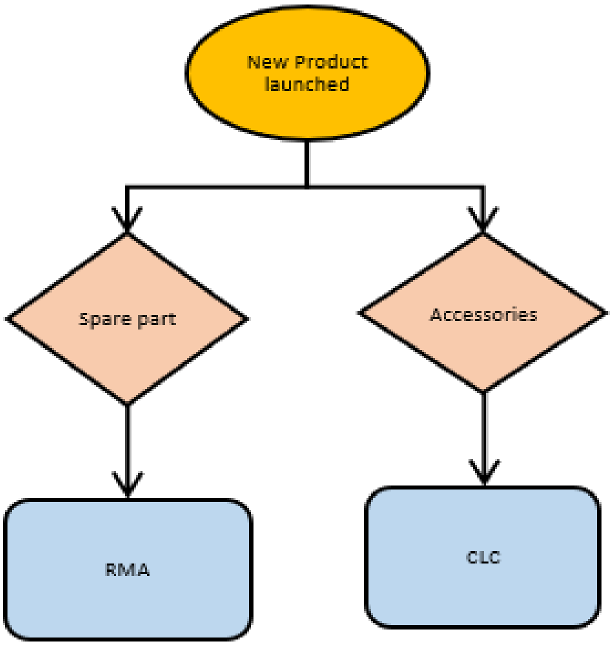

Figure 6.1: Categorization based solution

Axis should also look towards increasing the capacity of the RMA as more spare parts will be moved in their inventory where an omnichannel network can be beneficial in having an effective inventory. An omnichannel approach has been mentioned in section 6.5.

6.4 Product Life Cycle Perspective

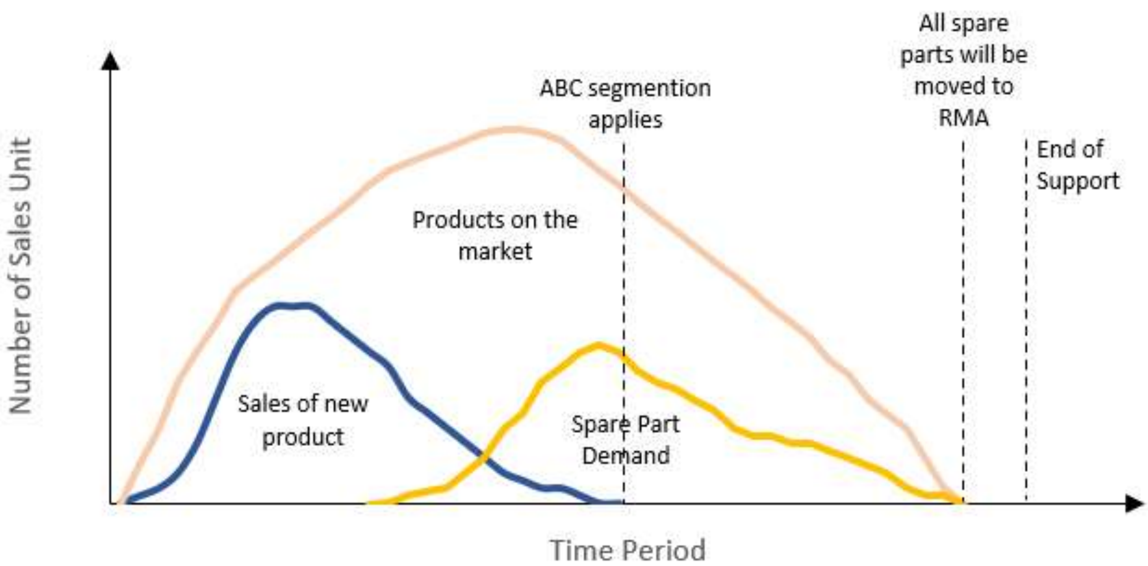

Figure 6.2: PLC of spare parts after proposed solution

It is essential for Axis to see the PLC perspective of the components. Based on the PLC of each component, it is important to understand which component will be in the market for a prolonged period. Spare parts in general stay active for a longer time depending upon the demand requirement and how many products they support. While categorizing the spare parts and accessories, Axis should also observe whether the component will stay for the short or long term. Moreover, additional future customer demand or current demand should not be considered because it will disrupt the overall flow of the system. If spare parts are kept in RMA, it will give better visibility to keep required inventories.

Based on their current supply chain, the spare parts movement based on the PLC of the main product is shown in Figure 6.2. Whenever the main product is discontinued, the ABC segmentation solution is applied, and spare parts are moved accordingly. Some spare parts are associated with several main products and in this case the segmentation solution is only applied when at least one main product is discontinued. After the discontinuation, the main product will no longer be available on the market, nor will the accessories. They will continue to provide support until the end of life, which is equivalent to an RMA. Once all the main products reach the end of the support stage, the spare parts will be moved either to RMA or it will be scrapped. Once all the main products are discontinued, the spare part is discontinued automatically. When the spare part gets discontinued, it shall move to RMA to continue to support until the end of support. An overall picture of how these steps can be followed is mentioned in Figure 6.3. In the future, once the product is categorized as a spare part, they will follow the process shown in Figure 6.1 which signifies that all of them will move to RMA.

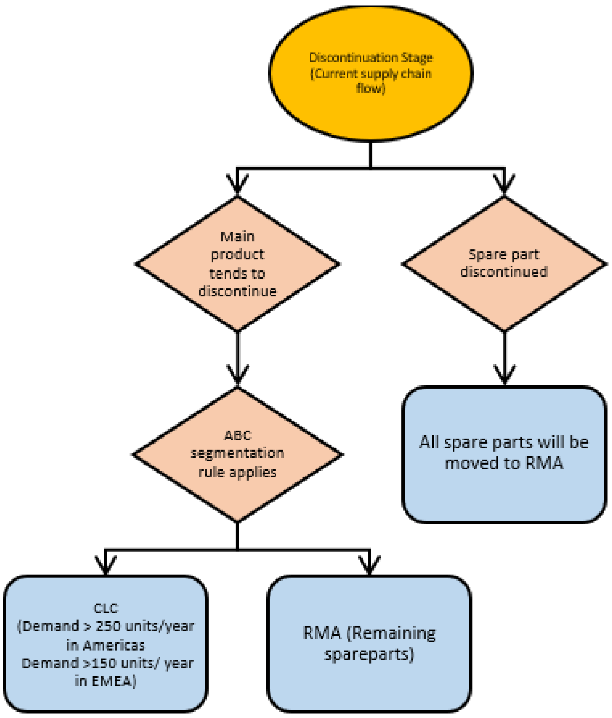

Figure 6.3: PLC based solution

6.5 Use of Omnichannel Network in RMA

Further literature on RSC was studied and the areas were explored that are related to Axis. Based on the information collected, it was realized that the RSC has a lot of scope where spare parts are more valuable to them. As the RMA partners were many, the discussion on multi-channel and omnichannel networks came into the presence. Li et al. (2024) mentioned various advantages of using omnichannel networks and the problems they worked on which is incredibly useful for Axis. From the literature study in section 3.1.2 and discussions carried out in Axis, omnichannel distribution is found to be suitable as it has more advantages than putting spare parts in many regions. Also, the demand is comparatively low for the spare parts and it can be transferred to its other RMA partners whenever the need arises for that specific spare part.

Following the ABC classification, many products are moved to the RMA which increases their stock levels and the total inventory. An implementation of omnichannel network distribution for all the spare parts in RMA will be an effective solution and is expected to be highly feasible in terms of spare part handling. There will be better visibility on stock levels as the low-demand products are grouped together which reduces the excess stocks thereby fewer scrapping products. Currently, Axis has two biggest CLC and RMA co-located, one in EMEA and another in the Americas region even though they maintain a separate inventory for both its supply chains. If all the spare parts were moved to the RSC inventories, it would be highly feasible as there would be better control and visibility of the spare parts inventories. Additionally, from a logistics point of view, the introduction of omnichannel will not be a major problem as the movement of spare parts will be easy as they are located very nearby, but the only limitation will be in implementation and adapting to new process management in the initial phase.

The movement of spare parts in the RSC is highly scattered and therefore the challenge of having separated stocks at various places gives less control in looking for spare parts with different inventories. There are many RMA partners for Axis located in all parts of the globe based on market segment and expertise. Most of the RMA partners are offices which are responsible for handling customers close to their region. But the inventory of spare parts is very less. On some occasions, they must get spare parts from the nearest CLC in order to fulfill customer orders.

6.6 Key Performance Indicators

The current KPI in the forward supply chain can be further broken down into sub-categories to provide greater clarity and identify the root cause of any problems. As observed during our analysis, some spare parts had a high amount of inventory left with no future forecast and no sales in the last few months, so having a KPI like inventory obsolescence or stock-out rate will help to optimize the inventory policy more and reduce in less scrapping of material.

The implementation of the segmentation strategy will push most of the spare parts currently in the forward supply chain into the reverse supply chain. Axis must ensure that similar KPIs used in the forward supply chain are also used in the reverse supply chain. This is because the movement of spare parts in the supply chain may trigger additional stock in the RMA inventory. Additional KPIs may need to be explored for the omnichannel network, where inventory will be common to both supply chains.

CHAPTER 7 - CONCLUSION

This chapter will state the conclusions of the study. Based on the research questions, the overall recommendations have been provided which will then follow with the limitations. Future research will give insights about what areas can be explored further in this study.

The main purpose of this thesis was to study the current status of spare parts in the FSC at Axis and recommend a strategy on how to handle the spare parts effectively by identifying the potential problems, challenges and gaps in their current working process. We studied many relevant literatures that helped us with our thesis to carry out a thorough analysis of the current working process in the forward and reverse supply chain. Conducting a thorough analysis revealed the gaps in the supply chain and a recommendation has been provided to fill the identified gap in the supply chain to enhance the overall efficiency at Axis.

7.1 Research Question

Research question 1: How can a systematic approach for spare parts inventory management be established, considering how it is handled and looking at the demand pattern in their existing supply chain?

Axis has a wide portfolio of products in the supply chain that are currently active in the market with a huge number of customers. The two supply chains in Axis namely forward and reverse are responsible for direct sales that bring revenues and providing services that include repairs and replacements to customers respectively. The range of products includes the main products, accessories and spare parts. In the current scenario, the importance of spare parts in the forward supply chain is unclear and lacks differentiation compared with the accessories. While conducting interviews, there was always confusion between accessories and spare parts. When spare parts are present in the forward supply chain, the intention is to sell them as an accessory to generate revenues. But this is not the case with reverse supply chains as they provide spare parts for free if they are under warranty and if not, then they charge according to the prices set. This means a proper categorization of spare parts for the Axis supply chain is required.

Based on our research, interviews conducted and ABC segmentation performed, a good approach would be to keep the spare parts in the reverse supply chain as they are highly responsible for providing support to customers. The annual demand volume for most of the spare parts was quite low, making the monthly demand patterns intermittent. This means that using forecasting software becomes meaningless because manual interference will come into the picture which increases the workload. It will be easy for Axis to move it in the RMA. However, this does not mean that all the spare parts will be shifted. Given the current spare part lists, the demand in EMEA having more than 150 units/year and in the Americas exceeding 250 units/year should be kept in CLC and can be sold as an accessory while the rest will travel to RMA to offer services. They can be sold according to the price list if the component is directly purchased or out of warranty. Also, it is expected that RMA should have a price list defined for all spare parts. Once these accessories get discontinued, they all will then move to RMA to continue offering services.

Once the new spare parts are launched, they will be kept in RMA throughout the PLC. They will never move in the CLCs. RMA must ensure that they will be responsible for any sales that come from the spare parts as the demand from distributors will be taken care of by them.

Research question 2: How can the proposed solution help with the categorization and strategic planning decisions on spare parts in the existing and future supply chain?

The definition of spare parts for Axis has been mentioned in Chapter 6. This definition will help Axis to understand the use of spare parts and its right location. It will also help them to differentiate between spare parts and accessories when the new component is set to be launched along with the main product. The bill of materials (BOM) of the main product usually defines the corresponding accessories and spare parts. Typically, a PU coming from EMS includes everything. The sales unit made by the manufacturing process in the main CLCs known as pick, pack and ship is usually done when a certain request of demand from distributors is made. Usually, the RMA team is included in these CLCs.

In the data collection process, it was observed that nearly half of the spare parts were inactive in the system i.e. no forecasting demand which requires a system cleanup if necessary. This will ensure to have a proper list of active spare parts which will be taken further for analysis. Strategic planning can be made while doing spare parts segmentation. It will be helpful in making decisions on which spare parts are to be kept in the forward and reverse supply chain. Simultaneously, the PLC and the demand volume should also be taken into consideration.

Based on the existing process of spare parts in the Axis supply chain, the ABC classification was incorporated in two different perspectives i.e. sales and services. The main focus with sales perspective will be to look for products that give high revenues. On the other hand, the service perspective will focus on products that have a high volume. The existing spare parts list has most of the components overlapping in both perspectives. So, no trade-offs come into the picture. However, in practice, service perspective is what Axis should consider in the future to do their analysis in order to increase their customer satisfaction.

In the future, product categorization is necessary to differentiate spare parts and accessories in the supply chain. Spare parts segmentation in the future will be done for the reverse supply chain in order to make sure they focus on selling those using this channel. Another focus should be to work in the ABC-XYZ classification that holds high and low-revenue products so that both revenues and demand volume are taken into consideration. Whilst new projects are coming up in future, this segmentation can be helpful.

Research question 3: With the proposed solution, what are the strategies required to drive a change in improving the spare part inventory decisions in the supply chain?

In their existing supply chain, using ABC classification, the A category will remain in the forward supply chain while the rest will move to the reverse supply chain. Once they are moved to RMA, they will be responsible for those components and taking care of their inventories.

Use of the omnichannel distribution network will be highly useful for handling the spare parts. A good feasible strategy would be to utilize the one big RMA inventory in Europe and one in America since both the supply chain inventory are located nearby. They will be used as the centralized hub to keep all the remaining and new incoming spare parts. This will be helpful in maintaining stock levels at the centralized RMA inventories and will provide high visibility and control over handling the quantities. These centralized hubs will deliver components to their nearby RMA partners. It is one of the useful methods to control excess inventories and make sure that obsolescence can be reduced to a certain extent. The big RMA partners should have enough inventories in stock for all spare parts. Additionally, more planning is needed to set lead times with the nearby partners in the region to supply the products within the time. The other partners need not keep any spare parts. Once the demand comes through the distributor, the order is placed with the nearby partner and then to the corresponding centralized RMA hub. The flow will continue to follow the same path as designed by the reverse supply chain process for replacements.

7.2 Limitations

With the research for this master thesis, we had some limitations which were a hurdle to conduct our analysis which could have validated more of our findings. The list of constraints has been listed down below. Even with these limitations, we successfully managed to do our analysis and a recommended proposal has been given.

1. Another aspect that was observed while taking interviews from the reverse supply chain team was that we could not gather much information on how many spare parts are kept in total with all the partners. The information is disintegrated, and they haven't one good document that holds the related information. We only managed to find information on the available spare parts in big RMA inventories in the Americas region and EMEA region. Still, it was challenging to do any analysis because the data was insufficient. Moreover, this thesis project was also connected with spare parts inventory in the CLC, so it was decided to skip them.
2. We always managed to receive most of the data from the employees who were interviewed during the thesis. For conducting ABC-XYZ classification, we could not manage to get the demand data of individual spare parts for every month, and it was hard to extract. Therefore, we decided to not include the segmentation in our analysis.
3. Time constraints are always challenging when the scope is broad, and the problem statements are unclear to begin with. When it comes to managing spare parts inventory, the question lies in what and how to manage it. It is also more towards what is the exact area of focus. In the first few weeks, the idea was to narrow down the scope of the thesis corresponding with the time limit. Therefore, a few of the areas such as demand forecasting, service levels, and understanding the stock levels cannot be discovered properly. Those are mentioned in the future scope.
4. We gave some time to go through the literature on inventory control policies and how Axis can work on optimizing inventories in the forward supply chain. We did not focus on stock policies such as reorder points, safety stocks and safety lead times.
5. The generalizability of the research is very limited as it was a single case study and a lot of qualitative data has been used. The quantitative data supported us in making decisions but most of the recommendations have been given based on the discussions held in the organisation.

7.3 Future Research

There were some areas of interest where the opportunity to explore more was found in our case study at Axis for the spare parts category. The area includes optimizing the inventory level, service levels and the optimum forecasting methodology. Improvement in these areas will benefit having an even better effective supply chain.

Optimize the inventory decisions.

Some organisations do not focus on inventory control practices. This means having a desired number of quantities in stock. Having high inventory levels increases obsolescence in the supply chain especially if the PLC is not long thereby decreasing the overall sales. Spare parts inventory has always been questioned in the FSC. Therefore, in future, another dimension that needs exploration is how to optimize the inventory decisions based on the demand volume.

Having service levels on spare parts.

As most of the spare parts are purchased from the suppliers, lead time plays an important role in getting the materials to the suppliers. Currently, Axis does not have defined service levels on the spare parts towards the customer end. In their segmentation, the spare parts lie in the last category which does not contribute to sufficient sales. Another dimension in the future should include desired service levels for the spare parts kept in the FSC. With few categories of spare parts, it would be great to set high service levels to ensure enough inventories are available. Based on the demand frequency, this can be allocated accordingly.

Develop forecast models at a component level.

Forecasting at a component level is essential to have good accuracy in the supply chain. Companies, in general, struggle to find appropriate and accurate forecasting models. In the case of spare parts and components with high variability, it is more challenging to get accuracy from the statistical forecasts in the system and this leads to more manual work. As there will be a very limited no. of spare parts in the forward supply chain that might act as an accessory, having a good forecast model is necessary. Therefore, components with appropriate forecast models require more exploration.

Academic perspective.

From an academic point of view, spare parts in the supply chain are a broad topic. Depending upon which industry it is being targeted, the use of spare parts will be completely different for the organisations. The authors during this study took additional time to find the relevant articles and journals.

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APPENDIX

General

What is your role at Axis? And how long have you been with Axis?

What are Axis's business and strategic goals?

Purchasing

How does the purchasing process work and what all are factors considered while placing an order?

How are parameters like EOQ, SS, SLT and MOQ decided for various products?

How many suppliers are available for a specific product?

How many spare parts come from EMS and other suppliers?

Does EMS also manufacture spare parts apart from the main products?

What is the lead time set by the suppliers with both EMS and other suppliers?

What is the ERP system Axis uses currently?

How does the ERP system work with respect to ordering components in the forward supply chain?

Does the ERP system provide any triggers, or does it have a range of time periods set within which the required number of quantities need to be ordered?

Supply chain

In the present scenario, how does the supply chain of forward and reverse supply chain work?

Does the supply chain for spare parts and other products the same or different?

What is the difference between spare parts and accessories in both supply chains?

Do the occasional holidays affect the Axis supply chain in any form? How is the planning done for products before occasions?

Forecasting

Does Axis use any forecasting model? If so, how do you do in both the supply chain?

How does the newly implemented software work? And how does it help in predicting better forecasts?

Do all the spare parts have the same forecasting model or is it different?

How does it affect the forecasting of those products considering there is no historical demand?

How much manual work in forecasting is done for spare parts as compared to other products in the forward supply chain?

How does Axis calculate the demand forecast accuracy for spare parts for all regions?

Does RMA demand planners also have a forecasting tool like the demand planners for CLC?

Distributor

How is the distribution network in the forward and reverse supply chain?

Do distributors keep stocks of spare parts in their inventory? And if yes, then how much inventory? Whether it is MTO or MTS?

Does the distributor get the products from the nearest CLCs or any of the CLCs?

Do distributors get requests for spare parts from customers or system integrators or resellers? How is the overall process?

How does the distributor deal with RMA partners in terms of services offered to customer? Do they sell products from RMA as well and how does that process follow?

How are the lead times set from the customer end i.e. the no. of business days of lead time?

Segmentation

What are the different segmentation processes used currently in Axis? If so, how does it work and is this segmentation applicable to all the products?

Are spare parts also included in those products and where do they lie in the categorisation?

How is the segmentation process of the products in the supply chain? What are the parameters used to do the segmentation of products?

Is the product segmentation done for both forward and reverse supply chains?

KPIs

What are the different KPIs used in Axis?

Are these KPIs enough to measure all the necessary parameters?

Are the KPIs in reverse and forward supply chains the same?

Product life cycle

What are the different stages of PLC and on what basis are the products defined in these stages?

How does the product life cycle work for the products, accessories, and spare parts? What are the stages to consider in the product life cycle?

Service level

How are the services defined in the forward and reverse supply chains?

Does spare parts also have a service level set towards the end customer or distributor? If not, then what could be the reason?

CLC

Does each spare part support multiple main products in the supply chain?

How are the spare parts in the current supply chain looked at? Is it categorized properly?

When the main product is discontinued, are the spare parts kept in the forward supply chain and if yes, for what period?

How does the internal shipment of products work between EMEA and the Americas?

Does Axis face any customer challenges with providing them with spare parts from CLCs?

How many suppliers does Axis have for a spare part? How is the selection of suppliers done for current and new products?

How is inventory control defined for the products in the supply chain? What are all parameters based on the literature diagram Axis follows in the ERP system?

RMA

Does RMA also sell the spare parts, or do they provide them for free to the end customers?

Does RMA also have a price list of the spare parts if they are selling the spare parts once the warranty period is over?

How does the RMA supply chain demand planning work with spare parts and accessories? Do you have any differentiation between the two components?

How does the process of product repairs and replacement work in RMA when the request comes from the technical services?

How is the product demand for spare parts in RMA? Do they have any high runners in their supply chain?

How does RMA plan its product inventory when a new product is launched in the market?

Does RMA also sell spare parts as sales units in their supply chain?

Are all the spare parts in RMA given for free or until the warranty is there with the customer?

Till what time the spare parts are kept in RMA once it is discontinued? How is it connected with the main product?

Technical services

How do the customer requests resolved by the technical services for their products and do spare parts also follow the same pattern?

What will be the first approach of the customer once the spare parts are sold through CLCs?

Who are the technical services highly connected with, RMA or CLC with respect to spare parts?

What is the consumer perspective towards the products and spare parts in terms of selling in CLC and providing services in RMA?

Logistics

How does the transportation in Axis work from EMS/supplier to CLC and from CLC to distributors?

Does Axis have defined incoterms with their transportation and how does it affect the decision-making process?

What are the factors considered for transportation planning from suppliers and the customer end?

How are the truck frequencies in the inbound and outbound CLCs?