Master's Thesis

Inventory management: a high-level analysis of selected process elements, and factors impacting plan performance

A case study at Alfa Laval

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Abstract

Title: Inventory management: a high-level analysis of selected process elements, and factors impacting plan performance - *A case study at Alfa Laval*

Purpose: The purpose of this thesis is to increase the effectiveness of the case company, Alfa Laval's, inventory management by finding challenges, opportunities, and gaps within their current inventory management practices.

Background: An essential part of an organization's planning and control is through inventory management, which helps manage supply and demand uncertainty as well as mismatches in upstream and downstream variables, as small changes in inventory management practices can greatly impact an organization's efficiency and responsiveness. Currently, Alfa Laval, a make-to-order (MTO) company, is implementing a new inventory management initiative, ATHENA, in hopes of reducing the amount of tied up capital. The initiative focuses on creating a global inventory management process, set of inventory planning principles, and key performance indicators (KPIs). However, Alfa Laval wants clarity on whether this is comprehensive enough or if there are gaps in the plan. Therefore, the following topics were analyzed: *Strategic alignment, Inventory management, Classification, Inventory control, Forecasting, Collaboration, Key Performance Indicators, and Organizational structures.*

Method: The research method of this master thesis was a single case study, with a single unit of analysis which was Alfa Laval's inventory management operations. The case study structure allowed a holistic, in-depth analysis of the phenomenon. An abductive research approach was also used as it provided flexibility in the formation and analysis of theories. The data in this thesis is primarily qualitative data from structured and semi-structured interviews.

Findings: This study found that Alfa Laval's ATHENA is a very comprehensive initiative and that the company has an adequate understanding of inventory classification, inventory control, and the usage of KPIs during the follow up stage as well as the need for strategic alignment and finding a balance between centralized and decentralized organizational structures. However, the findings showed that the plan lacks focus on external variables that enable better inventory management. Primarily, forecasting and collaboration. For example, as an MTO company, Alfa Laval should focus on forecasting for components, as these items have an "independent demand" not directly linked to the unit demand. Additionally, in order to reduce the bullwhip effects on the supply chain and therefore inventory management, Alfa Laval should focus on increasing data quality shared with key suppliers and implement a "key customer" pool for interaction.

Keywords: *Inventory Management, Make-to-Order, Forecasting, Collaboration, Strategic Alignment, KPIs, Organizational Structures, Alfa Laval*

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Table of Content

List of Figures

List of Tables

List of Abbreviations

ATO	Assemble-to-Order
BOM	Bill of Materials
BU	Business Unit
CODP	Customer Order Decoupling Point
CPFR	Collaborative Planning Forecasting and Replenishment
CV	Coefficient of Variation
DFG	Days of Finished Goods
EOQ	Economic Order Quantity
ERP	Enterprise Resource Planning
GCC	Global Core Component
GPHE	Gasketed Plate Heat Exchanger
IDS	Inventory Days of Supply
JIT	Just-in-Time
KPI	Key Performance Indicator
LA	Local Assembly
MRP	Material Requirements Planning
MTO	Make-to-Order
MTS	Make-to-Stock
NI	Non-stocked Item
OPP	Order Penetration Point
OWC	Operating Working Capital
ROCE	Return on Capital Employed
ROP	Reorder Point
ROS	Return on Sales
S&OP	Sales and Operations Planning
SCM	Supply Chain Management
SI	Stocked Item
SIP	Sales in Process
SKU	Stock Keeping Unit
TII	Total Inventory Investment
WIP	Work in Process

Chapter 1 - Introduction

This chapter provides the reader with necessary background information on the research area, organization, and problem at hand. The proposed research questions, scope and limitations will also be presented. To conclude, an overview of the material covered in each chapter will be included.

1.1 Background

In recent years, companies have become increasingly focused on properly managing their supply chains. This is largely due to an increased understanding that better supply chain management can have positive impacts on performance. Supply chain management (SCM) is defined by Mentzer et al. (2001) as, “The systematic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purpose of improving the long-term performance of the individual companies and the supply chain as a whole”. One of the biggest challenges related to SCM is trying to adequately balance supply and demand (Jacobs et al., 2011, pp. 88-89). When demand exceeds supply, companies struggle to provide a good service level. When supply surpasses demand, companies end up with overstocked inventories and large amounts of tied up capital. Therefore, inventory management has become a cornerstone ability within SCM and is seen to be essential in gaining a competitive advantage (Axsäter, 2006, p. 1).

According to ASCM (2022), inventory is defined as, “Those stocks or items used to support production (raw materials and work-in-process items), supporting activities (maintenance, repair, and operating supplies) and customer service (finished goods and spare parts)”. Each type of inventory in a supply chain has a different role, with the three most discussed being raw materials, work in process, and finished goods (Meindl & Chopra, 2016, p. 501). Therefore, the purpose of inventory management is to understand the placement and quantity of various types of stock within the company and across the supply chain (Handfield & Bozarth, 2015, p. 28).

In general, inventory management is an essential part of an organization's planning and control, and can assist in managing supply and demand uncertainty as well as stabilizing mismatches between upstream and downstream factors (ASCM, 2022; Handfield & Bozarth, 2015, p. 347-348). Small changes in inventory policies can significantly impact a supply chain's efficiency and responsiveness (Meindl & Chopra, 2016, p. 44-49). As its goal is also to control conflicting objectives and internal capabilities, while maintaining a certain level of customer satisfaction, companies who lack inventory management practices often end up with an excessive amount of inventory. Excess inventory can hide supply chain issues and increase the number of obsolete products. Therefore, there is significant potential for improvement if the implementation of inventory management methods can help reduce stock levels and make cash available for other purposes. This is largely due to the amount of tied up capital that is held in raw material stocks, work in process, and finished goods inventory.

The inventory management policies should be aligned with the company's strategic decisions and inventory held should serve a purpose by helping the organization achieve its goals. For example, a company whose goal is to be responsive to customer needs should naturally hold more inventory than one whose primary focus is on keeping costs low (Fisher, 1997; Meindl & Chopra, 2016, p. 50). Therefore, depending on the organizational goals, the implementation of inventory management practices might look very different, but the methods will still be the same. While there are best practices within inventory management, the implementation and implications has become increasingly complex. This is largely due to increased globalization as it has increased uncertainty and made it difficult to holistically understand the state of an organization's inventory (Gibson et al., 2018, p. 19). In this sense, a focus on good inventory management practices and strategies is needed to optimize, integrate, and monitor supply chains performance.

1.2 Case company

Alfa Laval is the global leader in the areas of heat transfer, separation, and fluid handling and has more than 3,900 patents (Alfa Laval, 2023). Alfa Laval's goal is to improve its customers' productivity and competitiveness in the energy, food and water, and marine industries. The company was founded by Gustav De Laval in 1883, and has its headquarters located in Lund, Sweden. Currently, Alfa Laval employs more than 17,000 people in 100 countries. The organization has 37 production units, 100 service centers, and holds roughly 30% of the global market share.

On an organization level, Alfa Laval is separated into three business divisions, *Marine*, *Food & Water*, and *Energy*. The energy division, which is the focus of this study, is separated into four business units (BUs), *Brazed & Fusion-bonded Heat Exchangers*, *Energy Separation*, *Gasketed Plate Heat Exchangers*, and *Welded Heat Exchangers*. This study is focused on the gasketed plate heat exchanger (GPHE) product group. Within Alfa Laval, each BU operates separately from each other, takes ownership of their goods and materials, and are in charge of their own production planning. Although the BUs do not share goods and materials, they can become internal buyers and suppliers to each other if needed. A similar system is used between each of the factories and regions.

The BU GPHEs global footprint includes three Global Core Component (GCC) factories and eight Local Assembly (LA) factories. Two of the factories are located at Alfa Laval's headquarters in Lund, Sweden, and the other locations for the GPHE factories are in India, China, the USA, Brazil, Japan, Korea, and Russia. The primary focus of the GCC factories is to produce and provide core components (plates and gaskets) to the LA factories. The LA factories are strategically placed to closely serve the market in which they are located. Figure 1.1 exemplifies the organizational structure.

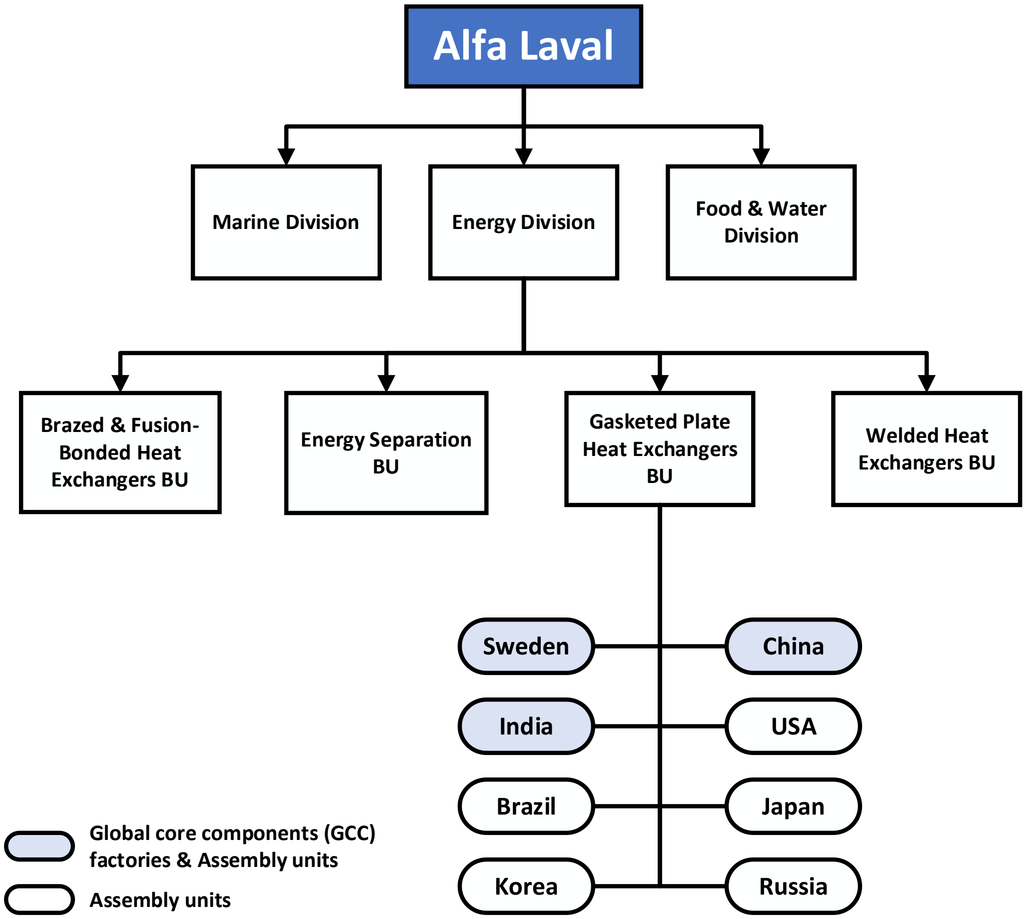

Figure 1.1: Overview of the scoped organizational structure at Alfa Laval (Based on Alfa Laval, 2023)

GPHEs as a product are used to optimize heat transfer and are ideal for managing the heating and cooling needs of customers. Alfa Laval GPHEs can be used in a wide array of industries and market segments, even extremely demanding hygienic processes (Alfa Laval, 2021). The frame holding the plates offers excellent flexibility for expansion or rebuilding, and the plates are available in different patterns, sizes, and material types. Customization is an essential part of Alfa Laval's offering, for example, the material range for the gaskets used in the GPHEs can vary from nitrile butadiene rubber to ethylene propylene diene monomer rubber, depending on the customers' needs. Figure 1.2 shows the general structure and components of a GPHE unit.

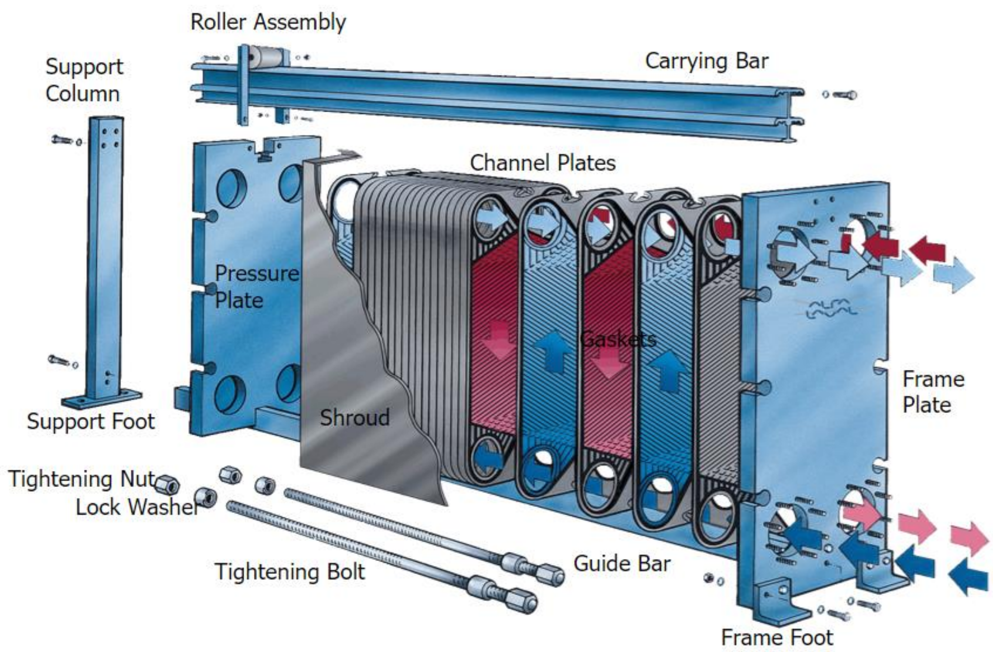

Figure 1.2: General structure of an Alfa Laval GPHE (Alfa Laval, 2021)

1.3 Problem formulation

A major challenge for many companies is to effectively manage global inventory levels through proper inventory management, for example, integrated monitoring of the supply chain and proper use of key performance indicators (KPIs). Currently, Alfa Laval uses Sales and Operations Planning (S&OP) processes to drive supply chain collaboration and balance supply and demand. However, they aim to find a global set of inventory planning processes to better manage their inventory and support the S&OP process in achieving its strategic goals. To drive this, they have begun to formulate and implement a new initiative, ATHENA. However, they are unsure if the initiative is comprehensive enough or if there are gaps in the capabilities of the organization that will hinder them from improving their inventory management.

The GPHE division of Alfa Laval has two types of factories, global core component (GCC) and local assembly (LA). GCC works in a make-to-order (MTO) and make-to-stock (MTS) approach depending on the classification of items, and LA operates in an MTO approach. Both factories interact with suppliers of both raw materials and components. However, GCC factories produce pressed plates and welded cassette components, which they internally supply to LA factories that manufacture completed GPHE units. In recent years, Alfa Laval has stored excess components and materials at both types of factories and has paid little regard to the large amounts of tied up capital held in their high levels of stock. This is largely due to the company’s focus on product availability and maintaining short lead times, regardless of the true customer needs and the impacts on other variables within the organization. As they have several global factories, this resulted in excess stock being held in multiple locations. While this served them well during the COVID-19 pandemic, as they could continue serving customers without reducing production rates due to large reserves of materials and components, they are now in need of reducing their tied-up capital. Therefore, they are looking to more effectively manage their stock levels and flows across their internal supply chain.

To analyze the problem, the authors identified best practices, policies, and performance indicators as well as the necessary competencies in order to successfully implement the inventory management changes.

1.4 Purpose

The purpose of this thesis is to increase the effectiveness of the case company, Alfa Laval's, inventory management by finding challenges, opportunities, and gaps within their current inventory management practices.

1.5 Research questions

The research questions included in this master's thesis are related to the purpose and aim to guide the author's work by providing necessary structure to the research process.

Research question 1: *How is the company currently working with inventory management?*

In order to find improvement opportunities within Alfa Laval's inventory management practices, it is necessary to understand the organization's current approach. Particularly with regard to how they assess their inventory, their use of KPIs, and what individual practices, policies, and procedures are being used when making inventory management decisions. It will be important to understand the motivations behind these attributes of inventory management so that an analysis with regard to their usefulness and practicality can be performed.

Research Question 2: *How can the company fulfill gaps and improve their inventory management practices?*

Once the current processes at Alfa Laval have been outlined, a comparison to relevant inventory management theory can be performed, which will highlight improvement possibilities for the organization. Particularly, it will be relevant to consider if their practices are comprehensive enough, and what competencies are needed in order to overcome barriers to implementing best practices. The competencies will relate to people and processes at Alfa Laval and the findings will be used to guide the development of their global inventory management initiative.

1.6 Focus and delimitations

This study was limited in terms of time and depth by the length of the thesis as it was conducted over a period of 20 weeks. To manage the scope of the study, the authors focused solely on the inventory management of GPHEs and the corresponding factories, even though Alfa Laval does hold inventory in additional locations. The inventory management practices related to spare parts and special cases were also excluded to limit the focus. At the GCC, while they produce both plates and welded cassettes, the inventory process that was analyzed centered only around the plate production. Additionally, inventory control aspects that set detailed plans and more specific directives at an operational level were not analyzed. Rather, a managerial view was taken to assess general practices and implementation needs that Alfa Laval should consider in their updated inventory management plans.

Another limitation was the customizability of Alfa Laval's GPHEs. In this sense, the company has upwards of thousands of unique stock keeping units (SKUs). Rather than looking at individual SKUs or groups of SKUs, a focus was placed on understanding product categorization tactics and corresponding category strategies.

Lastly, the inability of the authors to engage in onsite visits at all of the facilities was a limiting factor. As this study assesses the inventory management of GPHEs on a global level, this puts limits on understanding the processes and capabilities of each location in an individual context. To combat this, the authors used digital meetings to gain the necessary insights into facilities. Additionally, to close certain gaps in the empirical aspect of the study, the authors used the Lund GCC and LA facilities as a reference point in understanding the processes and procedures used at the other locations. This decision was made as the Lund location is the Alfa Laval headquarters where inventory management directives are put into place.

1.7 Thesis outline

Chapter 1 - Introduction
This chapter aims to provide the reader with necessary background information on the research area, organization, and problem at hand. The proposed research questions, scope and limitations will also be presented. To conclude, an overview of the material covered in each chapter will be included.

Chapter 2 - Methodology
This chapter will describe the procedure and research methodology that has been used throughout this study. Particularly, the motivation behind methodological decisions that were made and how they support the goals of this thesis and the available information and processes.

Chapter 3 - Literature Review

This chapter will provide a comprehensive overview of currently available research literature on the relevant topics related to inventory management. The topics covered will provide the basis for this thesis and this chapter will conclude with a model depicting the relationships between them. There are eight primary areas: Strategic alignment, Inventory management, Classification, Inventory control, Forecasting, Collaboration, Key Performance Indicators, and Centralized vs. decentralized structures.

Chapter 4 - Empirical Findings at Alfa Laval

This chapter outlines the supply chain structure of the BU GPHE at Alfa Laval, as well as the current processes and future directives related to inventory management. The information is primarily based on employee interviews and archival documents provided by Alfa Laval, with observational information occasionally being used to support these findings.

Chapter 5 - Gap Analysis & Recommendations

This chapter will perform a comparative analysis of the topics covered in the literature reviewed against the empirical data collected regarding the inventory management practices and processes used within the BU GPHE at Alfa Laval. This comparison will provide the basis for finding gaps between theory and practice, and therefore guide the formation of the recommendations.

Chapter 6 - Discussion

This chapter will provide a discussion on the theoretical recommendations in the context of the case company, Alfa Laval. It will include practical insights regarding implementation barriers, necessity of the recommendations, and reasoning behind the company's current ways of working.

Chapter 7 - Conclusion

This chapter will provide our concluding remarks, including a revisitation to the purpose of this study and the research questions. An explanation of how the research questions were answered will be provided. Additionally, both the practical and theoretical contributions will be outlined, as well as recommendations for future research studies.

Chapter 2 - Methodology

This chapter will describe the procedure and research methodology that has been used throughout this study. Particularly, the motivation behind methodological decisions that were made and how they support the goals of this thesis and the available information and processes.

2.1 Structure of research

To adequately describe the research method that was used throughout this study, the research onion, by Saunders, Lewis & Thornhill (2012, p. 161), will be used as inspiration, as shown in Figure 2.1. The outer layer begins by identifying the research approach followed by the selected research strategy, design, and methods used throughout the study.

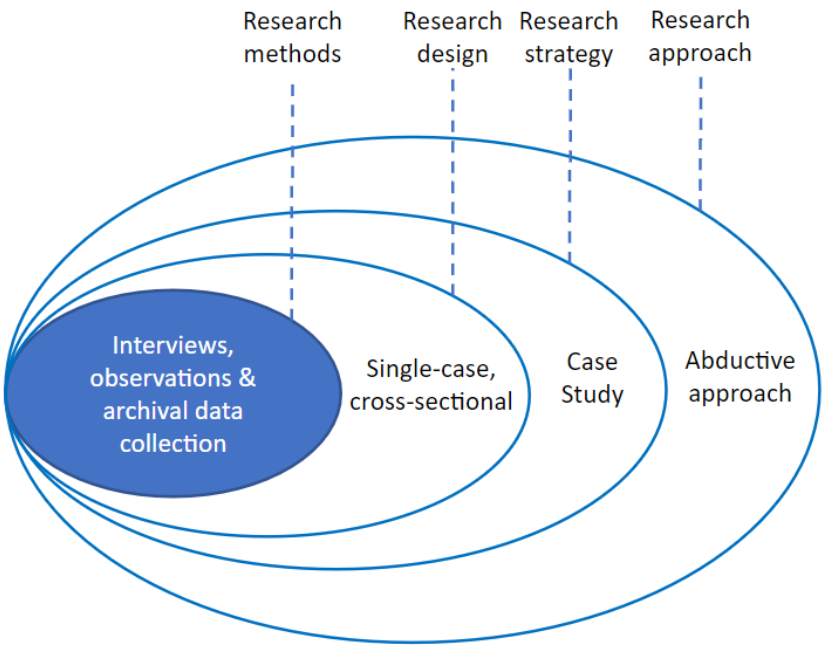

Figure 2.1: The thesis methodology visualized using a research onion (Inspired by Saunders, Lewis & Thornhill, 2012, p. 161)

2.2 Research approach

There are two main types of research approaches that are commonly used, inductive and deductive reasoning (Saunders, Lewis & Thornhill, 2012, pp. 145-149). Inductive reasoning is used when you begin a research process by collecting data to explore a phenomenon and then form a theory based on your findings. On the other hand, deductive reasoning is used when you begin the research process by doing a literature review to understand a formed theory and then try to test said theory. Conversely, oftentimes in business and management, it is difficult to stick to one approach. Instead, the researchers flow back and forth between the two approaches, which forms a combined approach that is referred to as abductive reasoning. The research approach and process for each of these alternatives, as well as their connection, is shown in Figure 2.2.

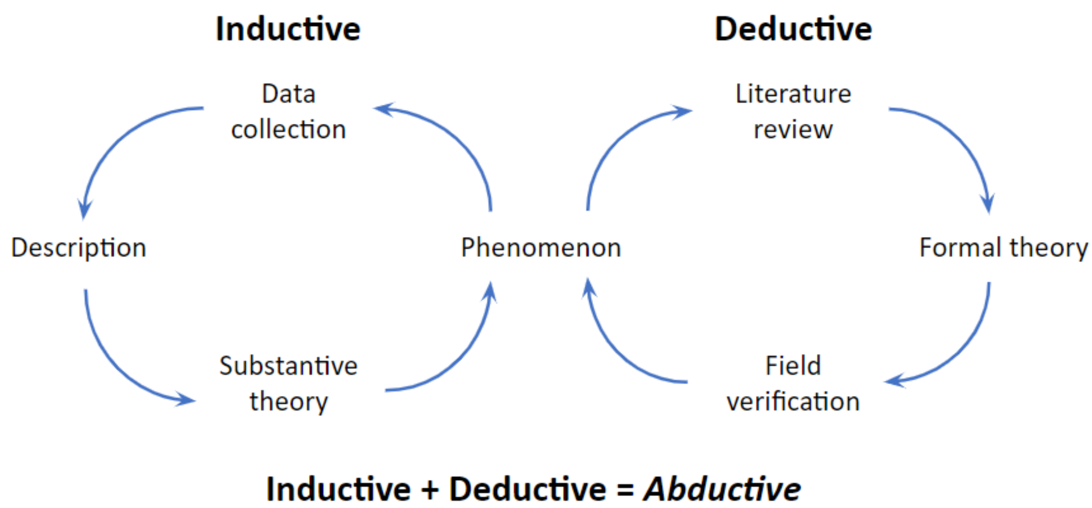

Figure 2.2: An adaption of Woodruff's (2003) diagram of the flow of abductive research (Olhager, 2022)

Using an abductive research approach allows for more flexibility in the formation and analysis of theories, as both empirical data collection and literature reviews can be done simultaneously (Saunders, Lewis & Thornhill, 2012, p. 148). For this reason, it was rationalized that an abductive approach would be the most suitable for this particular study, as its purpose was to compare the processes of the case company against literature. In this regard, to form the foundation of the study, both inductive and deductive reasoning would be done in parallel, particularly in the early stages of the project.

2.3 Research strategy

According to Yin (1994, p. 4), there are three conditions that should be considered when deciding which research strategy to use, which are, *"(a) the type of research questions posed, (b) the extent of control an investigator has over actual behavioral events, and (c) the degree of focus on contemporary as opposed to historical events."* An overview of the possible research strategies based on these various conditions is shown below in Table 2.1.

Table 2.1 Various research strategies for different situations (Yin, 1994, p. 6)

Strategy	Form of research questions	Requires control over behavioral events?	Focuses on contemporary events?
Experiment	How, why	Yes	Yes
Survey	Who, what, where, how many, how much	No	Yes
Archival analysis	Who, what, where, how many, how much	No	Yes/no
History	How, why	No	No
Case study	How, why	No	Yes

With these conditions in mind, this thesis' research questions are proposed as "how" questions, as they aim to understand *how* case company's inventory management processes are currently working and *how* relevant literature can contribute to filling in gaps within their current practices. Additionally, the researchers do not have control over behavioral events with regard to the case company and the research is focused on contemporary events. Therefore, there were three possible research strategies: *Survey, Archival analysis, and Case study.*

This thesis used a *case study* research strategy to assess the case company and answer the posed research questions. This decision was made by considering several factors, for example, the maturity of the research area and previous knowledge available, the time constraint of the project, and the involvement and resource availability at the case company. Given these aspects, the other strategies were excluded as they were not reasonable given the particular context of the study. For example, given the time constraint of the project's duration, lack of respondents, and context specific nature of the problem, survey research was excluded. Similarly, archival analysis was excluded as the focus is more heavily on contemporary events although it may use archival data as support. Additional drivers for using a case study strategy presented by Voss, Tsikriktsis & Frohlich (2002), who state that it is a relevant strategy to us when it is important to analyze the phenomenon in its natural setting as there are variables and aspects of the phenomenon that are still unknown. Therefore, given that the cause of the formulated problem was unclear, using a *case study* strategy allowed for necessary contextualization of the problem and in-depth analysis.

2.3 Research design

The purpose of a case study can vary from initial exploration to more advanced theory testing (Yin, 1994, p. 3; Voss, Tsikriktsis & Frohlich, 2002). In the exploration stage, the goal is to formulate research questions and ideas. This phase is followed by identifying and understanding the key variables that impact a specific phenomenon. However, in the most advanced stages of case study research, the developed theories and corresponding hypotheses are tested.

According to Saunders, Lewis & Thornhill (2012, p. 160), the nature of a research project is either exploratory, descriptive, explanatory, or shares a combination of these characteristics. Moreover, Yin (1994, p. 4) argues that the boundaries between these strategies are sometimes unclear, and there are large areas where they overlap. Due to the nature of the research questions, this study was an explanatory research case. This type of research focuses on answering "*how*" and "*why*" events happen since such questions deal with operational links that require analysis over time, instead of solely frequencies or incidences (Yin, 1994, p. 6). However, exploratory and descriptive research characteristics were also utilized, especially during the initial study phase, where clarity, understanding, and an accurate picture of the topic needed to be formed. This included data gathered through in-depth individual interviews with "experts" and group interviews (Saunders, Lewis & Thornhill, 2012, p. 171).

The research horizon was cross-sectional due to the phenomenon analysis being conducted in a limited amount of time. Cross-sectional research seeks to explain how factors relate to different companies or describe a phenomenon's incidence. Moreover, it uses multiple research strategies, such as qualitative data analysis based on interviews conducted over a short period (Saunders, Lewis & Thornhill, 2012, p. 190). The qualitative data will be analyzed using the pattern-matching technique. This will be explained in Section 2.3.1 and discussed again with regard to internal validity in Section 2.5.3.

In addition to the maturity and purpose of the case study, decisions must be made regarding the number of cases included in the study as well as the type of unit of analysis. With regard to the number of cases, either a single- or multiple-case study can be performed. Since this study is focused on analyzing the process of one company, Alfa Laval, it is a single-case study. In terms of the unit of analysis, this study uses a holistic approach as it analyzes the company's inventory management practices on a broad level to understand the importance of different factors. Therefore, a Type 1 research design was used. Yin (1994, p. 42) justifies using a Type 1 research design when, *"no logical subunits can be identified and when the relevant theory underlying the case study is itself of a holistic nature."* Figure 2.3 shows the different types of research designs for case studies.

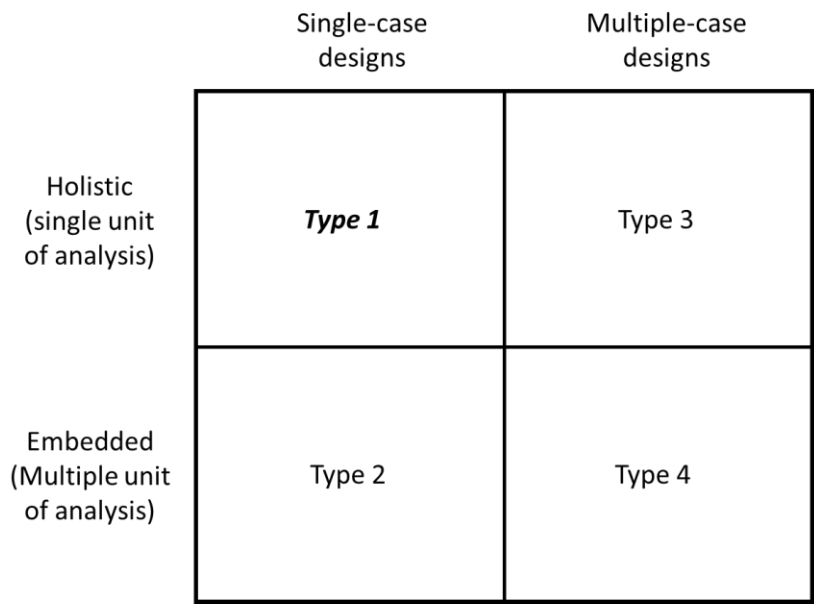

Figure 2.3: Basic types of designs for case studies (Yin, 1994, p. 39).

2.3.2 Qualitative data analysis

Pattern-matching will be the primary data analysis technique used in this study. By connecting and comparing common patterns found in existing research, with the empirical findings found at the case company, similarities and differences can be found (Yin, 2018, pp. 106-112). The relevant existing literature will be outlined in Chapter 3 and the findings from the case company will be presented in Chapter 4. Following this, a gap analysis will be completed and summarized in Chapter 5, which will highlight the most important similarities and differences.

2.4 Research methods

In order to describe the case context, formulate an understanding of the problem, and answer the research questions, multiple research methods were used to collect primarily *qualitative* data. Qualitative data was collected to provide a basic understanding of the relevant underlying processes and decisions that were necessary to answer the posed research questions. Additionally, an in-depth literature review was conducted to gain a thorough understanding of inventory management processes and practices on a theoretical level, while interviews, observations, and archival records were used to collect data related to the specific context of the case company's inventory management processes.

2.4.1 Literature review

Literature reviews have two primary goals: firstly, to provide a concise overview of current research by identifying recurring patterns, themes, and concerns, and secondly, to facilitate the identification of the core concepts in a particular field, thereby assisting in the development of the theory (Seuring & Müller, 2008). Thus, the literature review provides a foundational understanding of the research study's focus and enables the researcher to gain a generalized overview of related theories. In this regard, a combination of both books and research articles was utilized in the present study. Suitable books and articles were recommended by professors with up-to-date, expert knowledge within the field of inventory management processes.

Moreover, additional literature was obtained primarily through material from previous courses available throughout the master's program. Furthermore, the search engine Web of Science was employed to find highly cited publications. Since the area of inventory control from a managerial perspective is broad and required a review of literature in several different focus areas, adhering to a singular search strategy was not possible in obtaining a holistic view of the topics.

Finally, when there was a discontinuity in deciding whether an article provided relevant information, a discussion was mutually held to determine its applicability. The discussions were conducted to ensure that the relevant information was not overlooked and that the selected literature sources were applicable to the research study's focus.

2.4.2 Interviews

Interviews are one of the most important and common sources of information in a case study, in which most of the data is collected (Yin, 1994, p. 84; Voss, Tsikriktsis & Frohlich, 2002; Saunders, Lewis & Thornhill, 2012, p. 372). Interviewers are a flexible way to gather data since different approaches and structures can be used. Open-ended interviews are the most common form used in case studies and give a good overview of the phenomenon. Moreover, the interviewee is allowed to talk freely about the subject and provides ideas concerning the topic area. Nevertheless, focus interviews provide a clear direction and allow respondents to answer specific derived questions (Yin, 1994, p. 85; Saunders, Lewis & Thornhill, 2012, p. 375). Therefore, a mix of these approaches was used during the study to obtain more relevant results. A sample of the interview guide is included in Appendix A. Depending on the role of the interviewee the authors selected relevant questions from the interview guide to be asked. The initial interviewees were selected based on expert advice given by our supervisor at Alfa Laval regarding who would provide essential information on inventory management under the S&OP process within the BU GPHE. Additional interviews were done on a recommendation basis from the initial interviewees. Table 2.2 provides information regarding the interview sessions held during the research period.

Table 2.2. List of interviews held throughout the project's duration

Employee Job Title	Region	Date, Duration
Global Supply Planner	Sweden	19-1-2023, 60 minutes

Global Supply Planner	Sweden	26-1-2023, 60 minutes
Global Supply Planner	Sweden	02-2-2023, 45 minutes
Operational Buyer - GCC	Sweden	15-2-2023, 105 minutes
Team Manager - GCC	Sweden	16-2-2023, 65 minutes
Master Planner - GCC	Sweden	22-3-2023, 60 minutes
Regional Product Manager	China	28-3-2023, 60 minutes
Senior Global Sales	China	28-3-2023, 60 minutes
Master Planner - LA	China	29-3-2023, 120 minutes
Material Planner - LA	China	29-3-2023, 45 minutes
Material Planner - GCC	China	29-3-2023, 60 minutes
Business Controller PG GPHE	Sweden	11-4-2023, 60 minutes
Master Planner - LA	Sweden	12-4-2023, 60 minutes
Project Coordinator - LA	Sweden	19-4-2023, 60 minutes

2.4.3 Observations

According to Yin (1994, p. 86) and Saunders, Lewis & Thornhill (2012, p. 355), two types of observations are used in case studies' data collection: participant observation and direct observation. Participant observation occurs when the observer is not merely a passive spectator but also participates in the events. On the other hand, direct observations include real-life scenarios, such as factory visits, meetings, and sidewalk activities. As a case study is meant to analyze the phenomenon in its natural setting, direct observations can be extremely valuable to the researcher and the research process. Particularly as they can add a more unfiltered dimension to the case and the collected information. This aspect is very relevant as the thesis analyzed a real-case problem faced by the company. Hence, this study used mostly direct observation as a source of information gathering. A list of the observations used in this study can be found in Table 2.3.

Table 2.3. List of observations held throughout the project's duration

Employee Job Title	**Region**	**Date, Duration**	**Explanation**
Factory Manager - GCC	Sweden	19-1-2023, 60 minutes	GCC factory operations tour
Unit Manager - LA	Sweden	21-1-2023, 50 minutes	LA factory tour

Purchaser - LA	Sweden	07-2-2023, 60 minutes	Purchasing department
Master Planner - LA	China	29-3-2023, 60 minutes	LA factory tour

2.4.4 Archival records

Archival records are an important knowledge source for case studies as they contain relevant past information useful to drive conclusions about the phenomenon, mainly if utilized in conjunction with other types of data gathering, such as observation and interviews (Yin, 1994, pp. 81-84; Voss, Tsikriktsis & Frohlich, 2002). Archival records can help to obtain insights that corroborate and expand evidence from other sources, conforming to or denying previous investigations. However, archival records should be used carefully since the data was created for different proposals and might contain undesirable biases. Archival records from the case company, primarily in the form of past and present presentation materials, were used to understand the changing directives set by the company.

2.5 Research quality

When planning and performing a case study, it is important that design tests are considered in an effort to ensure that the research is of high quality (Yin, 1994, pp. 32-38). The tests are related to validity and reliability but can be broken down into four categories as shown in Table 2.4. Validity considers how well the measures address the study's focus. Reliability measures the accuracy of the data and study. Each of the four tests can be considered during different stages of the research process, where specific tactics can be used to ensure the quality of the case study.

Table 2.4. Case study tactics for four design tests (Yin, 1994, p. 32)

Test	Case study tactic	Phase of research which tactic occurs
Construct validity	Use multiple sources of evidence	Data collection
	Establish chain of evidence	Data collection
	Have key informants review draft report	Composition
Internal validity	Do pattern-matching	Data analysis
	Do explanation building	Data analysis
	Do time-series analysis	Data analysis

External validity	Use replication logic in multiple-case studies	Research design
Reliability	Use case study protocol	Data collection
	Develop case study database	Data Collection

2.5.1 Triangulation

A case study does not typically use statistical analysis to ensure the accuracy of the researchers reasoning, but instead provides combinations of information and data types to come to conclusions that are supported in various ways. This tactic, referred to as *triangulation*, is considered to be a major benefit of case study research and be split into four categories (Yin, 1994, p. 91):

1. **Data triangulation:** The use of multiple sources
2. **Investigator triangulation:** The use of multiple evaluators
3. **Theory triangulation:** The use of multiple theoretical perspectives
4. **Methodological triangulation:** The use of multiple methods

When using *data triangulation*, it is beneficial to converge the various lines of inquiry, as opposed to leaving the lines of evidence separate. The difference is shown visually in Figure 2.4 which is inspired by Yin (1994, p. 93), but represents lines of evidence used within this particular case study. The main benefit of using a converged method is that facts from each line of evidence can be compared and contrasted in order to lead to increased convincibility and information accuracy as sources can corroborate one another (Yin, 194, p. 92).

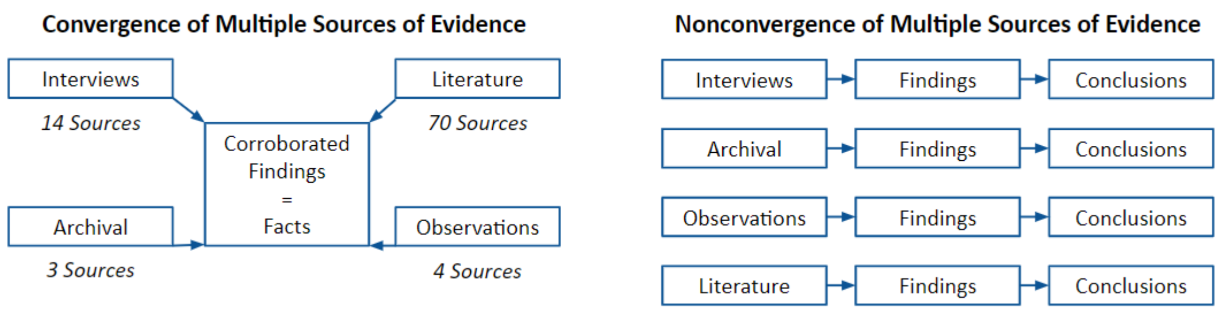

Figure 2.4: Convergence of multiple sources of evidence inspired by Yin (1994, p. 93)

2.5.2 Construct validity

Construct validity is often extremely problematic during case study research as it is easy to construct measures that are not adequately related to the subject that is being studied, primarily because they use “subjective judgements” (Yin, 1994, p. 34). In order to ensure the construct validity of this case study, multiple data collection methods have been used in combination with multiple sources. For example, information was collected through interviews, observations, and archival records to ensure that information was accurate. A thorough record of the data collection process has also been kept and the report draft was reviewed by particularly relevant interviewees to ensure the reporting quality.

2.5.3 Internal validity

Internal validity refers to how well casual relationships are supported (Yin, 1994, p. 35). If a conclusion is made about a causal relationship, yet there is another factor that cannot be adequately ruled out, this proves to be an internal validity issue. Therefore, as this is an explanatory case study, proving causal relationships is important. This study used pattern-matching to address concerns of internal validity by analyzing the impacts that foreign factors may have on answers. By understanding the role and impact of biases and the possibility of inaccurate responses, the potential effects can be managed. Additionally, by using triangulation of information and sources, the collected empirical data was corroborated, and connections were made.

2.5.4 External validity

External validity is concerned with generalizability, which is often a large issue for single-case studies as they lack a sample that allows for the findings to be translated to the larger population (Yin, 1994, pp. 36-37). Typically, cases are selected for the representative qualities in an effort to make a single case study generalizable, however, it is oftentimes more appropriate to generalize the case study findings to theory, similarly to how experimental research findings are generalized. As this is a single case study, the findings are specific to the case company, Alfa Laval, however, the solutions can be translated to similar cases to a certain extent as the practices are not case specific. Any adaptations that have been made to make the practices and solutions context specific have been thoroughly explained to enable future replicability of the study and findings.

2.5.5 Reliability

Reliability refers to whether the data collection techniques and analytic procedures would produce consistent findings if repeated on another occasion or if a different researcher replicated them (Yin, 1994, p. 37; Saunders, Lewis & Thornhill, 2012, p. 192). The correct documentation of actions and procedures is critical to ensuring reliability, reporting each part of work fully transparently to permit external judgment (Yin, 1994, p. 37; Saunders, Lewis & Thornhill, 2012, p. 192; Voss, Tsikriktsis & Frohlich, 2002). To ensure reliability of the research, two databases were created, one for qualitative information and one for quantitative data. Additionally, all information was transparently reported, regardless of the findings.

Chapter 3 - Literature Review

This chapter will provide a comprehensive overview of currently available research literature on selected topics related to inventory management. The topics covered will provide the basis for this thesis and this chapter will conclude with a model depicting the relationships between them. There are eight primary areas: Strategic alignment, Inventory management, Classification, Inventory control, Forecasting, Collaboration, Key Performance Indicators, and Organizational structures.

During the literature review process, several relevant topics were found to have a strong connection to, or impact on, inventory management as they were repeatedly mentioned in multiple sources. A general overview of the topics, including both external factors and process elements, is shown below in Figure 3.1.

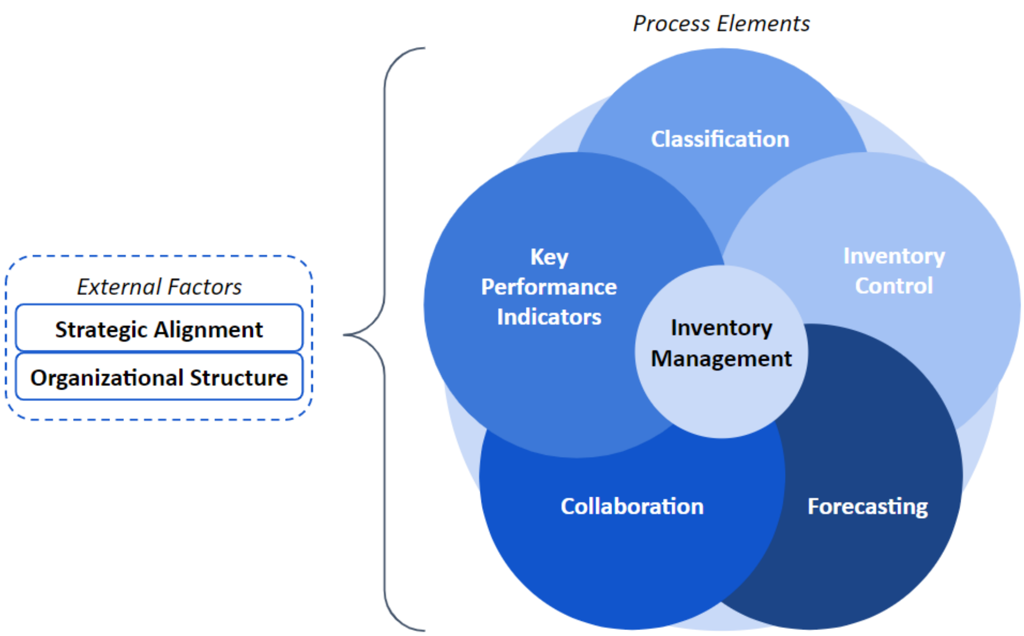

Figure 3.1: Topics found to have a significant connection to inventory management (Created by the authors)

3.1 Strategic alignment

Before analyzing inventory management in-depth, it is essential to understand how strategic goals should drive supply chain decisions, and therefore outcomes, including aspects related to inventory management. A company's competitive strategy defines, in relation to its competitors, the specific customer needs that the organization aims to fulfill through its products and services (Meindl & Chopra, 2016, pp. 19-20). The strategy is constructed by considering factors such as product cost, delivery time, variety, and quality. The competitive strategy is focused on one or more customer segments and delivering products and services that meet their specific needs.

3.1.1 Supply chain strategy

A framework by Fisher (1997) states that the first step in creating a supply chain strategy should be to understand the nature of the demand of the supply chain's products. According to Meindl & Chopra (2016, p. 27), two demand attributes should be considered, demand uncertainty which is the "uncertainty of customer demand for a product" and implied demand uncertainty which is "uncertainty for only the portion of the demand that the supply chain plans to satisfy and attributes the customer desires"'. These attributes should be analyzed through characteristics including product life cycle, contribution margin, product variation, average forecasting error, average stockout rate, average seasonal markdowns, and lead-times for make-to-order (MTO) items (Fisher, 1997). A supply chain's products will then fall into one of two categories: innovative or functional products. Innovative products are those with unpredictable demand while functional products have more predictable demand. Table 3.1 highlights some of the main characteristics that are considered when categorizing a product.

Table 3.1. Functional versus innovative product characteristics (Inspired by Fisher, 1997)

Aspect of demand	**Functional** ***(Predictable demand)***	**Innovative** ***(Unpredictable demand)***
Product variety	Low *(10 to 20 per category)*	High *(millions per category)*
Average margin of error in the forecast	10%	40% - 100%
Average stock out rate	1% - 2%	10% - 40%

Functional products' demand patterns are easily forecasted because supply and demand are more balanced, as there is minimal uncertainty (Fisher, 1997). Therefore, the supply chain strategy should be focused on minimizing physical costs related to supply chain activities, for example, production, assembly, and transportation. This strategy is referred to as being physically-efficient as its main goal should be to supply demand at the lowest possible cost. Contrarily, products with unpredictable demand patterns are considered innovative and are susceptible to supply and demand imbalances. Additionally, innovative goods typically have higher profit margins which creates a need for the supply chain to focus more on reducing market mediation costs related to mark downs due to an excess supply, or lost sales due to a lack of supply. This strategy is referred to as being market-responsive as its main goal is to respond quickly to changing customer demand. Using Fisher's (1997) framework, the correlation between product and supply chain strategy is shown below in Figure 3.2. Expanding on this however, Meindl & Chopra

(2016, pp. 29-31), explain that both implied uncertainty as well as responsiveness and efficiency, operate on spectrums which require trade-offs.

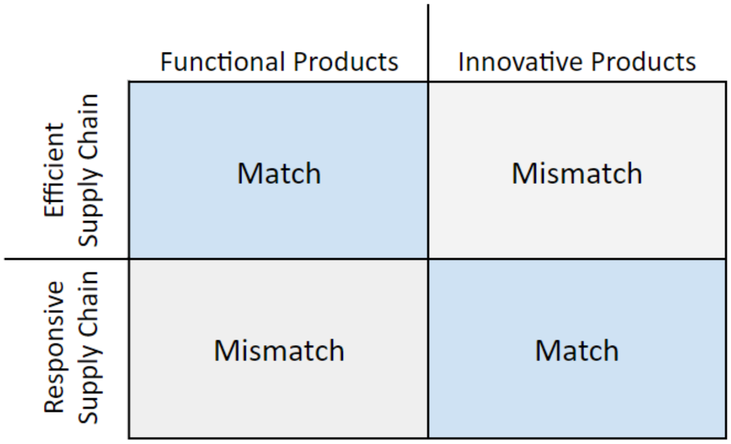

Figure 3.2: Matrix matching types of supply chains to products (Fisher, 1997)

Additionally, the various functional strategies need to fit together with the supply chain strategy in order to build up the capabilities needed to satisfy the customer demands (Meindl & Chopra, 2016, pp. 31-35). For example, the design, processes, and resources within manufacturing, inventory management, and purchasing should support the overall goal of the supply chain. As the attributes operate on spectrums, when aligning the functional strategies, the degree of responsiveness and uncertainty need to match across the entire supply chain, but the distribution can be allocated unevenly across various supply chain actors to provide an optimal solution in totality.

Another difficulty arises when the products sold and the customer segments being served have varying levels of demand uncertainty (Meindl & Chopra, 2016, pp. 31-32). In this scenario, choosing a singular strategy does not result in a strategically aligned and tailored supply chain. Instead, products and customer segments should be categorized and treated separately depending on the level of uncertainty. This approach allows for optimization of responsiveness so that resources, and subsequent costs, are not wasted in areas that have characteristics more closely connected to efficiency and functionality.

3.1.2 Strategic decoupling point

Another important factor that drives strategic alignment and creates clarity regarding the role of inventory in a supply chain is the customer order decoupling point (CODP) or order penetration point (OPP). According to Sharman (1984), the OPP is the production process point where the product specification is settled, which should be the last point where inventory is held. The OPP is responsible for differentiating manufacturing systems such as MTO and make-to-stock (MTS). Hence, the OPP determines which activities are forecast-driven and which are customer order-driven. Therefore, upstream activities should be forecast-driven, while downstream activities should be customer order-driven (Olhager, 2003). Figure 3.3 shows an example of the OPP for different activities.

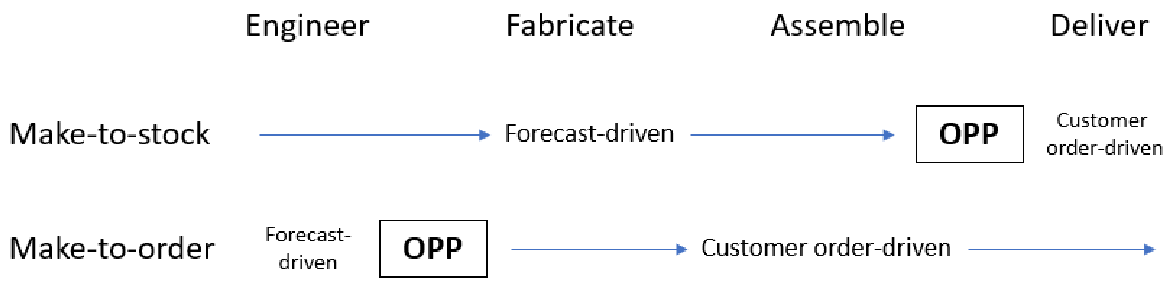

Figure 3.3: Product strategy and order penetration point relation (Based on Olhager, 2010)

Concerning manufacturing strategy decisions, there are differences between pre-OPP and post-OPP operations (Olhager, 2003; Olhager, 2010; Cannas et al. 2019). Downstream operations require the flexibility inherent in a job shop. Since the manufacturing firm manages the inventory replenishment process at the OPP, the strategy of increasing capacity when there is an actual increase in demand can be used. A lead-type capacity strategy is required for downstream operations to avoid lengthy and variable customer order lead times. Thus, if capacity is tight for customer-order-driven activities, demand volatility will transfer to lead time volatility. Once the OPP provides a decoupling point between upstream and downstream activities, the perspectives are extended to the outside vertically integrated contacts. For instance, suppliers upstream and customers downstream aim to provide efficient links to the closest internal activities through collaborative efforts (Olhager, 2003). Moreover, in a manufacturing planning and control level, low-volume items should follow a chase planning strategy and a MTO process for master planning, which fits the downstream. Furthermore, high volume items should have a level planning approach for sales and operations planning and a MTS process for master planning, which fit the part of the supply chain upstream of the OPP.

Sales forecasts are entered for MTS product groups and the differences between supply and demand result in changes in inventory levels, while customer orders and forecasts are entered for MTO product groups and the differences between supply and demand result in changes in backlog levels (Olhager, 2021). Therefore, MTO companies should determine target backlog levels for each product group during the S&OP process. This includes factors such as the maximum and minimum backlog levels, planned order times, and maximum acceptable customer waiting time. Backlog refers to all customer orders that have been received but have not yet been shipped and have a scheduled delivery date in the future. Overall, the practical implication for managers is that markets with standardized products, high volume, low variants, and short lead times should be designed and controlled by level strategy, MTS, rate-based, and JIT-type approaches. In contrast, markets with highly customized products, low-volume, wide product range, and long lead times should be planned and controlled using chase strategy, MTO, time-phased, and MRP-type approaches (Olhager & Selldin, 2007). A chase planning strategy means that production output is changed to chase demand. In contrast, a level production strategy implies that production is at a constant uniform output rate, with inventory build-ups and reductions over the time. Furthermore, the differentiation between MTO and MTS provides a necessary contingency factor in supply chain management and manufacturing. Thus, MTO companies benefit from external logistics integration with suppliers. In contrast, MTS companies benefit from internal lean practices and supplier rationalization (Olhager & Prajogo, 2012).

Nevertheless, Demeter & Golini (2014) provides a relationship between the company's manufacturing system and the type and quantity of inventory held. It allows inventory managers to identify the typical inventory configurations and the drivers behind them, providing a powerful strategic tool. Generally, companies with more inventory in upstream operations, instead of work-in-process or finished goods, are engineer/make-to-order. Those companies are typically positioned more upstream in the supply chain than any other clusters and use global sourcing more intensively. They likely have inventories to provide a buffer in case of sudden disruptions or uncertainties. Therefore, deciding between MTO and MTS production depends on inventory costs, back ordering, time factors, demand volume, variability, specificity, and predictability. MTO is better for high inventory costs, while MTS suits significant back ordering and control costs. Long and unpredictable times require MTS with buffering, while short and reliable times use MTO (Perona, Saccani & Zanoni, 2009). Even the product structure and bill of materials can impact if an item is most appropriate to MTO or MTS strategy. In assembly-to-order (ATO) systems, standard components or subgroups can be held in stock and assembled to order. The same can occur in manufacturing when a semi-finished item can become diverse finished products. Usually, ATO systems are driven by modularization.

3.2 Inventory management

Inventory management is considered one of the most important aspects impacting financial performance of organizations and has been a major theoretical focus for operations management research (Capkun, Mameri & Weiss, 2009; Nenes, Panagiotidou & Tagaras, 2010). Many types of inventories can be held ranging from raw materials or components to finished goods (Song, van Houtum & Van Mieghem, 2020). The primary goal of maintaining an input inventory is to prevent production idling, while finished goods inventory provides a buffer to help manage imbalances between supply and demand (Song, van Houtum & Van Mieghem, 2020; Williams & Tokar, 2008). Regardless of the inventory type, inventories occupy space while creating high logistics costs and tying up capital (Song, van Houtum & Van Mieghem, 2020; Demeter & Golini, 2014). According to Longo (2011, p. 95), inventories can affect supply chain performance and costs in three ways: *values tied up, degrees of flexibility, and levels of responsiveness*. In some cases, inventory is estimated to account for up to 60% of a firm’s assets.

Therefore, inventory placement throughout the supply chain has become a strategic decision based on essential inventory planning which aims to balance fulfilling customer requirements with logistics costs (Song, van Houtum & Van Mieghem, 2020).

Inventory planning decisions are typically made by considering the consequences of trade-off decisions between high holding costs and the risk of obsolescence, as well as lost sales due to a lack of supply and poor service levels (Baker, 2007; Chinello, Herbert-Hansen & Khalid, 2020; Nenes, Panagiotidou & Tagaras, 2010). The inventory policies should therefore guarantee an acceptable service level while minimizing unnecessary inventories. According to Pawlak & Małyszek (2007) and Chen, Frank & Wu (2005), inventory levels should be “low but not too low”, because both bloated and completely diminished levels of inventory will lead to poor performance. Therefore, inventory can be kept to ensure product availability but should only be increased as long as the benefits outweigh the costs (Michalski, 2008; Chinello, Herbert-Hansen & Khalid, 2020).

In the past, the most prevalent methods in inventory management have been lean practices (Capkun, Mameri & Weiss, 2009; Demeter & Golini, 2014). However, the management and role of inventories has changed as globalization has created more complex supply chains with additional actors and flows, changing customer requirements, as well as greater distances between supply chain nodes (Chinello, Herbert-Hansen & Khalid, 2020). Therefore, as globalization continues and supply chains become increasingly customer-driven, firms must decide to continue operating on efficiency or choose to become more market-responsive. For example, lean management is thought to have some limitations for networks that are globally dispersed or have large variations of products (Demeter & Golini, 2014). In a global context, inventories help firms manage uncertainty by creating buffers to hedge against disruption risks and allow firms to be more responsive even in volatile market situations, all of which helps avoid lost sales. Therefore, in certain situations, being lean is counterproductive, and not in line with higher firm performance.

If inventory is to be held, it needs to be strategically placed in order to add value to the supply chain, therefore, understanding the forces that drive inventories and the best management practices to manage these factors is vital (Baker, 2007; Chinello, Herbert-Hansen & Khalid, 2020). In recent literature, dominant topics for effectively managing inventory include inventory classification, increased collaboration and coordination among supply chain actors and nodes, and accurately forecasting even when there are complex demand processes.

3.3 Classification

A well-defined classification system for inventory and items is crucial for streamlining operations and optimizing resource utilization. Thus, classification is divided into inventory types and item classification.

3.3.1 Classification of inventory types

Inventory management is a crucial aspect of supply chain management (Handfield & Bozarth, 2015, pp. 345-347; Meindl & Chopra, 2016, p. 50). The two most common types of inventories are cycle stock and safety stock. Cycle stock is the inventory of products or components that companies use gradually and replenish in bulk by their suppliers. It is considered active inventory, constantly in use and replenishment. However, holding a large amount of cycle inventory comes at higher carrying costs due to production, transportation, or purchasing in large lots to exploit economies of scale. On the other hand, safety stock is extra inventory companies hold to protect against uncertainty in demand levels or replenishment time. It is held in case demand exceeds expectations, and companies only plan to use it if necessary. The decision of how much safety inventory to carry depends on the level of uncertainty in demand. Thus, companies must balance the cost of holding safety inventory against the potential cost of stockouts when determining the optimal amount of stock to own.

To optimize supply chain management, it is crucial to understand the different types of inventories beyond cycle and safety inventory (Handfield & Bozarth, 2015, pp. 345-347; Meindl & Chopra, 2016, p. 51). The four other common types of inventories are anticipation, hedge, transportation, and smoothing inventory. Anticipation inventory is held before expected demand to ensure the rapid availability of products to customers. Hedge inventory is a buffer against unforeseen events threatening a company's strategic objectives. Transportation inventory represents the inventory "in transit" from one supply chain partner to another, and it can represent high costs, especially over long distances. Finally, smoothing inventory helps align upstream production levels with downstream demand to prevent excess inventory buildup or stockouts. By understanding these inventory types, supply chain managers can make informed decisions about inventory management to minimize costs and improve supply chain efficiency. Figure 3.4 shows the representation of different inventory types.

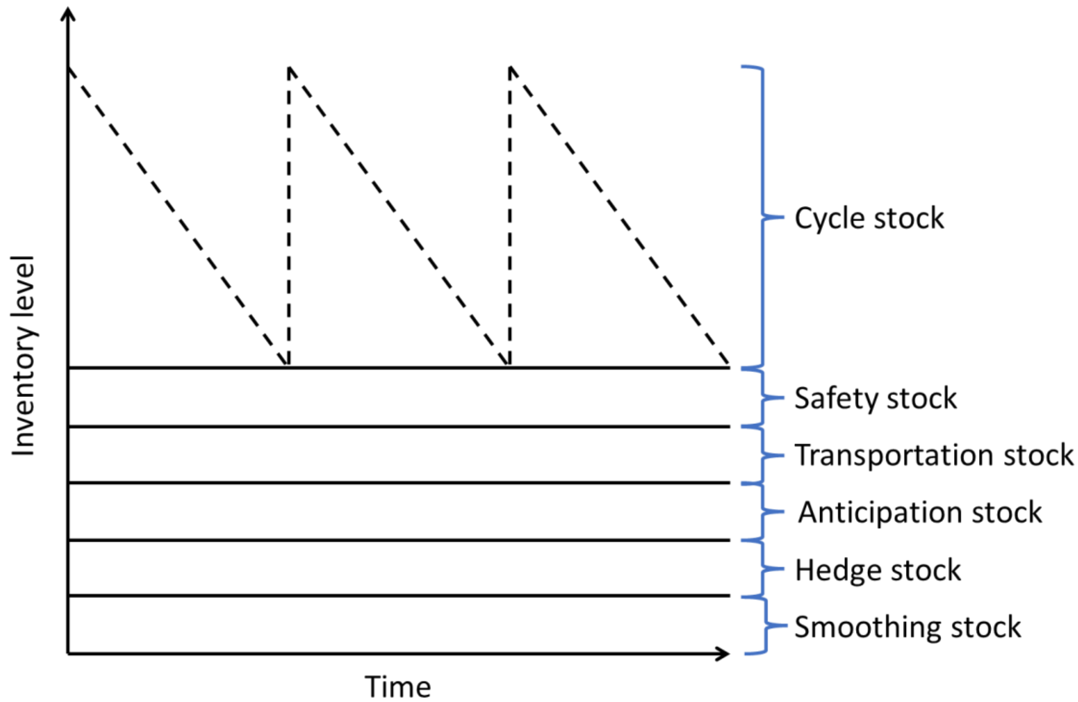

Figure 3.4: Types of stock (Based on Handfield & Bozarth, 2015, pp. 345-347)

3.3.2 Item classification

Theoretically, each item in inventory can be analyzed individually; however, companies generally have thousands of items in stock, and this solution is typically infeasible (Axsäter, 2006, p. 301; Ghorabaee et al., 2015; Chinello, Herbert-Hansen & Khalid, 2020). Hence, dividing the inventory into groups and applying the same control system and forecast method for each specific group is manageable and largely applied in practice. Different techniques for grouping inventory items exist in the literature and depend on the company's requirements. However, it should typically consider marketing (sales) and production factors.

Moreover, managers can use diverse inventory strategies for different classes of items and even prioritize the most critical items in inventory (Hua et al., 2018). Thus, a generic inventory control policy, needing a particular level of management effort and control is used for all items in each category. This aggregation process should dramatically reduce the number of SKUs requiring extensive management attention. Therefore, an appropriate order or reorder policy can be established for each class (Chen et al., 2008; Lolli et al., 2019).

Moreover, the same classification system can be used for components, raw materials, and finished goods (Olhager, 2023). However, any classification system should be concerned with the same type of items. For instance, raw materials or purchase components are one item type, semi-finished goods or modules are different ones, and finally, finished goods are a third type.

Thus, components cannot be combined with modules or finished goods in the same classification system.

Item classification methods commonly found in the literature and explored in this master thesis are ABC analysis, demand variability, and ABC-XYZ.

ABC analysis

ABC analysis is one of the most widely used techniques to classify items and it consists of three categories (Chen et al., 2008; Rădăşanu, 2016; Douissa & Jabeur, 2016). Category A includes the essential items, category B contains the relatively important items, and category C includes the moderately unimportant items. The classical ABC analysis follows Pareto's analysis of the irregular distribution of incomes. ABC analysis is easy-to-implement and effective in many inventory systems. Thus, this approach is still widely utilized in practice. The ABC analysis works as the most critical SKUs in terms of dollar usage are placed in category A, which requires the management's most significant effort and attention. The least important SKUs are put into category C, where the least effort is applied; other SKUs belong to the middle category B. The 80/20 rule is applied, where 80% of total annual usage comes from 20% of SKUs. Therefore, this rule indicates that the number of SKUs in category A is considerably smaller than the total. Even though the exact values differ from company to company, the 80/20 rule is largely applied to many real-world situations. Moreover, ABC analysis offers a convenient way to categorize products to their respective sales volume. Then, ABC categories are assigned their respective service level. For instance, items in category A demand a high service level (95-99%). Items in category B require a medium service level (90-95%). Finally, items in category C need a lower service level (80- 90%). Figure 3.5 shows a representation of the ABC analysis.

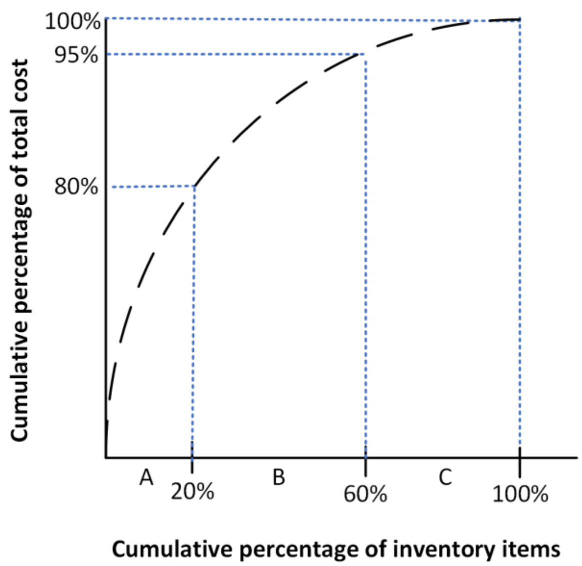

Figure 3.5: ABC analysis following the Pareto rule (Inspired by Chen et al., 2008)

However, the ABC analysis classification is usually subject to further adjustments. For example, the financial use of some SKUs might be unimportant, but their stock-out cost might be high (Chen et al., 2008; Rădăşanu, 2016). At the same time, other SKUs might have high financial use but sufficient and consistent suppliers. Therefore, SKUs can be traded to another group. This reclassification process is relevant because some criteria, other than financial use, might be more critical in determining the importance of the SKUs. Therefore, a more efficient method for finding an optimum service level or an appropriate order policy should be evaluated in the long term based on the business point of view. For instance, the target service level can be defined as a trade-off between the inventory cost and stock-outs. Consequently, a cost analysis can determine the service level.

Demand variability

Even though the ABC analysis is a simple and effective way to classify items, this method has clear limitations, and further analysis should be done. Another classification method is proposed by D'Alessandro & Baveja (2000).

D'Alessandro & Baveja (2000) divided items into stock items and non-stock items (MTO and MTS), considering the coefficient of variation (CV). The authors justified this classification method due to the case-studied company having customer-demand patterns that were not predictable and short lead times for most products, even though with more than 800 products in the portfolio and no formal demand-forecasting process. Therefore, the customer demand should be satisfied by the excessively built stock.

The CV is the ratio of the standard deviation to the mean (Meindl & Chopra, 2016, p. 317). Considering the demand with a mean of μ and a standard deviation of σ, CV is calculated using Equation 3.1.

$$CV = \frac{\sigma}{\mu} \tag{3.1}$$

The coefficient of variation measures the uncertainty's size relative to demand since the standard deviation alone cannot capture this difference. For instance, it acknowledges that an item with a μ of 100 and a σ of 100 has more significant demand uncertainty than an item with a μ of 1,000 and a σ of 100.

After calculating the CV, a graphic with the average demand on the x-axis and demand variability on the y-axis should be plotted. The Pareto analysis (20/80) separates high variability products from low-variability products in the y-axis. However, according to D'Alessandro & Baveja (2000) and Scholz-Reiter et al. (2012), $CV < 0.52$ can be considered low-variability. It means, theoretically, 20% of the total items will have $CV < 0.52$.

Furthermore, quadrant 1 (Q1) indicates high volume and low variability, quadrant 2 (Q2) suggests high volume and high variability, quadrant 3 (Q3) implies low volume and high variability, and quadrant 4 (Q4) indicates low volume and low variability. Finally, Q1 products should be available for shipment to customers under the MTS strategy (stock items), and Q3 should require longer lead times from customers under a MTO strategy (non-stock items) (D'Alessandro & Baveja, 2000). Figure 3.6 shows an illustration of this classification system.

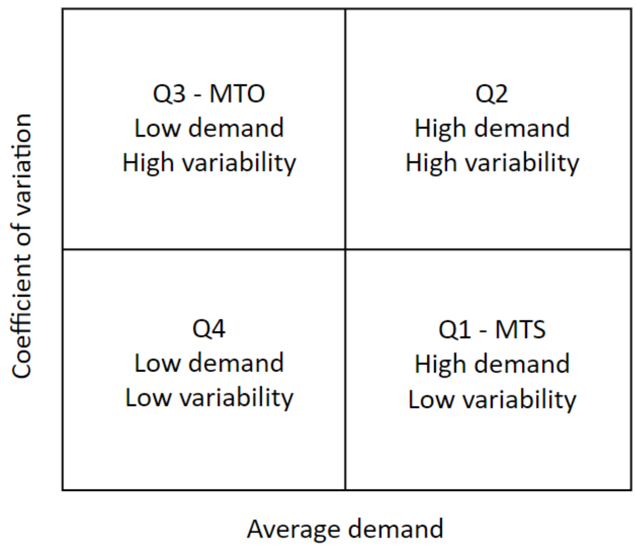

Figure 3.6: Coefficient of variation classification (Based on D'Alessandro & Baveja, 2000)

ABC-XYZ analysis

The last classification method can be considered an integration of the ABC and demand variability analyses (Buliński, Waszkiewicz & Buraczewski, 2013; Stojanović & Regodić, 2017). The ABC axis follows the same approach explained in the previous ABC analysis section, considering the items' financial value, where:

$A = 0 - 80\%\ of\ the\ total\ value\ of\ items$
$B = 80 - 95\%\ of\ the\ total\ value\ of\ items$
$C = 95 - 100\%\ of\ the\ total\ value\ of\ items$

The XYZ axis considers Formula 3.1 to calculate the CV, and divide items into:

$X = CV < 0.5$
$Y = 0.5 < CV < 1$
$Z = CV > 1$

The combination of these two analyses provides a 3 x 3 matrix. Figure 3.7 shows the ABC-XYZ analysis matrix.

Demand variability \ Item value	A	B	C
X	High value Low variability	Medium value Low variability	Low value Low variability
Y	High value Medium variability	Medium value Medium variability	Low value Medium variability
Z	High value High variability	Medium value High variability	Low value High variability

Figure 3.7: ABC-XYZ analysis matrix (Based on Stojanović & Regodić, 2017)

After dividing items into segments, assigning inventory replenishment policies for each group is essential. Bialas, Revanoglou & Manthou (2020), argue that a company should first focus on assigning inventory replenishment policies for groups AX, BX, AY, and BY, as these items have more predictable demand and are more valuable. Moreover, items AX and BX are appropriate for JIT reorder points with a fixed lot size strategy or VMI (vendor-managed inventory). Also, AY and BY items can follow an EOQ (economic order quantity) policy which relies on an accurate forecasting analysis. However, Z and C items are low values and high variability, which are challenging to manage but less critical for the business (Stojanović & Regodić, 2017; Bialas, Revanoglou & Manthou, 2020).

3.4 Inventory control

In general, the strategic importance of controlling inventories is widely accepted and there are some general techniques that form the basis for inventory control in practice (Axsäter, 2006, p. 1). According to Olhager (2019), inventory control aims to provide solutions for how much should be ordered, how order initiation should be done, and how uncertainty should be managed. In general, inventory management procedures and processes should be standardized across the supply chain (Sánchez-Rodríguez et al., 2006). This can help to limit misinterpretations of information, enhance the shareability and relevancy of information to other supply chain actors and allow for monitoring.

Inventory management, however, cannot be decoupled from other supply chain functions in an organization but rather balances the functional objectives (Axsäter, 2006, p. 1). This balancing act can be difficult as the various objectives are often in opposition of one another, for example, a financial agenda may be to reduce inventory to free tied up capital, while the sales division aims to hold large quantities of inventory in order to quickly respond to customer orders.

This balance is managed through an inventory control system which uses stock levels, forecasted demand, and various cost factors to analyze when an order should be placed and to determine the order quantity (Axsäter, 2006, p. 46). Each inventory system comes with parameters to optimize. However, since these problems are multi-dimensional, one policy or system is unlikely to fit every scenario, yet there are some commonly used sets of parameters (Perona, Saccani & Zanoni, 2009). In practice, modified inventory models, hybrid combinations of decoupling points, and various parameters are likely needed, but the traditional models will be explained in the following sections.

3.4.1 Economic order quantity

The most commonly used method to determine the optimal order quantity is the economic order quantity (EOQ) formula (Axsäter, 2006, pp. 52-53). The basis of the formula is to balance the costs of holding inventory and the costs related to order replenishments. The EOQ model is based on the assumptions that demand is constant and continuous, ordering and holding costs are constant over time, the batch quantities are delivered at once, and lastly shortages are not allowed. The goal of the model is to find the optimal order quantity that minimizes the total cost, which is shown visually in Figure 3.8. The formula is shown below in Equation 3.2.

$$Q = \sqrt{\frac{2Ad}{h}} \tag{3.2}$$

Where,

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

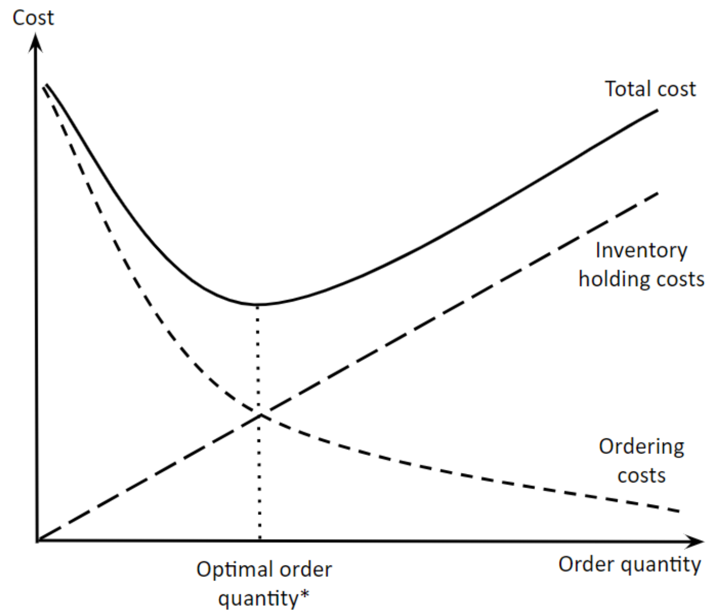

Figure 3.8: Total Cost Curve (Handfield & Bozarth, 2015, p. 353)

The ordering, or setup, costs are typically fixed costs associated with initiating a replenishment order (Axsäter, 2006, p. 44). For example, they can include administrative costs for the ordering handling process or transportation costs. When considering holding inventory, there is an opportunity cost associated as an organization has capital tied up in the held inventory. Therefore the majority of the holding cost is considered to be capital costs, however other costs including those related to storage, material handling, possible obsolescence, as well as insurances and taxes should be considered. Typically, the inventory holding cost is calculated as a percentage (i), usually between 0-20%, of the products unit value (V), therefore $h = iV$ (Berling, 2022).

Upon solving for the EOQ, the total cost of ordering can be found using the formula in Equation 3.3 (Axsäter, 2006, p. 53).

$$C(Q) = \sqrt{2Adh} \tag{3.3}$$

A benefit of using the EOQ formula is its simplistic nature and the fact that it is relatively insensitive to large deviations in order quantities in terms of costs (Axsäter, 2006, p. 54). However, in practice, it is highly unlikely that the assumption of no backordering holds true, and there is typically some sort of penalty or backorder cost related to customers waiting for goods that should be considered when calculating the optimal order quantity. Additionally, the assumption that costs remain constant does not consider that in practice there are often quantity discounts for ordering larger batches.

3.4.2 Reorder point

In combination with the optimal order quantity, the value at which an order should be triggered needs to be calculated. The most common method is referred to as the reorder point (ROP) formula which is shown below in Equation 3.4 (Handfield & Bozarth, 2015, pp. 351-356). The ROP formula considers the demand rate (d) and lead time (L), which are assumed to be constant.

$$R = dL \tag{3.4}$$

However, in practice, the demand rate and lead time are rarely constant which requires the reorder point to be set slightly higher to account for the unknown variability in the demand and lead time patterns (Handfield & Bozarth, 2015, pp. 345-346). This uncertainty is balanced through the use of safety stock (SS) which is an additional stock that is held in case of unexpected spikes in demand or changes to replenishment times in order to avoid having supply shortages. Therefore, Equation 3.5 shows the modified formula for calculating the reorder point that is used when incorporating safety stock and considering that the demand rate and lead time are no longer constants.

$$R = \underline{d}\,\underline{L} + SS \tag{3.5}$$

The formula for calculating safety stock will be presented in the following Section 3.4.3.

3.4.3 Service level and safety stock

As previously stated, the role of safety stock is to act as a buffer to ensure that demand can still be satisfied in the event of incorrect forecasting and demand uncertainty (Meindl & Chopra, 2016, pp. 314-315). Demand can be highly uncertain and if stock is not available for purchase, the backlash can be detrimental to an organization in terms of lost margins. However, costs are also increased as a result of holding additional inventory, therefore there must be a balance when considering how much extra stock to hold. Therefore, a common method of setting the safety stock is by connecting it to the service level. Both the service level definition used and what is considered an acceptable service level will affect the level of safety stock. The most commonly used definition is S_1, the probability of not stocking out during an order cycle (Axsäter, 2006, p. 95).

To adequately consider the trade-off between stock-outs and holding excess inventory, Meindl & Chopra (2016, p. 316) recommend three key questions:

1. What is the appropriate level of product availability?
2. How much safety inventory is needed for the desired level of product availability?

3. What actions can be taken to reduce safety inventory without hurting product availability?

The equation for safety stock is shown below in Equation 3.6, where z corresponds to the required service level (Handfield & Bozarth, 2015, pp. 355-356). The zValues are shown below in Table 3.2.

$$SS = z\sqrt{\underline{L}\sigma_d^2 + \underline{d}^{\,2}\sigma_L^2} \tag{3.6}$$

Where,

$\underline{d}$ = average demand per time period
$\underline{L}$ = average lead time
σ_d^2 = variance of demand per time period
σ_L^2 = variance of lead time
z = number of standard deviations above the average demand during lead time (higher z values lower the probability of a stockout - service level)

Table 3.2. zValues used to calculate safety stock based on service level (Handfield & Bozarth, 2015, p. 356)

zValue	Corresponding service level
0.84	80%
1.28	90%
1.65	95%
2.33	99%

Considering the formula, the level of safety stock is impacted by the lead time and demand uncertainty, average lead time, and the desired level of service (Handfield & Bozarth, 2015, p. 356).

3.5 Forecast

The main drivers in MTO systems are actual customer orders, while MTS companies are driven by forecasts of future orders (Gansterer, 2015). However, forecasts also play an essential role in MTO systems. They are considered in high-level decision-making to balance capacity requirements and production quantities for medium/long-term planning horizons. Moreover, MTO companies primarily forecast for raw materials/purchase components, which is the level that experiences "independent demand" (Olhager, 2023). This means the demand for raw materials and components is not directly related to the demand for the final product but is determined by the company's production requirements.

When analyzing forecasting, the starting point is to distinguish the forecast types. Handfield & Bozarth (2015, p. 267) separate forecasts into three common types: demand forecast, supply forecast, and price forecast. For the purpose of the study, demand forecast, and supply forecast are the most relevant since they directly impact inventory management, while pricing forecast is a financial aspect.

The demand forecast estimates the quantity of a product that customers will buy during a specific period (Handfield & Bozarth, 2015, p. 267). It helps businesses to plan production, inventory, and supply chain activities. Demand forecasting aims to determine the market requirement for a product so that a business can adjust its operations to meet the customers’ needs. At the same time, supply forecasting estimates the availability of a product at suppliers or manufacturers by considering supplier capacity, lead times, and production schedules. It helps businesses to plan procurement, production, and inventory activities. All push processes in the supply chain are performed in anticipation of customer demand, whereas all pull processes are performed in response to customer demand (Meindl & Chopra, 2016, pp. 177-181). The manager must plan the activity level for push processes, such as production, transportation, or any other planned activity. For pull processes, the manager must plan the available capacity and inventory level rather than the actual amount to be executed. In both instances, the manager must first forecast customer demand. However, disconnections can occur when each stage in the supply chain makes separate forecasts, which rarely align with each other. The result is a mismatch between supply and demand. Although, when all supply chain stages work together to produce a collaborative forecast, the forecast tends to be much more accurate.

According to Axsäter (2006, pp. 7-8) and Bongsug (2009), forecast data is crucial to supply chain planning and influences various activities such as production, inventory management, and material sourcing. There are two ways to forecast future demand: one relies on historical data and mathematical models such as moving average and exponential smoothing. This approach is commonly used in computerized inventory control systems, and the main advantage is that it can handle large amounts of data and be regularly updated to provide accurate forecasts. While the other approach involves gathering demand data from salespeople who might or might not use mathematical models and might receive information from customers. At the same time, consensus forecasting is gaining popularity and involves collaborative efforts among different groups ranging from salespeople to business or sales managers. As a result, single-number forecasting is available for master production planning, improving forecast accuracy.

Collaborative Planning, Forecasting, and Replenishment (CPFR)

An important follow up aspect of the sharing of demand data is to engage in collaborative planning, without this, coordination cannot happen (Meindl & Chopra, 2016, pp. 257-265). One approach is to use collaborative planning, forecasting, and replenishment (CPFR) which is a practice that, “combines the intelligence of multiple partners in the planning and fulfillment of customer demand”, allowing the expertise of multiple supply chain actors to be utilized (Småros, 2003).

Depending on the industry and point of application in the supply chain, the implementation of CPFR can look very different (Meindl & Chopra, 2016, pp. 257-265). However, a key factor to enabling the implementation of CPFR is that the supply chain actors have standardized practices for information sharing, and synchronized data. Assuming that the infrastructure for adequate information sharing is in place, better information is available to all actors on an increased number of variables (Småros, 2003). In addition to isolated historical demand patterns, information from other supply chain actors, for example promotions or raw material price increases, can be shared which can avoid the creation of conflicting plans. An aspect that sets CPFR apart from simply forecast sharing, however, is that an additional emphasis is placed on the creation of a joint business plan as well as guidelines and rules for the collaboration. In this sense the individual parties spend time and money ensuring that their objectives and actions are mutually beneficial.

It has been observed that introducing CPFR can significantly reduce inventory levels as a result of more accurate forecasting (Småros, 2003). CPFR can be very beneficial to MTO systems which encounter high levels of demand uncertainty. This is because it enables better coordination which results in increased forecasting accuracy through better visibility across the supply chain. However, even though there are many benefits to implementing CPFR, it is not very widespread. This is because of major barriers to implementation including a lack of information sharing infrastructure, lack of forecasting resources or processes, and the general complexity of the model.

3.6 Collaboration

When it comes to collaboration, research is conflicting on whether internal or external coordination is more important (Norrman & Naslund, 2019). Some say that internal coordination, among actors within the value chain, is more significant as a starting point while others believe that external integration stimulates internal integration, so it should precede. Alternatively, some research points to the fact that they are interlinked and should be prioritized simultaneously to support collaboration across all supply chain actors.

The value chain includes different company activities that work together to provide customer value, and these activities are known as generic value-added activities (Feller, Shunk & Callarman, 2006). In the past, Porter (1985) connected the value chains of different companies to create a value system. At the same time, the supply chain includes all the activities involved in producing and delivering a final product or service, starting from the supplier's supplier and ending with the customer's customer (Feller, Shunk & Callarman, 2006). The main focus in supply chains is on managing costs, improving efficiency, and ensuring the smooth flow of materials from their different sources to their ultimate destinations. In general, the value chain is related to a firm's internal activities, while the supply chain relates to external activities that connect the value chains of different companies. Thus, collaboration was analyzed from both a value chain and supply chain perspective.

3.6.1 Value chain coordination

Oftentimes, managers view the organization as several independent departments (Rummler & Brache, 1991). However, this ignores the customer and product perspective, but more importantly, it ignores the flow of activities and processes between the various functions. Primarily who is involved in processes, how they are executed, and the purpose of the process. In order to understand these interactions, a cross-functional, horizontal view of the process structure along the value chain should be considered. This is vitally important as some of the most critical areas for improvements lie in the interfaces between functional departments.

Additionally, effective management requires a cross-functional effort, alignment, and integration between various units including sales, manufacturing, finance, marketing, and so on in order to satisfy customer demand (Boros et al., 2017; Norrman & Näslund, 2019). However, this is easier said than done as traditional organizational structures are built around a siloed mentality and inherently create conflicts over resources and power between the different units which can be further exacerbated by interpersonal issues. For example, according to Stone (2004), conflicts and a lack of collaboration across the value chain can stem from a competitive rather than team-oriented company culture, unclear policies and procedures, inadequate interpersonal and communication training, and pro-conflict managers.

Regardless of the source, a lack of internal collaboration across the value chain can create divergent objectives among the functional departments and takes the focus away from the organization’s overall wellbeing (Rummler & Brache, 1991; Stone, 2004; Norrman & Näslund, 2019). Instead, each unit will work towards their own individual, suboptimal goals. For example, according to Norrman & Näslund (2019), functional performance measures are usually in conflict with each other. Some solutions to solving this and increasing collaboration include creating common goals and objectives, measuring the financial outcomes of cross-functional initiatives, and creating mutual accountability/reward systems.

3.6.2 Supply chain collaboration

In supply chain management, collaboration is defined as the sharing of responsibilities including planning, management, execution, and follow up measurement between two or more companies (Min et al., 2005). In general, it is a main driver for effective supply chain management and can help manage the inherent complexity as well as the possible negative impacts that come from a lack of coordination, most prominently the bullwhip effect (Meindl & Chopra, 2016, p. 248). The bullwhip effect is the phenomenon where supplier orders tend to have a more considerable variance than sales to the buyer; thus, customer demand is distorted (Bayraktar et al., 2008). This demand distortion propagates upstream in the supply chain in an amplified form. Elevated inventory levels and inadequate customer service rates typically represent symptoms of the bullwhip effect.

A lack of coordination typically arises when supply chain actors have conflicting objectives focused on individual profit maximization, or due to non-existent, delayed, or distorted information sharing (Meindl & Chopra, 2016, pp. 248-249). Sometimes a lack of coordination is intentional, while other times it is a result of supply chain complexity. For example, if an organization has a large product range, sharing timely, accurate, and detailed information on each product can be costly and time consuming. However, consequences of the bullwhip effect include lead time, inventory, and production holding cost increases as well as profit margin and product availability decreases (Bayraktar et al., 2008). Therefore, the challenge today is to develop coordination with internal, functional supply chain actors and also engage in external collaborations with both suppliers and customers, in spite of increasing supply chain complexity.

According to Min et al. (2005), the primary benefits of collaboration are:

- Better demand planning capabilities, inventory visibility, and new knowledge/skills
- Reduced inventory and cost savings
- Increased responsiveness and access to target markets

Additionally, Meindl & Chopra (2016, p. 260), state that a major benefit is a reduction in duplication of jobs which can save time and money across the supply chain. In an MTO setting, this idea of collaborative and coordinated decision-making provides the greatest benefit rather than the direct cost reductions (Olhager & Prajogo, 2012). This is because firms who have higher levels of external interactions tend to perform better in terms of customer service, delivery accuracy and lead-time, quality, and flexibility. These are attributes that give supply chains a competitive advantage against competitors in an MTO environment.

While collaboration is considered a core aspect of supply chain management, it lacks widespread implementation in practice (Min et al., 2005). Primarily as there are many barriers to implementation. These barriers can include aspects like a lack of trust, lack of information sharing capabilities, and/or varying isolated objectives. Min et al. (2005) recommends that supply chain actors work on aligning objectives, defining roles and responsibilities, enhancing their information capabilities, and building relationships with their supply chain partners.

3.6.3 Supply chain information sharing

A foundational aspect of enhancing coordination throughout the supply chain is through information sharing. Primarily because mutual trust is necessary for supply chain actors to engage in coordination, therefore, by sharing accurate and timely information, your supply chain partners will be more inclined to collaborate with you (Meindl & Chopra, 2016, p. 260). This also enhances supply chain visibility, or the ability to access high quality information that is useful for balancing supply and demand, which will allow the supply chain to respond more effectively (Kembro & Selviaridis, 2015; Meindl & Chopra, 2016, p. 260; Kalaiarasan et al., 2022). This smoother flow of information reduces uncertainty in the supply chain by blurring boundaries of various supply chain actors and inevitably reduces the bullwhip effect (Vanpoucke, Vereecke & Muylle, 2017). In recent years, it has only become easier to engage in information sharing as information technology has developed.

According to Kembro & Selviaridis (2015), information sharing can happen on all three organizational levels resulting in varying benefits. On an operational level, information regarding demand/sales data, changes to production, and deliveries should be shared. This will support the daily flow of goods and allow for operational process optimization. On a tactical level however, midterm forecasts, trends, and changes including, for example, plans for design upgrades should be shared. This information is used to look ahead from roughly 1-3 months and works to synchronize capacity and plan resource allocations to support matching supply and demand. Lastly, on a strategic level, yearly forecasts and marketing strategies including planned promotions should be shared to be transparent about future plans for growth along the supply chain. Additionally, a joint business plan should be created between the supply chain actors. These actions are mainly to strengthen trust and ensure that the chain is equipped to handle future expansions.

By sharing these various types of information, organizations can see both short- and long-term benefits like reduced inventory, better planning capabilities and risk management, improved profitability, and cost performance, as well as many others (Kembro & Selviaridis, 2015; Kalaiarasan et al., 2022). The benefits primarily arise as supply chain visibility becomes greater, because there is a decrease in uncertainty which is a root cause of suboptimal decision-making.

Unfortunately, while the number of benefits that arise from information sharing are plentiful, there are several barriers to implementation that have slowed the development and use in a practical setting. Many organizations lack access to quality information, meaning that their data is often received in an untimely manner, is inaccurate, and possibly not credible (Kembro & Selviaridis, 2015). Yet, even if they overcome that barrier, they traditionally lack technological integration or the ability to share the data with their supply chain partners. Additionally, barriers stem from more human factors such as a lack of trust, or a fear of dependency and loss of power due to possible asymmetric benefits. All in all, however, it has been shown that engaging in information sharing lays the foundation for better coordination, performance, and relationships between supply chain partners.

3.7 Key performance indicators

In 1995, Eccles suggested a significant change in how businesses measure performance. Rather than solely relying on financial figures, companies also considered a broader range of measures, such as quality and market share. Many companies have been tracking these non-financial measures for some time. However, the real revolution lies in giving them equal importance to financial measures when making strategic decisions, promotions, bonuses, and other rewards, as there is usually a financial bias. At the same time, according to Neely, Gregory & Platts (1995), performance measurements quantify an action's effectiveness and efficiency. Effectiveness is the degree to which a customer's needs are fulfilled, while efficiency measures how economically a company's resources are used to meet a predetermined level of customer satisfaction. Performance measurement systems refer to the complete range of metrics employed to estimate the effectiveness and efficiency of actions.

In the context of production and inventory management, planning and execution of supply chain management often have gaps. However, continuous efforts to close these gaps are necessary for higher supply chain performance (Chae, 2009). Performance metrics or key performance indicators (KPIs) provide visibility and help assess the accuracy of supply/demand planning and execution, revealing gaps between the plan and execution and offering opportunities to identify and correct potential problems. The SCOR model provides a valuable framework for developing supply chain performance metrics by identifying potential KPIs for the meta-level processes of plan, source, production, and delivery. However, choosing the correct number of key KPIs is a challenge, and companies should start with a few KPIs to monitor and manage the comprehensive supply chain processes successfully (Chae, 2009; Bialas, Revanoglou & Manthou, 2020).

This study will focus on the planning phase of the SCOR model, where inventory management is inserted and involves crucial elements of all supply chain activities, including sourcing, production, and delivery. Regarding performance, it is essential to keep track of various planning activities, such as forecasting demand, S&OP, and inventory & distribution requirement planning (Chae, 2009). A range of articles and books was analyzed, and the most used KPIs to monitor inventory management are shown in Table 3.3.

Table 3.3. KPIs for inventory management monitoring

KPI	Authors	Comment
Inventory Days of Supply (IDS)	(Shepherd & Günter, 2006; Chae, 2009; Bialas, Revanoglou & Manthou, 2020)	There are multiple ways to calculate IDS. One common method is shown below: $IDS = \frac{the\ average\ value\ of\ inventory}{the\ annual\ cost\ of\ goods\ sold} * 365$
Days of Finished Goods (DFG)	(Shepherd & Günter, 2006; Chae, 2009; Bialas, Revanoglou & Manthou, 2020; Galankashi & Rafiei, 2022)	Days of Finished Goods helps to understand the inventory levels relative to the demand and provides insight into how long the existing inventory will last based on average daily usage. Similar to the IDS but at a finished product level.
Obsolete inventory	(Shepherd & Günter, 2006; Chae, 2009; Handfield & Bozarth, 2015; Meindl & Chopra, 2016; Bialas, Revanoglou & Manthou, 2020)	Obsolete inventory refers to the worth of the portion of the warehouse inventory that has remained unused for a specific period of time.
Service level	(Shepherd & Günter, 2006; Axsäter, 2006; Handfield & Bozarth, 2015; Meindl & Chopra, 2016; Bialas, Revanoglou & Manthou, 2020; Galankashi & Rafiei, 2022)	Service level is a KPI that represents the proportion of material requests that can be fulfilled using the available stock. It can be incorporated to ensure that optimizing inventory management costs does not lead to a delay in meeting demand requirements.
Inventory turnover	(Shepherd & Günter, 2006; Axsäter, 2006; Handfield & Bozarth, 2015; Meindl & Chopra, 2016; Bialas et al., 2020; Galankashi & Rafiei, 2022)	Inventory turnover indicates how frequently the inventory has been replaced over a period of time. A low turnover rate indicates higher expenses because items are held for extended periods. It is calculated by dividing the cost of sold goods by the average inventory value. There is an inverse relationship between inventory turnover and IDS, where higher values of IDS correspond to lower values of inventory turnover, and vice versa.
Total inventory investment	(Olhager, 2010; Chod, 2017; Tsai & Zheng, 2013)	Total inventory investment is the total value invested in inventory at a specific moment, covering the expenses incurred on the raw materials, unfinished products, and finished goods. It is crucial for companies with tangible products as it impacts their cash flow, profitability, and overall financial well-being. Inventory control aims to minimize the total inventory investment without reducing service level.

ROCE (Return on capital employed)	(Shepherd & Günter, 2006; Axsäter, 2006; van Weele, 2014; Handfield & Bozarth, 2015; Meindl & Chopra, 2016; Galankashi & Rafiei, 2022)	ROCE is a financial metric that indicates a company's capacity to produce profits concerning the capital invested in its operations. It allows assessing how effectively a company employs its capital to generate earnings.
Forecast Accuracy or Forecast error	(Shepherd & Günter, 2006; Axsäter, 2006; Chae, 2009; Handfield & Bozarth, 2015; Meindl & Chopra, 2016)	The formula used involves finding the minimum value between the actual number of sales and the amount predicted, which is divided by the maximum value between the actual sales and the prediction. This formula should be applied for each salesperson, sales subsidiary, product, and product category to calculate forecast accuracy.
Supply lead time	(Axsäter, 2006; Handfield & Bozarth, 2015; Meindl & Chopra, 2016)	Supply lead time measures the time between an order's placement and arrival. Longer lead times negatively impact a supply chain's agility/responsiveness and increase inventory levels due to increased uncertainties. Therefore, MTO companies should actively work towards reducing lead times, even if it creates high costs. On the other hand, MTS companies should balance the costs and benefits of reducing lead time.
Order lead time	(Handfield & Bozarth, 2015; Meindl & Chopra, 2016)	Order lead time provides an overview of the order processing system's effectiveness. If lead times are long, there are likely bottlenecks in the process. Order lead time measures the number of days a product takes to start being produced until the final delivery. This is useful in determining operational efficiency, and keeping track of this metric can help identify production, warehousing, or logistics inefficiencies.

The most used KPIs to monitor inventory management were segmented into two categories. First, KPIs were divided into those directly related to inventory and indirectly related. The second step divided the KPIs into financial and non-financial aspects. The segmentation is shown in Figure 3.9.

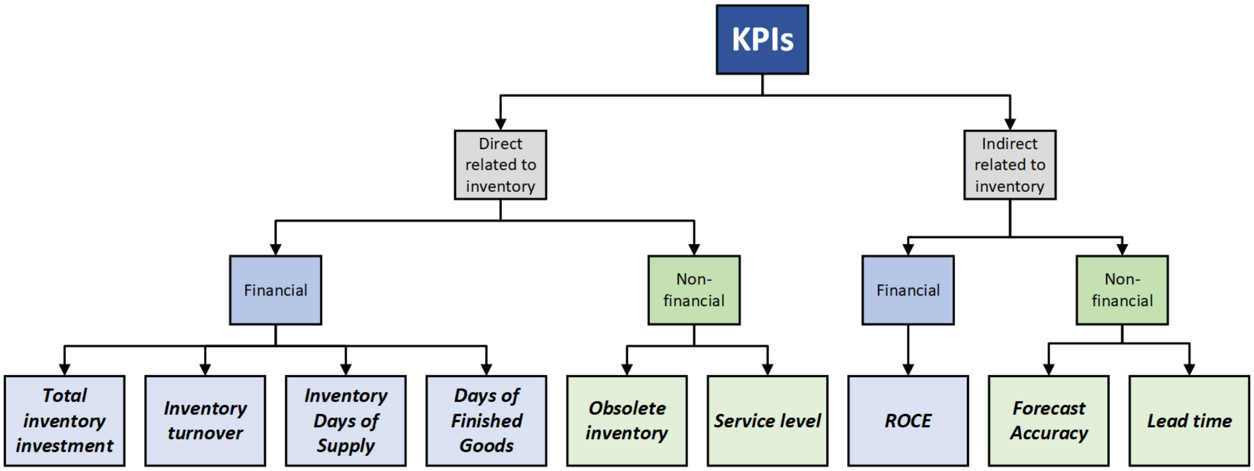

Figure 3.9: KPI segmentation (Created by the authors)

Finally, the DuPont analysis is a financial analysis tool created by DuPont Corporation in the early 1900s that calculates a company's return on investment using two factors: sales margin and capital turnover ratio (van Weele, 2014, p. 12). It is used to gain insights into a company's financial health and profitability by breaking down the relationship between KPIs. In the inventory management context, the DuPont analysis can be used to financially measure the relationship between the total inventory investment and the ROCE (Return on capital employed). Figure 3.10 shows an example of the DuPont analysis in a fictional company.

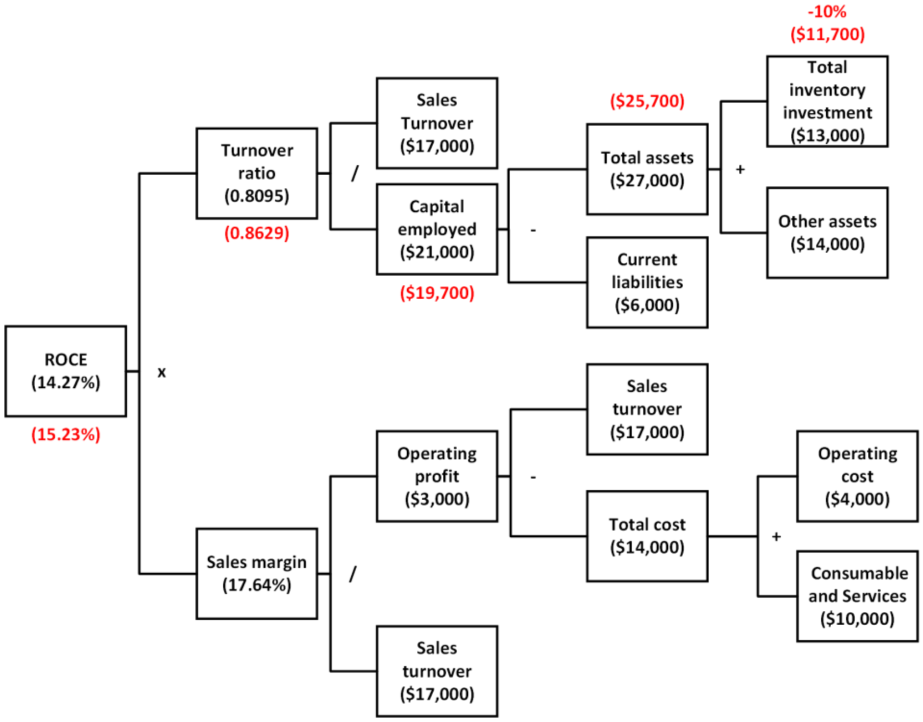

Figure 3.10: DuPont analysis example relating the impact of TII to ROCE at a fictional company (Inspired by van Weele, 2014, p. 12)

3.8 Organizational structures

Defining the organizational structure of a supply chain is crucial to understanding the roles and responsibilities of the different actors involved (Johnson et al., 2014; van Weele, 2014, p. 286). Therefore, it is important to discuss the differences between centralization and decentralization of the decision-making processes within an organization. Figure 3.11 visualizes a range of structures along the spectrum of centralized and decentralized, including hybrid organizational structures.

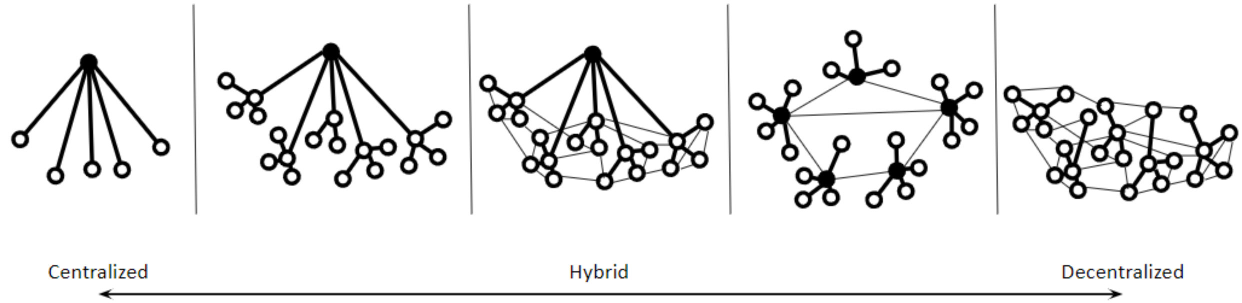

Figure 3.11: Spectrum showing examples of organizational structures (Created by the authors)

Traditionally, there has been a push for centralization in supply chain management due to the benefits of standardization, economies of scale, and maintaining expert knowledge (Johnson et al., 2014; van Weele, 2014, p. 286). However, there are also advantages to a more decentralized structure, including better relationships with external partners, improved service levels, and reduced costs due to decisions made closer to the customer. Some level of centralization is necessary to align decisions with organizational goals, even when taking a decentralized approach. For example, a central planner can make stocking decisions for the entire system in multi-level inventory systems, where a product moves through several locations before reaching customers (Lee & Whang, 1999). However, in practice, many supply chains operate in a decentralized manner, with site managers responsible for specific activities and decisions at each location. Each site operates as a responsibility center, and the site manager's performance is evaluated based on centrally defined performance metrics. Nevertheless, decentralization can create a misalignment of incentives between the delegating party (the principal) and the delegates (the agents). To address this issue, a set of rules, known as a measurement scheme, can be implemented to specify accounting methods, transfer pricing schemes, performance metrics for site managers, and operational constraints. This scheme ensures that sites compensate each other for transferring goods, proper performance metrics are used to evaluate managers, and limitations are followed.

It has been shown that having centralized decision-making within a supply chain, particularly in a MTO setting, can improve supply chain performance (Sahin & Powell Robinson Jr., 2005). In line with contingency theory however, there is not a singular, universal structural design that will fit all organizations (Boute, Dierdonck & Vereecke, 2011). Rather, there are situational factors that will influence optimal structure, oftentimes resulting in hybrid options, mixing both centralized and decentralized attributes. Therefore, understanding the strategy through the environment, and competitive factors a supply chain competes on, will allow there to be a structural fit.

3.9 Summary

The literature review has identified eight pertinent topics that impact how companies engage in inventory management across their supply chain and operations. The topics have been arranged in a logical sequence, starting from the broad perspective of strategic alignment, and then gradually narrowing down to specific topics related to inventory management. Figure 3.12 shows the relationships between the topics discussed in this chapter.

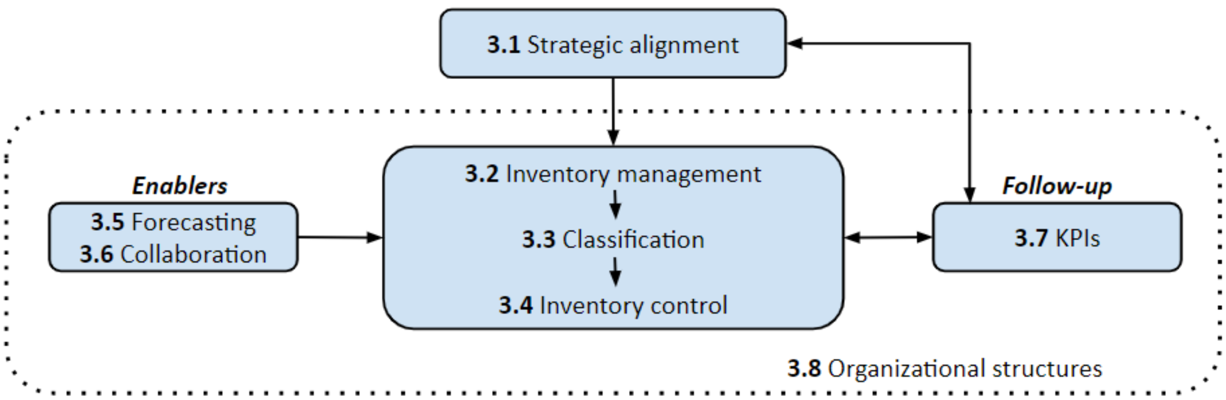

Figure 3.12: Relationship between the topics used in the literature review (Created by the authors)

The alignment of a company's strategy (3.1) has a direct impact on its approach to inventory management (3.2). This, in turn, affects how the company classifies types of inventory and items (3.3), ultimately determining the inventory control approach (3.4). This is because the operational decisions should be clearly aligned and assist the organization in reaching the supply chain’s strategic goals. Therefore, the classification of inventory and items should reflect the supply chain strategy, and this will impact the methods and parameters used to control the different categories.

At the same time, inventory management (3.2) is driven by crucial aspects such as forecasting (3.5) and collaboration (3.6), which are enablers of effective inventory management. For example, even if the proper classification methods have been defined and inventory control parameters have been set, if they are based on inaccurate forecasting information, the results and therefore treatment of the inventory will be incorrect. Similarly, if there's a lack of collaboration or information sharing, there will be increased uncertainty and possibly lower trust in the inventory management system. Therefore, the enablers provide the necessary foundation for implementing more effective inventory management practices.

Nevertheless, a company measures the success of its inventory management (3.2) through relevant KPIs (3.7), which should have targets that are in line with the company's strategic decisions. The relationship between the strategy (3.1) and KPIs goes both ways as they should inform each other. A similar relationship is seen between the KPIs and the inventory management, classification, and control techniques, as the output from these inform the KPIs but the KPIs also help the management techniques evolve.

Lastly, a global company's decision-making approach can be centralized, decentralized, or a hybrid of both (3.8). The chosen approach will impact the chain of command, dictate how decisions are made and executed, and determine where along the supply chain information is shared. Therefore, the chosen approach indirectly impacts all previous topics besides strategic alignment.

Chapter 4 - Empirical Findings at Alfa Laval

This chapter outlines the supply chain structure of the BU GPHE at Alfa Laval, as well as the current processes and future directives related to inventory management at Alfa Laval. The information is primarily based on employee interviews and archival documents provided by Alfa Laval, with observational information occasionally being used to support these findings.

4.1 Alfa Laval GPHE supply chain

The high-level description of the Alfa Laval gasketed plate heat exchanger (GPHE) supply chain is shown in Figure 4.1, including raw material and component suppliers who sell directly to both global core component (GCC) factories and local assembly (LA) factories.

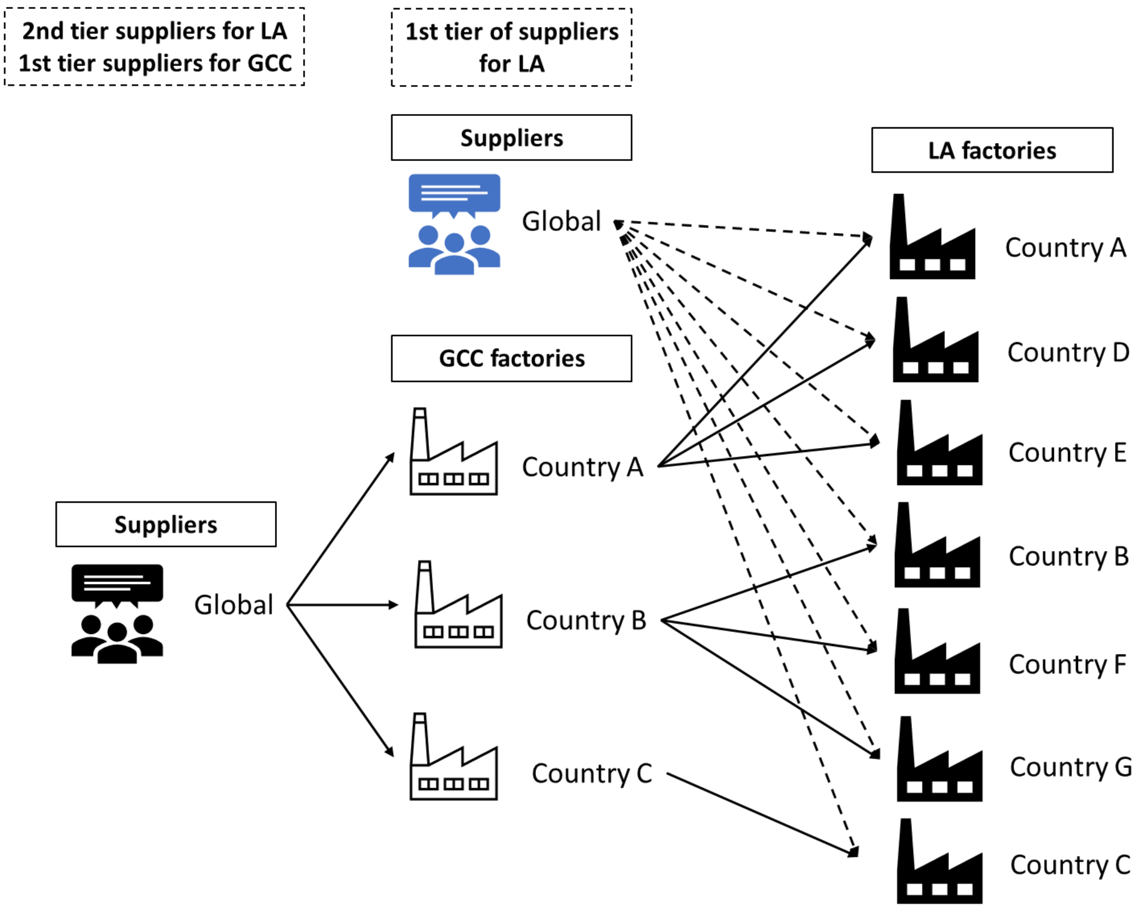

Figure 4.1: Alfa Laval GPHE supply chain (Created by the authors)

Alfa Laval GCC factories work with global and local suppliers. Raw materials, stainless steel, coils, and gaskets are purchased globally, while packaging, pallets, and plastics are bought locally for each factory. Nevertheless, global suppliers are responsible for the most significant expenses in sourced components, and the lead time can vary significantly. For instance, more unique items, such as specific gasket polymers, can have over a year of lead time, making the process's uncertainty very high. Alfa Laval's LA factories also work with global and local suppliers, whereas GCC factories are considered suppliers to the LA factories. For some items, such as specific types of gaskets, plants exchange units with each other. The GPHE operations are shown in Figure 4.2.

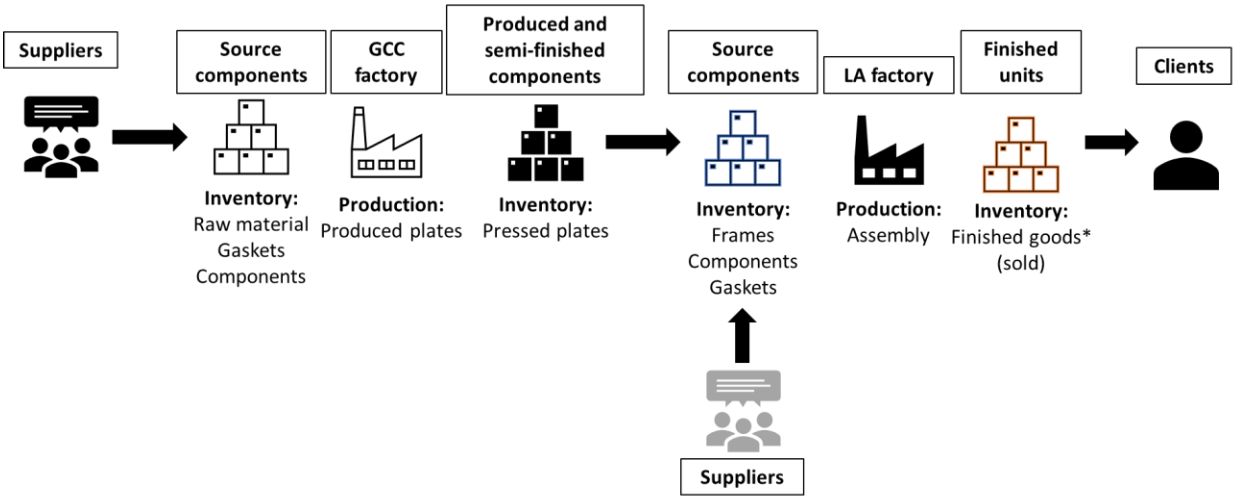

Figure 4.2: GPHE operations and holding inventory (Created by the authors)

Regarding inventory, the GCCs is responsible for raw materials of stainless steel, coils, gaskets, and components upstream of its operation and pressed plates and components downstream. On the other hand, the LAs are responsible for frames and other components to assemble the heat exchange upstream of its operation and finished products downstream. However, the finished products are already sold, waiting for delivery, or waiting to be picked up by the customers. So, no unsold units are stored at LA factories.

4.2 Strategic alignment

The GPHE business unit (BU) has three strategic goals:

- Be the #1 Heat Transfer Service company.
- Provide the #1 Experience for all customers.
- Be the #1 in Transforming Energy market.

In order to work towards these goals, the BU has several operational focus areas, one being sales and operations planning (S&OP), and is monitoring financial targets related to profitable growth, efficiency, and the bottom line. Within the S&OP operational focus areas, ATHENA is a major supporting initiative, with the creation of a unified set of inventory principles and policies being a main deliverable for 2023.

4.2.1 Supply chain strategy

The components produced at the GCCs, and the finished GPHE units that are assembled at the LAs, have different characteristics and levels of uncertainty related to the products.

As previously mentioned in Section 4.1, the GCC factories produce plates which are bought internally and are then used by one of the LA factories for the production of a complete GPHE unit. As the GCCs sell to an internal customer, a larger amount of information on their customer's needs is typically readily available. Additionally, while the outputs in terms of plate and gasket design can be high, the number and variety of inputs used in their production is low. Lastly, there are only a few raw material suppliers for identified critical components, and Alfa Laval works to maintain positive relationships with them to sustain a secure supply of raw materials. While the number of possible suppliers and inputs increases the possible impact of risks related to disruptions, there is generally a low level of supply and demand uncertainty related to the production of plates. Additionally, they have relatively low levels of forecasting error, minimal stock-outs, and have medium levels of product variation, these characteristics are outlined in Table 4.1.

Table 4.1: Pressed plate characteristics

Aspect of demand	**Pressed plates**
Product variety	~ 1200 variations
Average margin of error in the forecast	~ 15%
Average stock out rate	~ 5%

Contrarily, while the components can be adequately forecasted for, the demand for finished GPHE units produced by the LAs is highly uncertain. This is largely due to the fact that each finished GPHE is tied to the specifications of a particular customer order and must therefore be assembled uniquely. This customization creates extremely high levels of product variation which leads to uncertainty. Additionally, while some customers are recurring, the BU GPHE does not have a pool of "key customers". The BU has tried to reduce the uncertainty by introducing standardization of the smaller GPHE units through a predetermined line. However, while there is a production incentive to enhance standardization, on the sales side there is a preference to continue being responsive to unique customer requests to ensure that they secure the orders.

Currently, Alfa Laval's strategy is to use their resources more efficiently while maintaining their current level of responsiveness and service provided to their customers. Therefore, they try to find a balance between an efficient and responsive strategy. The balancing can be seen through the division of their factories. Much of the standardization and pre-stocking of finished goods is done at the GCC locations in the form of plates where uncertainty is lower. This is because they have increased their abilities to forecast raw material needs and customer demand patterns as the goods are sold internally. Alternatively, customization and final assembly is postponed and done at the LA factories in order to be flexible to the uniqueness of customer demands.

4.2.2 Strategic decoupling point

According to the interviews, the BU GPHE has placed its decoupling point between the GCC and LA factories. As a result, the GCC factories follow a make-to-stock (MTS) approach to produce pressed plates. In contrast, the LA factories assemble finished units of heat exchangers using an assemble-to-order (ATO) method. However, Alfa Laval's product has little degree of modularization. Figure 4.3 illustrates the company's strategic decoupling point.

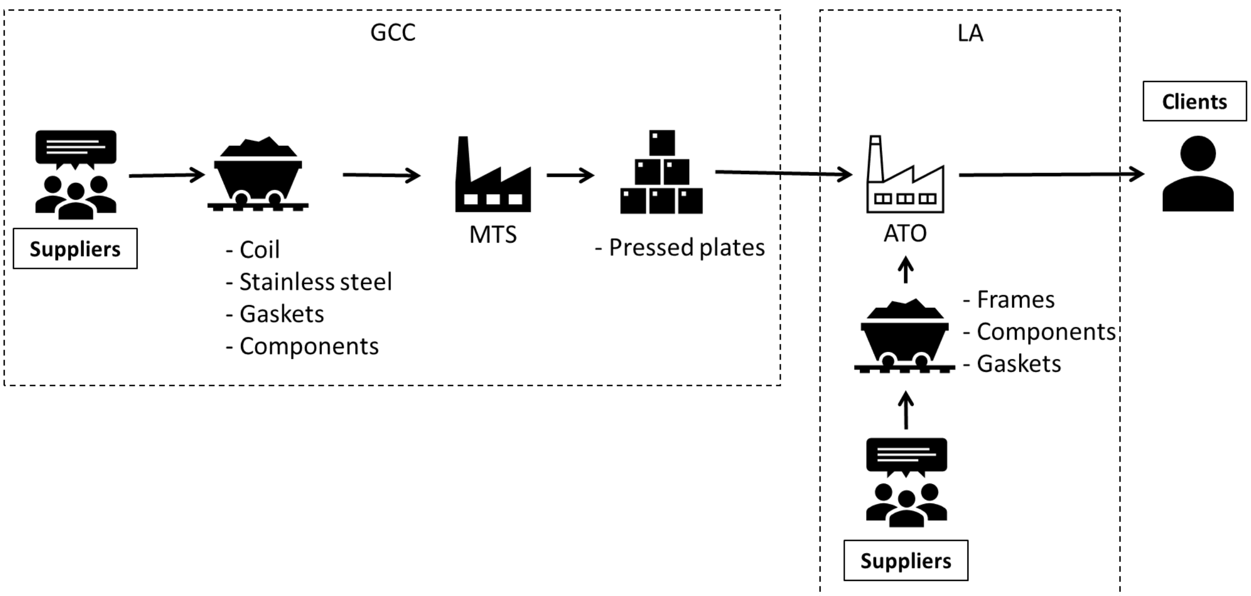

Figure 4.3: The strategic decoupling point of the BU GPHE (Created by the authors)

Overall, the BU's strategic decoupling point allows the company to balance efficiency and flexibility, ensuring the company meets customer demands while optimizing their operations. Therefore, the upstream operations at the GCC factory are characterized by a focus on efficiency, while the downstream operations focus on providing the necessary customization to meet customers' requirements.

4.3 Inventory management

In recent years, excess components and materials have been stored at the factories to rapidly fulfill customer demand by ensuring availability, which has led to an increase of tied up of capital. This approach was beneficial during the COVID-19 pandemic, but now Alfa Laval wants to reduce their inventory levels and better manage their stock flows across the supply chain. Currently, Alfa Laval is facing a challenge in globally managing inventory levels. Therefore, the S&OP department within the BU GPHE is working to implement a global set of inventory planning principles and policies under an initiative named ATHENA. ATHENA is the new inventory management and differentiated planning framework which aims to enhance assortment control, availability, and production efficiency. ATHENA is an iterative process with four main steps. The four steps of the process are shown below in Figure 4.4. Each step will be discussed in more detail in the following sections.

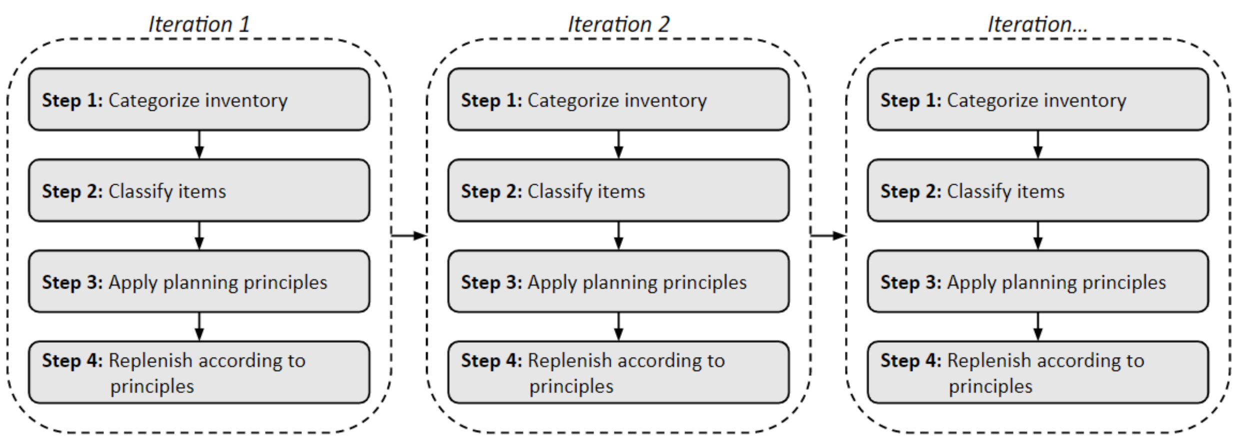

Figure 4.4: High-level overview of the ATHENA differentiated planning process

Within the GPHE operations, there is an excess inventory of raw materials and components upstream, as well as in its work-in-process (WIP) and sales-in-process (SIP) downstream. The largest portion of tied up capital is held in raw material and component stocks, which include gaskets and stainless steel in the form of coils and sheets. However, Alfa Laval also expends a significant amount of capital on SIP, which also takes up valuable space in the warehouse as the goods are finished but have not yet been invoiced and delivered to the customer.

ATHENA aims to enhance the availability of necessary components and goods while minimizing inventory levels. This is accomplished by reducing the time that products spend in stock, minimizing the presence of incorrect items, and increasing the availability of accurate items. Thus, minimizing the risk of obsolete components and products and ensuring that customers can access the required items.

4.3.1 Inventory types

ATHENA uses inventory classification to understand the composition of its inventory using a unified method. This allows the BU to analyze, describe, and explain the inventory drivers as well as understand how to address inventory issues. Thus, the company clearly notices where to reduce inventory and in which part. ATHENA divides the stock into six types: cycle stock, safety stock, pipeline stock, anticipation stock, hedge stock, and overstock. Figure 4.5 illustrates the company's inventory classification.

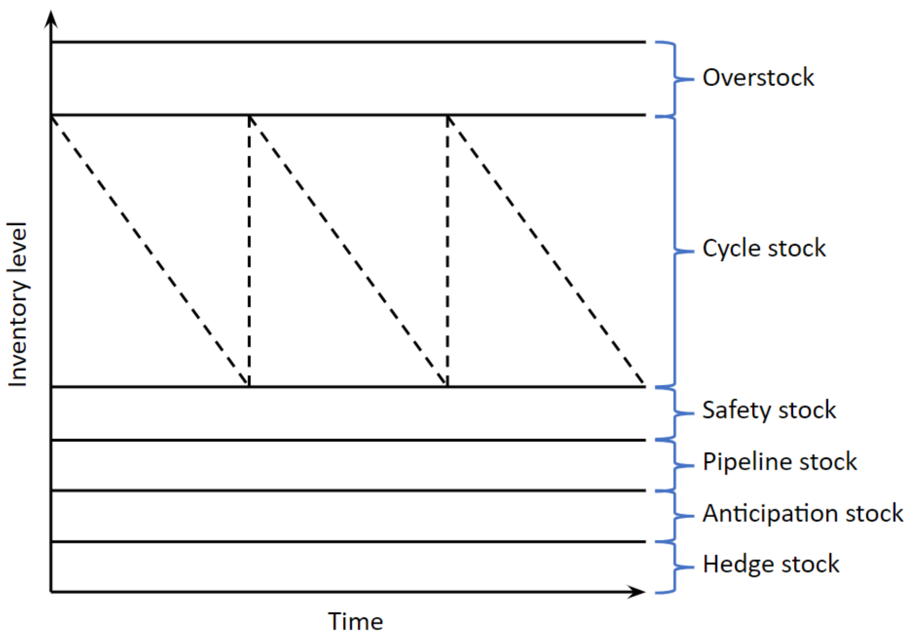

Figure 4.5: ATHENA inventory classifications

Cycle stock is the inventory frequently used and replenished in batch sizes, and it is often considered active inventory, constantly in use and replenishment. Safety stock is inventory used to fulfill the demand in case of unexpected uncertainties and imbalances between demand and supply. Pipeline stock consists of more than only inventory in transit but also SIP and WIP. Anticipation stock consists of inventory that covers expected imbalances between demand and supply. Hedge stock is used as a buffer against unforeseen events threatening the company's operations. Finally, overstock is considered an excess of inventory for which no explanation or reason can be found to hold this type of stock.

Moreover, ATHENA examines the ownership of different types of inventories and categorizes them based on Figure 4.6. For example, cycle stock, safety stock, and other inventory types can be produced by the GCC or LA factories, such as pressed plates or frames, or acquired by the purchasing department of the LAs or GCCs, such as gaskets or other components.

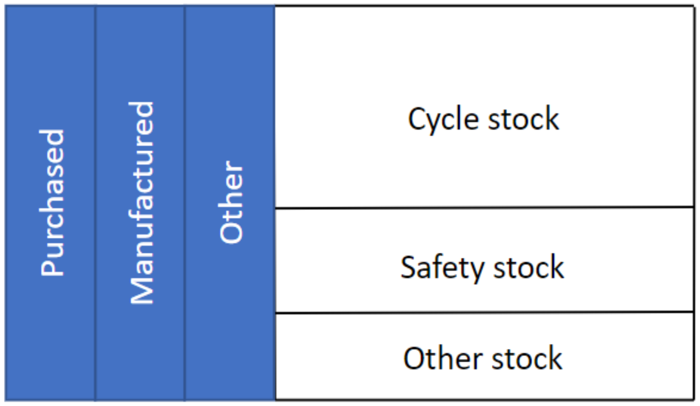

Figure 4.6: ATHENA inventory ownership

4.3.2 Item classification

To enhance manageability, ATHENA employs item classification methods in its inventory management system. ATHENA uses the double ABC or ABC-XYZ method to classify items. This classification method is used to categorize raw materials, components, gaskets, and pressed plates, at the LAs and GCCs. Figure 4.7 shows ATHENA's classification method.

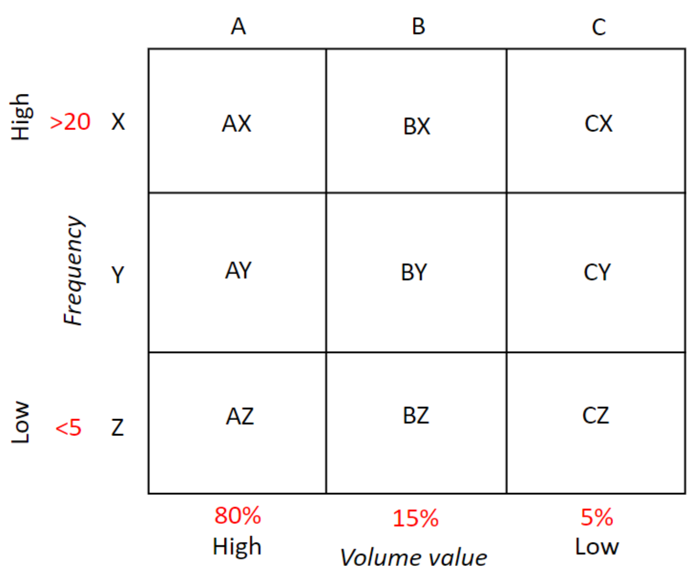

Figure 4.7: ATHENA item classification method

The frequency, along the vertical axis, is determined by calculating the number of times it has been picked within the previous 52 weeks. This calculation results in a value ranging from 0 to 52, with items that have been picked more than 20 times classified as high frequency, and those selected less than five times categorized as low frequency. This analysis is flexible and interactive, which means an item selected 19 times could be considered high frequency. On the other hand, the horizontal volume value axis is determined by an item's consumption over the last 12 months and its cost. Given that reducing tied up capital is a top priority for Alfa Laval, the primary focus is on optimizing inventory levels of AX items, which have a significant financial impact. After categorizing items into 9 groups according to predefined rules, the ATHENA process implements internal principles for each category using the matrix. The planning principles are presented in Figure 4.8.

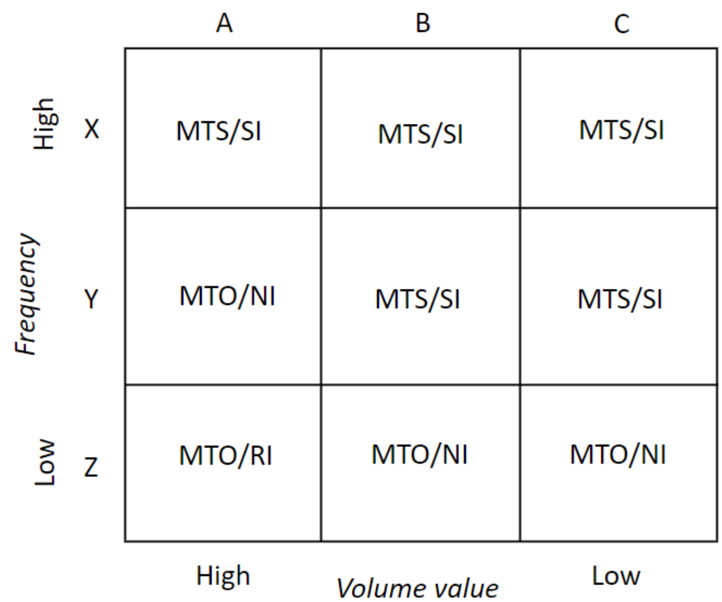

Figure 4.8: ATHENA's planning principles according to classification method

Further definitions of each category, as defined by ATHENA, are beyond the scope of this thesis. Generally, high frequency picked items adopt the MTS strategy for plates and a stocked item (SI) strategy for raw materials and components, while low-frequency-picked items follow the make-to-order (MTO) for plates or non-stocked item (NI) approach for raw materials and components. The volume value determines whether an MTO/NI or MTS/SI strategy is used for middle-frequency-picked items.

4.4 Inventory control

Currently, inventory control parameters for order quantities and order initiation or reorder points, are automatically calculated when using two enterprise resource planning (ERP) systems. The ERP systems use historical data and cost factors to determine parameters. This creates standardized calculation procedures, and therefore output parameters.

Additionally, the safety stock is automatically calculated in the system for locations using the older ERP system. However, in locations using the new ERP system, the safety stock is manually calculated using Excel. The primary driver for the safety stock calculation is a centrally determined service level. The role of safety stock within the BU is to minimize production down time and ensure the availability of components and raw materials in the event of unexpected demand or supply disruptions. As the finished goods are manufactured in a MTO fashion, there are no safety stocks of finished goods.

It has been observed that while the common inventory control parameters are calculated, additional parameters and tools are needed in order to have a more adequate visualization of the true position of the inventory. Currently, the inventory position is visualized in some locations by extracting the parameters from the ERP system and putting them into Excel for additional calculation.

4.5 Forecast

The BU GPHE implements a systematic approach to analyzing demand forecasts, which is integrated into the demand planning process of the S&OP framework. To predict demand, an advanced demand planning software is used which leverages historical order data and mathematical models. Additionally, local sales employees and key account managers provide valuable input by sharing insights on upcoming sales and significant projects, allowing for necessary adjustments to be made to the initial forecast. The final demand forecast covers a time horizon of 1 to 15 months, and only significant changes, such as new major projects or significant market shifts, are encouraged to be incorporated. This approach ensures that minor fluctuations in the forecast are self-corrected over time, while significant changes are promptly incorporated to improve the accuracy of the overall forecast. In coordination with local areas, the S&OP team centrally manages the development of the forecast and distributes it globally at the end of the process. Therefore, one forecast is used to inform all global locations. This process can be seen below in Figure 4.9.

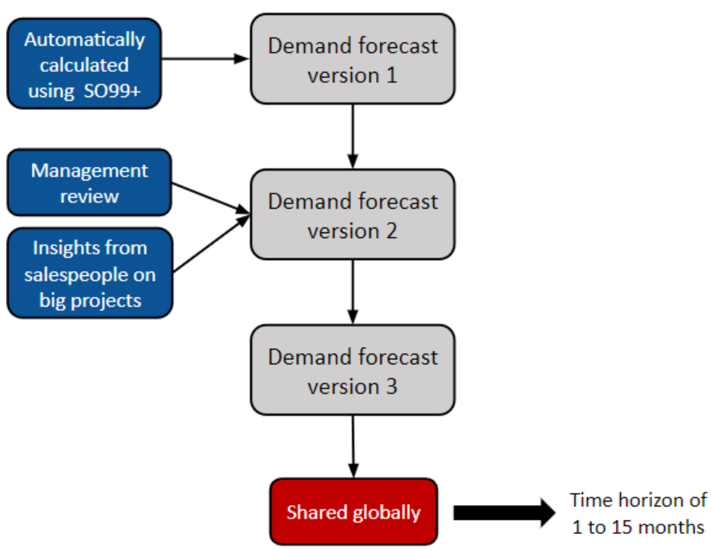

Figure 4.9: Forecast creation process (Created by the authors)

However, while this process provides good visualization at a product-type level, there are some concerns regarding the flexibility and level of detail of the forecast. For instance, the forecast creation process does not support adjustments from small insights, and there are several product types that are broken down into different levels of customization. As a result, although the forecast is accurate at a product-type level, it is generally less accurate for customized products. This has created a lack of trust in the forecast due to questions regarding accuracy.

At the same time, the forecasting process can often lack structure and standardization at the component level. Typically, factories attempt to break down the forecast provided by the S&OP team into component levels. However, the process varies across different locations worldwide, and a non-mathematical approach is often employed to assist with the calculation. Additionally, Excel is used, and the data is frequently not aggregated. These factors, combined with the high level of customization, contribute to increased complexity and uncertainty in the analysis. For example, while the total quantity of coils demanded might be estimated accurately, predicting the specific ratio of types of coils, such as thickness and size, can be more challenging. This ultimately leads to inaccurate forecasts at the component level. Nevertheless, after this analysis, the forecast is shared with suppliers to plan their production, which can affect the purchasing of raw materials and supplies.

On the supply side, there is not a forecasting process that estimates the supply availability. However, parameters such as capacity, lead time, and production schedule are checked in monthly meetings for the most critical suppliers, such as those supplying gaskets, stainless steel, and coils. Moreover, the BU GPHE does not have a collaborative planning, forecasting, and replenishment process. While the forecast includes insights from salespeople to create demand forecasts, the company does not engage with customers or suppliers to develop a more detailed forecast plan.

4.6 Collaboration & information sharing

The BU GPHE has implemented some level of collaboration among both internal actors along their value chain, as well as with external supply chain partners. Collaboration is driven by a need to problem solve, manage costs and customer requirements, and smooth process flows.

4.6.1 Value chain

Although the different factories operate as separate entities, they still belong to the same organization, Alfa Laval, and share internal links. Therefore, all internal processes, functions, and facilities are considered to be a part of Alfa Laval’s value chain.

Within the BU GPHE, value chain collaboration is done through organized processes that work to align planning across various functions in order to increase performance and reach

organizational goals. When considering inventory management, the S&OP process is a primary collaborative mechanism as it creates an iterative cycle where cross-functional meetings are held on both central and local levels. During these meetings forecasts and expectations are discussed and the agreed upon outcomes inform planning. Considering this, each of the locations has strong communication with the central headquarters in Lund. Additionally, in terms of information sharing, S&OP has standardized the type of information that is collected and shared among various value chain actors and has allowed planners to gain insights into other aspects of the organization that oftentimes indirectly impact their roles.
On a functional level, at each location, there are open channels of communication between areas including purchasing, production, sales, and operations. Information is typically shared formally through monthly meetings, but also through informal channels when problems arise, and firefighting is needed to diffuse an issue. The informal collaboration often allows for faster and more relevant solutions to be realized, particularly when it is done on a local level, rather than reporting each issue to the central office in Lund. In this sense, there is collaboration, but it has been stated that there is a need for increased information visibility to enhance the speed at which information could be retrieved from other functions.

When it comes to collaborating and sharing information between the different factory locations, both formal and informal interactions take place. For example, sometimes master planners at the GCCs and LAs share information regarding best practices with each other informally, yet the cyclical processes of S&OP tend to be more formal. For example, the three GCC locations share information during the supply planning phase, and coordination between the LA sites is typical when there are large projects that require coordinated production from multiple facilities. The BU GPHE also coordinates the global purchasing decision for gaskets for all the factories. To facilitate this, the BU implemented a coordination and information-sharing system where data from all the global locations is available and managed by a global coordinator purchaser. This enables the BU to prioritize orders, exchange gaskets between locations, and analyze capacities for better decision-making.

However, traditionally, forecasts are not shared between the various factories and information related to the inventory availability at each location cannot be seen by other factories. This is largely due to each factory operating as a separate entity.

ATHENA aims to clarify the roles and responsibilities of individuals along with the sequential steps of the inventory planning process. The initiative will also outline the connections between inventory management and other management processes within the organization. Additionally, the plan will consolidate information needed during the inventory analysis process into one inventory analysis tool that can be integrated with ERP systems to analyze the necessary inventory parameters. Lastly, ATHENA will be followed up with a global set of key performance indicators (KPIs) that are connected to the organization's strategic targets. Overall, ATHENA aims to improve Alfa Laval's inventory planning through a clear and coordinated initiative.

4.6.2 Supply chain

In relation to suppliers, the BU GPHE has streamlined its relationships with certain key component suppliers due to the uniqueness of the products and the volatility of the international market caused by the current global context. Currently, the demand for the compounds used in some core component production outweighs the available supply which has put a constraint on the availability of the components. The coordination system that has been implemented to overcome this challenge consolidates and shares long-term forecasting from all factories with suppliers. It also requires suppliers to share their current and long-term capacity, enabling the company to gain visibility into its needs and the suppliers' ability to fulfill orders.

Additionally, Alfa Laval also has a close relationship with core raw material suppliers as these include the primary inputs for the production at the GCCs and can be extremely expensive. The company shares forecasting and capacity information two months in advance on a long-term basis with these suppliers. Additionally, since the lead time for these goods is stable, the challenge arises from managing, coordinating, and allocating capacity between all suppliers, two months in advance.

Furthermore, gaskets and stainless steel are indispensable elements of the sourcing process, given their critical significance in the production of GPHEs and the substantial capital investment required for inventory. However, the BU GPHE has a vast network of over 200 suppliers worldwide, making it difficult to establish streamlined relationships with each one of them. Therefore, depending on consumption patterns and where it falls on the critical scale, suppliers are managed either globally or locally using supply agreements. Figure 4.10 shows the level of information-sharing between the BU GPHE and its suppliers and customers.

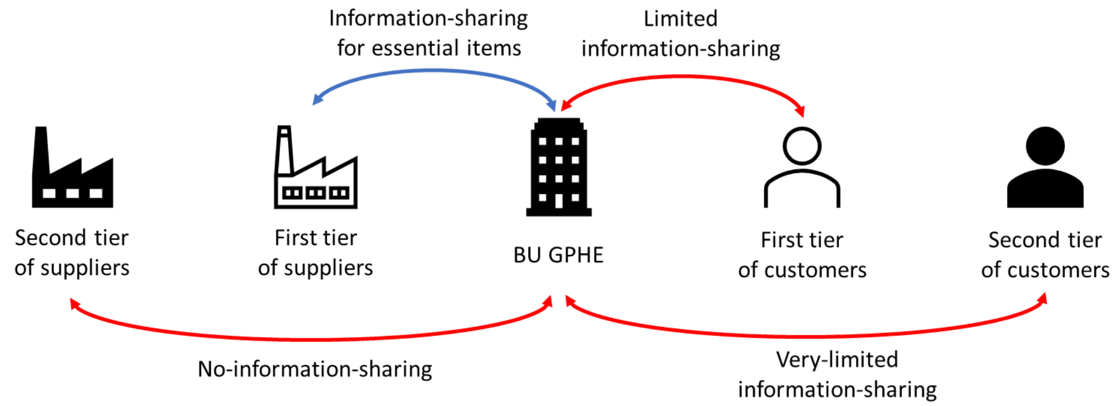

Figure 4.10: GPHE supply chain information sharing (Created by the authors)

In contrast to the BU's relationship with upstream actors, their downstream operations have limited collaboration and information sharing with its customers. For example, although the BU sells its products to a combination of direct customers, distributors, and other sales agents, they lack direct access to demand data and have limited streamlined communication channels. Consequently, BU GPHE relies on analyzing and gaining insights from a broader, more generalized market perspective rather than specific customer needs.

4.7 Key performance indicators

Currently, ATHENA provides clear goals to better manage the BU GPHE's inventory. The BU GPHE intends to increase the return on capital employed (ROCE) and the return on sales (ROS) by fully implementing the plan, which aligns with the Alfa Laval's financial scorecard, shown in Figure 4.11.

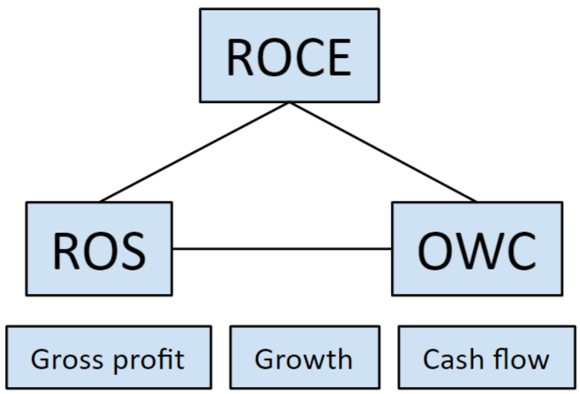

Figure 4.11: Alfa Laval's Financial Scorecard

An explanation of the financial scorecard is presented in Table 4.2. ATHENA will help the BU achieve its goals in terms of ROCE and ROS by reducing the Inventory Days of Supply (IDS) and, at the same time, minimizing the number of incorrect items and increasing the number of accurate items in stock.

Table 4.2. Alfa Laval's Financial Scorecard explanation

KPI	Explanation
ROCE	Return on Capital Employed
ROS	Return on Sales
OWC	Operating Working Capital

Moreover, Alfa Laval employs an operations scorecard to evaluate its business performance, which comprises four levels: strategic, tactical, operational, and foundation. The scorecard is analyzed using a top-down approach, starting from the strategy level and progressing to the underlying KPIs linked to the level above. The proximity of the KPIs to each other should signify their interconnectedness, allowing for a comprehensive evaluation of the organization's operations. Alfa Laval's scorecard is shown in Figure 4.12 and Table 4.3. Nevertheless, the scorecard helps define the KPIs from a high level to operational and factory levels.

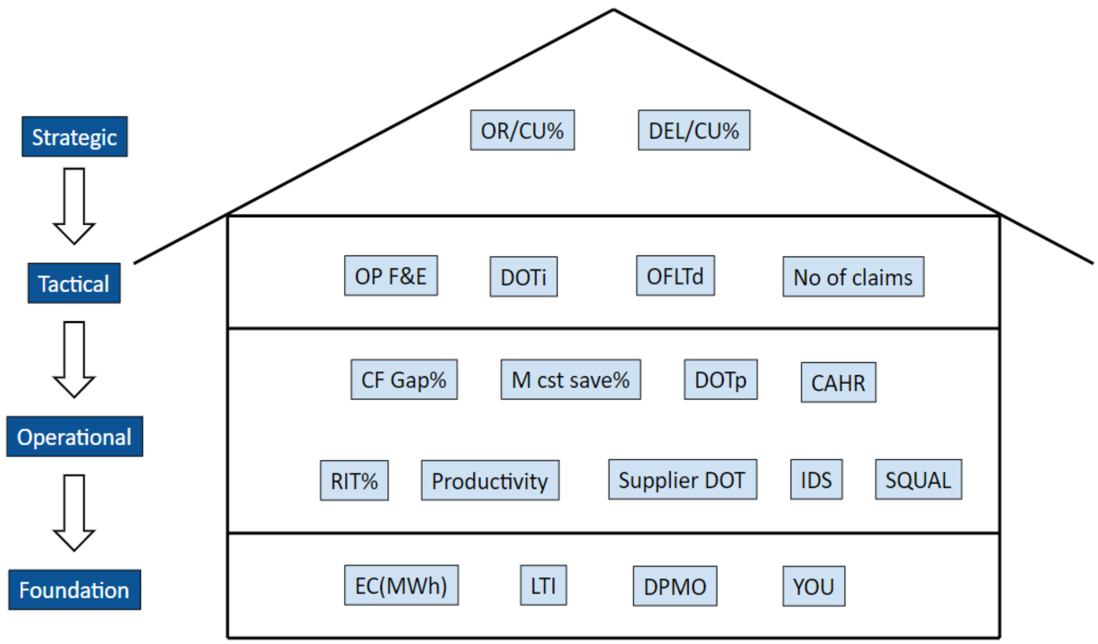

Figure 4.12: Alfa Laval Operations Scorecard

Table 4.3. Operational scorecard measure explanations

KPI	Explanation
OR/CU%	Orders received Actual vs. Orders received Costing update
DEL/CU%	Deliveries Actual vs. Deliveries Costing update
OP F&E	Operational Factory & Engineering result
DOTi	Delivery on Time Invoiced
OFLTd	Order Fulfillment Lead-time Discrepancy
No of Claims	Number of received External claims

CF Gap%	Cost Flex Gap %
M cst save %	Material Cost Savings
DOTp	Delivery on Time Packed
CAHR	Correction Action Hit Rate
RIT%	Rate of Indirect Time
Productivity%	Productivity
Supplier DOT	Supplier Delivery on Time
IDS	Inventory Days of Supply
SQUAL	Supplier Quality
EC (MWh)	Energy consumption (MWh)
LTI	Lost Time Injuries
DPMO	Defects Per Million Opportunities
YOU	Compass Index

Moreover, common KPIs found in multiple locations are plan adherence, forecast accuracy, forecast bias, service level, showing the company has standard KPIs besides the ones provided in the scorecard. However, the Alfa Laval scorecard, and therefore the ATHENA initiative, has only one standard KPI to analyze inventory at an operational level: IDS. The formula for calculating IDS is shown below in Equation 4.1.

$$IDS = \frac{Average\ Net\ Inventory}{Annualized\ Average\ Delivery\ Pace} * 365 \quad (4.1)$$

However, additional analysis of the inventory performance is examined in a decentralized manner, and each location follows up stock levels using its own KPIs. KPIs commonly found were inventory turnover, and inventory value. Still, IDS is the KPI most used to follow up inventory and includes raw materials, components, WIP, and SIP.

4.8 Organizational structures

In 2017, Alfa Laval was restructured to increase the focus on stronger business units, for example the BU GPHE. This change opposed the previous structure which had a large number of divisions that were customer segment focused, which was the case 5-10 years ago. This restructuring increased management's ability to make decisions, as ownership for product groups in terms of purchasing, operations, and sales became more unified centrally. Centralization has provided clearer organizational structures as well as guidelines and goals, which are outlined by the BU GPHE, yet executed on a local level.

In addition to restructuring, the implementation of the S&OP process has increased the standardization of the planning and decision-making processes. With regard to inventory management, the output data from S&OP provides the basis for global operations, creating a common, centrally defined thread between all of the factories, with the aim of ensuring that they are working in the same manner. ATHENA enhances this on a more operational level as it provides a singular set of policies and principles to assess inventory and engage in differentiated planning. This is particularly important for larger factories with more offerings which complicates planning and production. Both S&OP and ATHENA work in line with Alfa Laval’s strategic goal of freeing up capital through inventory reduction. Soon, aspects like the calculation for safety stock will be standardized and decided based on centrally accepted service levels.

To some extent, however, the structured chain of decision-making and standardization of processes has decreased flexibility and the speed at which decisions can be made on a more local level. Alfa Laval operates in several regions that have different market demands, which makes it difficult for some locations to adhere to central directives. Additionally, it requires more time and preparation to raise concerns to the central BU which can cause delays in response times. Lastly, some locations have very successful operations that they trust, which deters them from adopting the central directives, and even if they are willing to change, there is a risk of misinterpretation.

Alfa Laval encourages factories to communicate with each other informally and share best practices in terms of operations and planning on a more detailed level. Additionally, each factory reports centrally chosen KPIs that are aligned with the organization’s strategic goals. In addition, each factory monitors additional KPIs that they believe are relevant for their operations and these can vary between factories. The way these KPIs are calculated or defined can also differ. However, some actors within the factories feel that they would benefit from having an increased number of centrally defined targets and goals to guide operations. In the future, an additional push for centralization will come in the form of standardized local KPI reports which aim to streamline even local monitoring.

Chapter 5 - Gap Analysis & Recommendations

This chapter will perform a comparative analysis of the topics covered in the literature reviewed against the empirical data collected regarding the inventory management practices and processes used at Alfa Laval. This comparison will provide the basis for finding gaps between theory and practice, and therefore guide the formation of the recommendations.

5.1 Strategic alignment

According to Meindl & Chopra (2016, pp. 19-20), a company's competitive strategy should define in relation to their competitors what sets them apart and gives them a competitive advantage. The strategy should consider factors such as organizational capabilities, costs, and customer needs. The business unit (BU) gasketed plate heat exchanger (GPHE) has outlined their strategy in the form of three strategic goals that clearly state the areas which set them apart from their competitors. Their aim is to provide the best service, customer experiences, and heat transfer products. Essentially the goal is to be #1 in the GPHE market. ATHENA aims to support this strategic objective by ensuring the correct inventory availability so that customer needs can be satisfied. The plan will decrease incorrect items while increasing the availability of accurate items, and in turn, should reduce overall stock. Therefore, by connecting the competitive strategy to ATHENA, implications of the impact of the differentiated inventory plan are clear, and consideration was taken on how the changes will impact responsiveness due to inventory reductions. Consequently, ATHENA is strategically aligned with the BU GPHE's goals, as recommended by Meindl & Chopra (2016, pp. 19-20).

5.1.1 Supply chain strategy

Internally, global core component (GCC) factories and local assembly (LA) factories have separate supply chain strategies due to the difference in products produced, end customers, and demand uncertainty. This is supported by Meindl & Chopra (2016, p. 31-35), as choosing a singular strategy given the mentioned characteristics would not result in a tailored supply chain. This separation allows for an optimization of responsiveness as they do not waste resources in areas that can operate more efficiently. This is also in line with the idea that responsiveness is on a spectrum and while the overall degree of responsiveness should match with the total level of uncertainty in the supply chain, the distribution can be uneven across the supply chain actors.

Considering this separation, the GCC produces plates for their end customer, the LA. When analyzing the characteristics of the plates to the attributes mentioned by Fisher (1997), they can be categorized more closely to a functional product. Although they do not fall below the threshold, the characteristics are on the borderline and sway more towards being functional as opposed to innovative, as shown in Table 5.1.

Table 5.1. Functional versus innovative product characteristics (Inspired by Fisher, 1997)

Aspect of demand	**Functional *(Predictable demand)***	**Innovative *(Unpredictable demand)***	**Characteristics of pressed plates *(GCC Lund)***
Product variety	Low *(10 to 20 per category)*	High *(millions per category)*	~ 1200 variations in total
Average margin of error in the forecast	10%	40% - 100%	~ 15%
Average stock out rate	1% - 2%	10% - 40%	~ 5%

Alternatively, the LA produces finished GPHEs for end customers. As the finished goods are tied to specific orders there are high levels of uncertainty concerning the specifications until the order is actually received. The uniqueness of the finished goods also creates a large variation in possible completed units, considering components, size, etc. Additionally, as they sell the units after all value-adding activities have been completed, we assume the profits margins are high. With these characteristics, we assume that the finished goods have unpredictable demand aspects, and fall more in line with innovative products, as outlined by Fisher (1997).

Considering the product categorization, Figure 5.1 below shows the placement of the products produced by each factory, as well as the recommended corresponding supply chain strategy (Fisher, 1997).

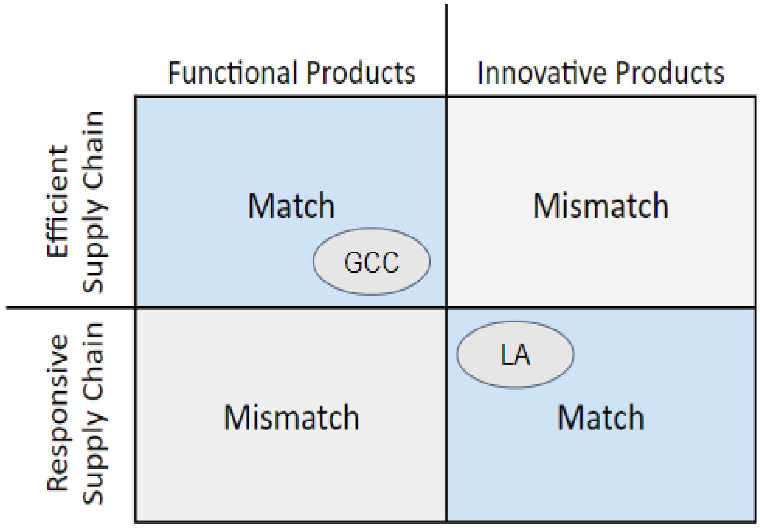

Figure 5.1: Matrix matching BU GPHE's supply chain strategy and product type depending on factory type (Based on Fisher, 1997)

Based on the findings, the BU finds a balance between responsiveness and efficiency by using both strategies where they best fit through the division of their factories. The combination of pre-stocking plates at the GCC, along with maintaining customization at the LA is supported by both Fisher (1997) and Meindl & Chopra (2016, p. 31-35), as it creates a tailored supply chain.

5.1.2 Strategic decoupling point

There are two ways to approach the analysis of the strategic decoupling point. One way is to consider Alfa Laval as a single entity, and in this case, the strategic decoupling point would be between the two factories. Under this assumption, LA operates on a make-to-order (MTO) basis, meaning production only starts when a customer places an order. In contrast, GCC operates on a make-to-stock (MTS) basis, relying on forecasting and demand planning.

However, in practice, GCC and LA are considered separate entities, each with its own strategic decoupling point(s). In this case, LA still operates on a completely MTO basis, indicating that the production is initiated solely in response to a customer's order. Moreover, GCC has two separate flows which are distinguished between MTO and MTS systems based on product classification into stock and non-stock items, considering total demand and monetary value. This division is highly supported by D'Alessandro & Baveja (2000), Olhager (2003), and Olhager (2010).

Additionally, according to Demeter & Golini (2014), assemble-to-order (ATO) companies have a high level of modularity. Therefore, although it was empirically found that LA works in an ATO approach and stands for local assembly, the LA factory cannot be referred to as ATO since the GPHE assembly process has a very low level of modularization as they assemble plates, components, gaskets, and frames rather than modules. The accurate division of the GPHE operations is shown below in Figure 5.2.

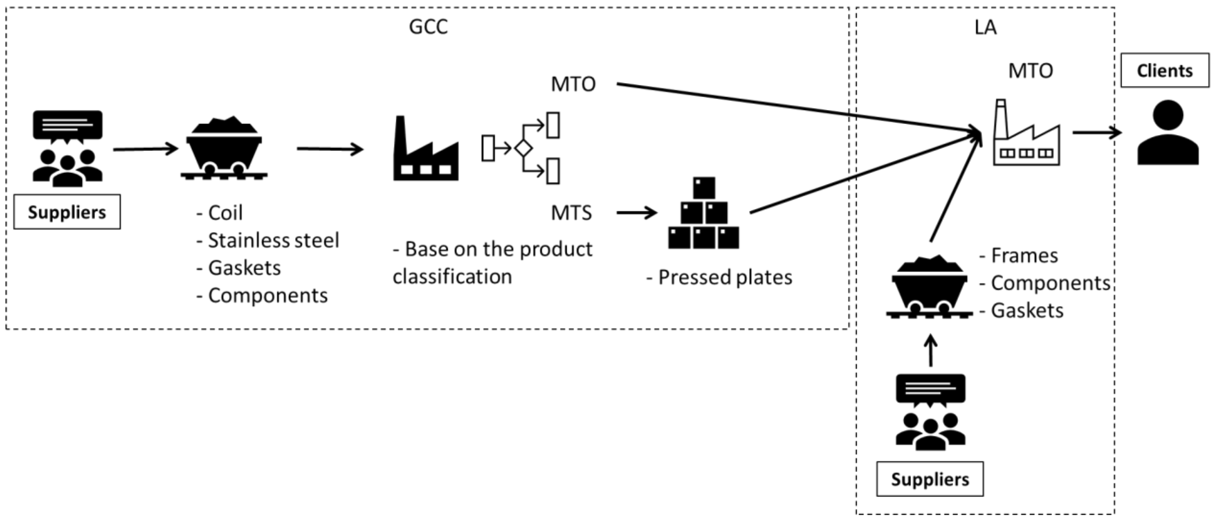

Figure 5.2: GPHE operations division into MTO and MTS (Created by the authors)

The use of decoupling points allows Alfa Laval to focus on cost reduction when applicable and necessary, at the GCC, while remaining responsive to end-customer demands through customization at the LA. This division of focus is strongly supported by both Olhager (2003) and Cannas et al. (2019).

By increasing the level of modularization, Alfa Laval could maintain its current level of responsiveness while also increasing standardization. This, in turn, would reduce the complexity of inventory management and lead to more efficient processes overall. With fewer items and a lower level of variability to analyze, the overall inventory management would become more streamlined, while shifting LA from a pure MTO to an ATO approach (Demeter & Golini, 2014). However, the additional benefits and drawbacks of modularizations beyond inventory management have not been studied. Therefore, the company should first evaluate whether this idea aligns with their strategic plan.

Furthermore, to enhance clarity, it is essential to clarify that GCC operates in two different lines: MTO and MTS. This differentiation would help operations distinguish between MTO and MTS plans, where MTO plans focus on backlog orders, and MTS plans concentrate on inventory levels of finished goods (Olhager & Selldin, 2007; Olhager, 2021). Therefore, the plan goals would be clarified, and operations could prepare themselves better, simplifying inventory management.

5.2 Inventory management

As mentioned by Longo (2011, p. 95), inventories can affect supply chain performance in terms of values tied up, degrees of flexibility, and level of responsiveness. Considering this, in recent years Alfa Laval has primarily focused on degrees of flexibility and level of responsiveness, without focusing on the capital tied up in their inventory. The large reserves of inventory have been used to prevent production idling as well as help manage imbalances in supply and demand as mentioned by Song, van Houtum & Van Mieghem (2020) and Williams & Tokar (2008). This approach was particularly helpful to Alfa Laval during the COVID-19 period, however, the excess number of components and material inventory is detrimentally impacting the company’s financial performance (Capkun, Mameri & Weiss, 2009; Nenes, Panagiotidou & Tagaras, 2010).

To address the large amounts of tied up capital, the BU GPHE created ATHENA to balance the inventory levels and capital employed in stock. ATHENA will help the company to improve assortment control, availability, and production efficiency by providing an understanding of whether the inventory is accurately held or non-essential. Consequently, ATHENA will address the two main sources of inventory tied up capital, which are components and raw material, and working-in-process (WIP). ATHENA shows that the BU GPHE has demonstrated a good understanding of inventory management, including the usability of inventory and the rationale behind holding stock since their goal is not to fully eliminate stock, but rather to ensure product availability as long as the benefits outweigh the cost (Chen, Frank & Wu, 2005; Pawlak & Małyszek, 2007; Michalski, 2008; Chinello, Herbert-Hansen & Khalid, 2020).

However, ATHENA will not address sales-in-process (SIP), the third largest source of tied up capital held in inventory. In addition to high costs, the SIP inventory takes up valuable space in the warehouse as the goods are finished but have not yet been invoiced and delivered to the customer. SIP is also problematic as Alfa Laval is a MTO company, and therefore should not have finished goods inventory (Olhager, 2021; Demeter & Golini, 2014). Consequently, SIP should in theory be zero, so the fact that this inventory category is so high is extremely inefficient. As such, Alfa Laval will benefit from optimizing its SIP processes to reduce costs and improve warehouse utilization. Currently, operations are responsible for SIP but have limited abilities to impact its reduction as they are not in control of invoicing. Therefore, it is recommended that the responsibility be partially shifted to the sales department, at least for orders that are complete without any part of the order still in WIP. If this solution is not possible, an alternative recommendation is to work with the sales department to create stricter contracting rules in terms of invoicing and delivery. These recommendations align with the arguments of Baker (2007) and Chinello, Herbert-Hansen & Khalid (2020) which state that strategically placing inventory in the supply chain should add value for the company. Currently, SIP does not add value for Alfa Laval.

5.2.1 Inventory types

Classification of inventory types is the first practical action in the new inventory management plan, ATHENA, within the GPHE business unit. Figure 5.3 compares the current inventory classification plan included in ATHENA as well as the theoretical approach provided by Handfield & Bozarth (2015, p. 345).

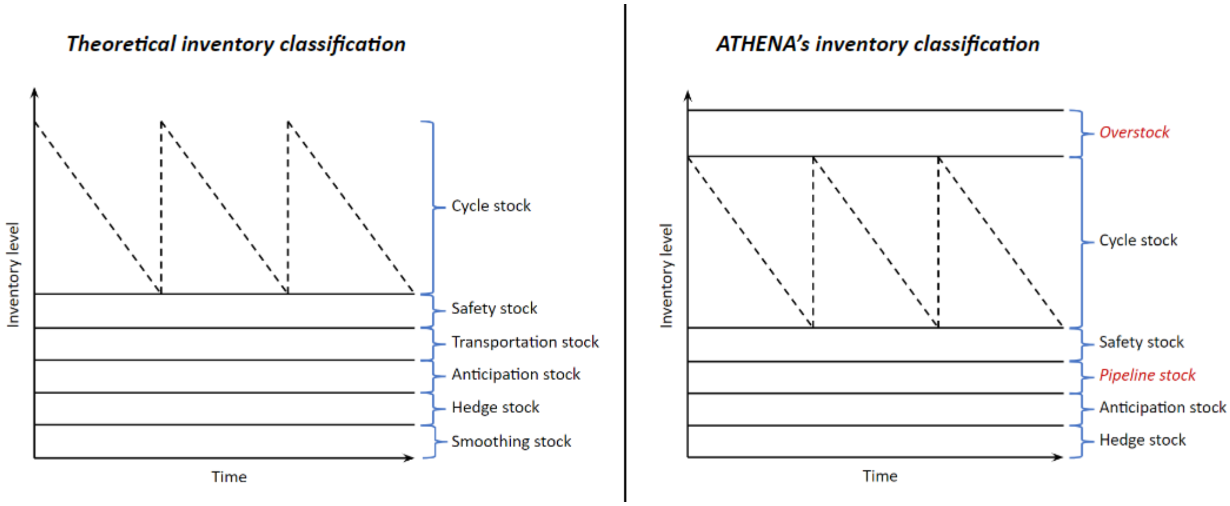

Figure 5.3: Inventory classification theory and ATHENA comparison (relevant deviations in red) (Based on Handfield & Bozarth, 2015, pp. 345-347; Alfa Laval, 2023)

ATHENA's and Handfield & Bozarth's (2015, pp. 345-347) methods provide six levels of granularity to differentiate inventory, of which five overlap. ATHENA also includes overstock as a classification which cannot be found in theory but is important on a practical level to understand if the company has stock that lacks a purpose. The two most important inventory classification types, cycle stock and safety stock, are utilized by Alfa Laval and their definitions are aligned with the theoretical concepts presented by Handfield & Bozarth (2015, pp. 345-347). Cycle stock is regularly replenished and continuously used in production or purchasing processes. At the same time, safety stock serves as an additional inventory buffer against demand uncertainty or potential delays in replenishment (Handfield & Bozarth, 2015, pp. 345-347; Meindl & Chopra, 2016, p. 51). In addition, ATHENA also employs the concepts of hedge and anticipation stock, which are in line with Handfield & Bozarth (2015, pp. 345-347). Hedge stock is used to manage unexpected events that might harm the company, while anticipation stock is utilized to address anticipated imbalances between demand and supply.

However, ATHENA has a different definition of transportation (pipeline) stock compared to Handfield & Bozarth (2015, pp. 345-347). Alfa Laval includes both SIP and WIP in its pipeline stock calculation, whereas Handfield & Bozarth's (2015, pp. 345-347) definition of pipeline stock only includes components and raw materials being transported from suppliers to a company. As a result, companies that use global suppliers and have longer transportation lead times, such as Alfa Laval, should have a larger pipeline stock. However, including WIP and SIP in this analysis might hide the visualization of how longer lead times affect the amount of capital tied up in transportation inventory.

While companies have the flexibility in terms of how to classify both WIP and SIP inventory, both inventories should not be categorized as pipeline stock, as this category has a clear definition and should include only inventory in transport from the suppliers to the company. By definition, WIP can be classified as cycle stock, anticipation stock, or even strategic stock, depending on the inventory management strategy. At the same time, as Alfa Laval is an MTO company, SIP could be categorized as overstock for completed orders waiting to be invoiced, or cycle stock for partially complete orders.

Overall, ATHENA uses an inventory classification method that is in line with theoretical recommendations in most cases, which helps the company make strategic inventory management decisions. However, it is recommended that WIP and SIP be removed from pipeline stock and placed in a more suitable classification. This will take further analysis to determine the most appropriate classification, particularly for WIP. There will be varying impacts that must be considered depending on whether WIP is included in cycle stock, anticipation stock, or strategic stock. For SIP, however, the classification should fall in line with the fact that Alfa Laval is an MTO company, and completed orders should be considered overstock.

5.2.2 Item classification

The second practical step in BU GPHE's new inventory management plan, ATHENA, is classifying items. This follows a logical sequence and is a crucial aspect of the plan.

During the literature review phase, three item classification methods were theoretically analyzed: *ABC analysis, demand variability analysis,* and *ABC-XYZ analysis*. These methods gradually increase in complexity, with ABC analysis being the most straightforward and widely used by companies worldwide (Chen et al., 2008; Rădăşanu, 2016; Douissa & Jabeur, 2016). However, this method is inefficient in classifying items since it does not consider demand patterns. To address this gap, demand variability analysis exclusively examines the demand variability of items and classifies them as either MTO/NI or MTS/SI (D'Alessandro & Baveja, 2000). However, this method does not include the financial aspect. Therefore, the ABC-XYZ method is the most comprehensive approach, using demand variability and financial analysis to classify items (Buliński, Waszkiewicz & Buraczewski, 2013; Stojanović & Regodić, 2017).

ATHENA classifies items by first dividing the inventory into raw material, component, and finished goods groups. This is followed by utilizing a modified version of the ABC-XYZ classification method and applying the same control system across the entire group, consistent with Axsäter (2006, p. 301) and Ghorabaee et al. (2015). Moreover, ATHENA uses the same classification system for components, raw materials, and finished goods groups, and each group is analyzed separately, which follows the theoretical approach provided by Olhager (2023).

However, the calculation method employed to analyze the ABC-XYZ differs from the literature. D'Alessandro & Baveja (2000) argued that the demand variability is calculated using the mean and the standard deviation of demand as shown in Formula 1 in Section 3.2.2. In contrast, ATHENA analyzes the number of times an item has been picked within a 52-week period. Despite the clear difference in the application of the ABC-XYZ method, the results should likely be similar. It is therefore recommended that the company use a small sample to compare whether both calculation methods result in similar outputs. The BU GPHE item classification and planning principles presented in ATHENA are shown in Figure 5.4.

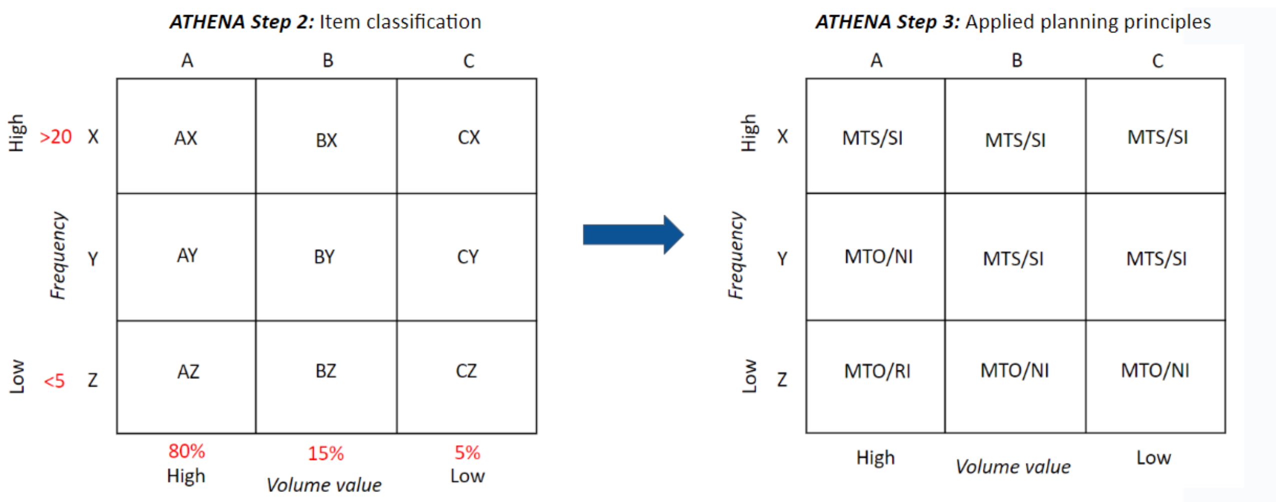

Figure 5.4: BU GPHE item classification method and planning principles

Moreover, the BU GPHE has started implementing this item classification method by focusing on optimizing inventory levels of AX items, which have a significant financial impact. This prioritization conforms to the findings of Stojanović & Regodić (2017) and Bialas, Revanoglou & Manthou (2020), and is in line with Alfa Laval's goal of reducing tied up capital. Therefore, ATHENA proved to understand the importance of item classification and uses the theory in line with the practice. Nevertheless, the detailed planning and replenishment principles applied to each square in the item classification method, such as AX, AY, and so on, is out of this thesis's scope.

5.3 Inventory control

In line with Olhager (2019), Alfa Laval uses an inventory control system to outline the order initiation process, with the consideration of uncertainty, for raw material and component stocks. While the calculations used to set order quantities and reorder points are not entirely clear, they are done with consistency across the organization through the enterprise resource planning (ERP) systems; therefore, calculations are highly automated. This consistency is important because as mentioned by Perona, Saccani & Zanoni (2009), each supply chain is unique, so modified or hybrid models might be used, but this makes them standard throughout the organization. This standardization is supported by Sánchez-Rodríguez et al., (2006), and will be enhanced further when safety stock levels are also automatically calculated using an execution software.

Additionally, Alfa Laval has a clear understanding of the role of safety stock in managing uncertainty, as they have connected it to the expected service level, as recommended by Meindl & Chopra (2016, pp. 314-513) and Axsäter (2006, p. 95). This also suggests that they have placed a focus on answering Meindl & Chopra's (2016, p. 316) questions regarding *what the appropriate level of product availability is,* and *how much safety stock is needed to ensure that.* With the introduction of ATHENA, Alfa Laval will also have better means to address the third question, regarding *what actions can be taken to reduce safety inventory without hurting product availability*. However, as the role of safety stock is to create a buffer in the event of incorrect forecasting, demand uncertainty, and long lead times, the third question is easier to answer and larger reductions can be seen if the forecasts are more accurate because the safety stock will need to balance less variability (Handfield & Bozarth, 2015, pp. 345-356; Meindl & Chopra, 2016, pp. 314-315).

While the use of, and standardization of, inventory parameters is in line with the recommendations from Sánchez-Rodríguez et al. (2006), Alfa Laval still has an excess amount of stock along the supply chain. Therefore, it is recommended that they investigate more thoroughly whether the formulas that are used accurately describe the situation at Alfa Laval. Primarily because there is a risk for inaccuracy as methods are typically based on many different, usually unlikely, assumptions that might not fit their particular scenario (Axsater, 2006, p. 54). Lastly, additional parameters should be considered for relevancy and use in the automated inventory control system (Perona, Saccani & Zanoni, 2009). For example, the inventory position, which is currently calculated manually, can provide better visibility for purchasing decisions as it considers on-hand inventory, backorders, and additionally on-order inventory.

5.4 Forecast

Forecasting plays a crucial role in planning medium to long-term operations for MTS and MTO companies, according to Gansterer (2015). At BU GPHE, demand forecasting at the product level is automated using advanced demand planning software that builds a 1 to 15-month forecast based on historical order data and mathematical models. The sales and operations planning (S&OP) team relies on this forecast to make critical decisions about production, capacity, demand, and supply during the S&OP cycle. The forecast is also shared with factories worldwide to aid in local decision-making. While the forecast is highly automated, salespeople provide input, and managers review significant changes before sharing it globally. This approach aligns with Gansterer (2015) and (Meindl & Chopra, 2016, pp. 177-181), which stress the importance of creating a forecast that incorporates insights from different areas of the company. Therefore, the company efficiently makes and wisely uses demand forecasting at the product level for the S&OP process.

An issue arises however when trying to forecast at the component level. After S&OP finalizes the product forecast, it is shared with factories, which then attempt to break it down into a component level forecast. However, this approach is disconnected from Olhager (2003), Olhager (2010), and Olhager (2023), who suggest that MTO companies focus on forecasting raw materials and purchased components. These items experience "independent demand," meaning the demand for these items are not directly related to the demand for the final product but instead determined by the company's production requirements. As a result, breaking down the product forecast into component forecasts for customized products becomes challenging and similar to a guessing game.

Therefore, it is recommended that the BU GPHE stop trying to break down the product forecast into component forecasts and start analyzing the demand for those items independently. This can be achieved in multiple forms. First, the company could use standard mathematical models provided by Axsäter (2006, p.7), Bongsug (2009) Meindl & Chopra (2016, pp. 181-182), such as moving average and exponential smoothing. Excel can be used to aggregate past demand data for each item and apply these techniques. However, more advanced software might be necessary for items with complex demand patterns in order to accurately forecast demand at the component level. Component forecast process should also be decentralized, but the expected outcome and follow up procedures could be centralized. This is because the actual forecasting processes can be different since demand patterns for the same component or raw material can vary depending on the specific market (Olhager, 2023).

Moreover, the interviewees have reported that there is no follow-up on the accuracy of component level forecasts. This is concerning because suppliers use these forecasts to plan their capacity and production for critical items. Not measuring the accuracy of these forecasts can lead to problems such as the bullwhip effect and barriers to optimizing inventory levels, as noted by Axsäter (2006, p.7), Kembro & Selviaridis (2015), and Meindl & Chopra (2016, pp. 181-182). Therefore, it is highly recommended that the company implement component forecasting and measure forecast accuracy following the implementation.

According to interviews, the BU GPHE does not have a system for forecasting supplier availability. However, they evaluate and plan key factors like capacity, lead time, and production schedules during monthly meetings with critical suppliers, including gaskets, stainless steel, and coils. As this method is currently effective, no further action is required regarding forecasting supplier availability.

Moreover, the interviewees have reported a lack of collaborative planning, forecasting, and replenishment (CPFR) process. Although the S&OP team works with salespeople to create demand forecasts, the company does not involve customers or suppliers in developing a more comprehensive forecast plan. Implementing CPFR could improve Alfa Laval’s forecasting at both product and component levels, which could lead to a reduction in inventory levels (Småros, 2003). However, according to Meindl & Chopra (2016, pp. 257-265), to implement CPFR effectively, all supply chain actors must have standardized practices for sharing information and synchronized data, including proper infrastructure for information sharing with all actors in the supply chain. Therefore, the implementation of CPFR is currently unrealistic since the company struggles with standardized IT systems across its multiple locations and has different priorities, such as creating forecasts at the component level.

5.5 Collaboration & information sharing

In line with Feller, Shunk & Callarman (2006), the BU GPHE defines all internal, value-adding activities as part of the company’s value chain. Additionally, their understanding of the supply chain includes all activities involved in the production and delivery of the final product.

5.5.1 Value chain

Internally, S&OP will drive information sharing and collaboration regarding inventory management within the value chain through the implementation of ATHENA. However, the initiative does not include information regarding increased collaboration and visibility between the factories. According to Rummler & Brache (1991), some of the largest areas of improvement can be found between functions, so this can create a large issue as each facility sees itself as a separate entity with divergent objectives. For example, when buying gaskets, there are very unstable and possibly long lead times, which create scare buying behaviors that further increase lead times as well as inventory levels. This is harmful to the overall objective to reduce tied up capital held in inventory and decreases Alfa Laval’s level of responsiveness. The company has worked to create more common incentives for various value chain actors by creating common goals and measuring financial performance in a cross-functional way (Norrman & Näslund, 2019).

Yet, this does not solve the lack of internal visibility as the separate factories still do not have access to information regarding inventory held at other locations. This prohibits more comprehensive inventory management through, for example, the sharing of plates, raw materials, and production capabilities. This could allow for quicker removal of slow-moving items or materials if locations had access to the need for and availability of goods elsewhere, as well as the possibility to reduce lead times and unnecessary production. Therefore, in addition to ATHENA, the BU GPHE should consider the flows between locations and create an information sharing system regarding the expensive but slow-moving items. The system should coordinate the removal of stock, but also weigh both the financial and non-financial costs and benefits of sending and sharing inventory between various locations.

5.5.2 Supply chain

To avoid the bullwhip effect, the BU GPHE works to collaborate with suppliers of key raw materials and components. For example, they have implemented a gasket coordinator who shares essential forecast information with suppliers, and in return receives both short and long-term capacity information. This exchange enables increased visibility. Similarly, capacity is managed through a coordinated effort with stainless steel suppliers. Although the BU GPHE cannot maintain a high level of collaboration with their additional ~200 non-key suppliers, their efforts are in line with Meindl & Chopra (2016, p. 248), who explain that the bullwhip effect is a product of a lack of coordination, conflicting interests, and distorted information.

However, although collaboration with key suppliers is high, the sharing of distorted information is an issue. For instance, since forecast accuracy is not measured on the component level, the possible sharing of inaccurate forecasts with suppliers can misguide their procurement and production. This distortion is a common barrier for actually using shared information in a practical setting, as mentioned by Kembro & Selviaridis (2015) and Kalaiarasan et al. (2022). To limit information distortion, correct forecasting on a component level is necessary, and this could be followed by collaboratively integrating suppliers into the forecasting process. This process could lead to decreased lead times and inventories, as well as increased responsiveness, according to Min et al. (2005) and Bayraktar et al. (2008).

In terms of customer collaboration, the BU GPHE does not have specified “key customers” who they interact with on a consistent basis outside of the ordering and specification process. Therefore, they do not create collaborative forecasts or have clear first-hand knowledge of the customers’ future requirements. By selecting a pool of recurring, key customers, to increase relationships with, the BU could enhance visibility and therefore decrease uncertainty around customer needs, which can be the root cause of suboptimal decision-making (Kembro & Selviaridis, 2015; Kalaiarasan et al., 2022).

Overall, it is recommended that the BU focus on maintaining their relationships with key suppliers while increasing the quality of the data that they share through better, more collaborative forecasting methods. Additionally, by selecting core customers and engaging in coordination efforts with them, the BU GPHE can obtain better performance in terms of customer service, delivery accuracy and lead-time, quality and flexibility as mentioned by Olhager & Prajogo (2012). These attributes are essential for obtaining a competitive advantage for an MTO company, like Alfa Laval. The recommendations are shown in Figure 5.5.

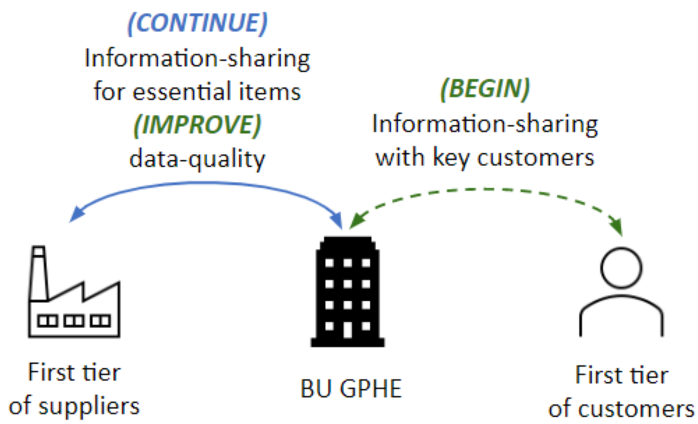

Figure 5.5: Recommended supply chain information sharing (Created by the authors)

5.6 Key performance indicators

Eccles (1995) and Neely, Gregory, & Platts (1995), studied how companies are financially biased when measuring the performance of their businesses. To avoid this issue, Alfa Laval uses a financial and an operation scorecard to follow up on their performance. The scorecards are used to relate key performance indicators (KPIs) to the organization's strategic goals and aim to reflect which measures the company believes are important to use when centrally analyzing their business. The financial and operational scorecards are shown in Figure 5.6 and the included KPIs are standardized across locations worldwide.

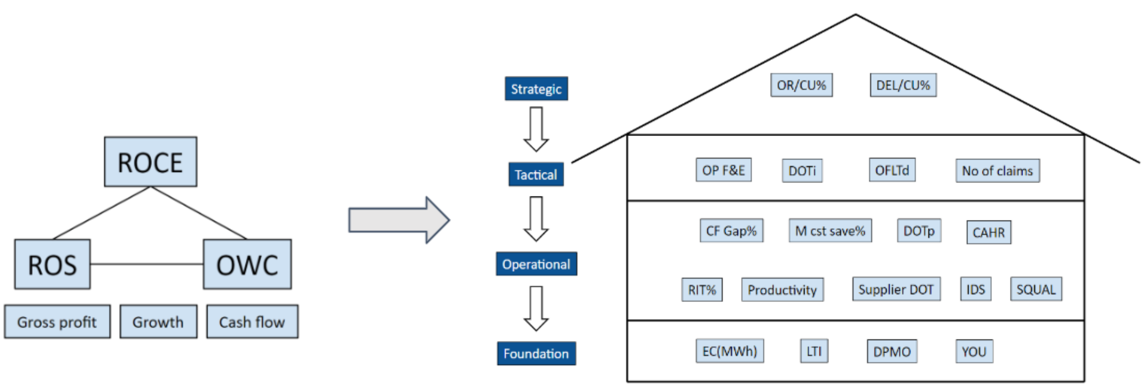

Figure 5.6: Alfa Laval Operation and financial Scorecards

Moreover, local factories monitor operations, including inventory levels, using additional KPIs, such as inventory turnover, and inventory value. At the same time, the ATHENA initiative follows the company's operation scorecard, which has only one standard KPI to analyze inventory at an operational level. Therefore, including more KPIs in the initiative is necessary to measure inventory properly between multiple locations. Considering this, Table 5.2 explores KPIs found in Section 3.7 regarding whether the BU GPHE already uses the selected KPIs in their operation and how the company should approach them in future analysis. The selected KPIs should be standardized and measured across all factories. Nevertheless, BU GPHE should still provide flexibility for locations to use additional KPIs to analyze their business locally since different regions worldwide have distinct requirements.

Table 5.2. KPIs for inventory management monitoring (Created by the authors)

KPI	Already used	Recommendations
Inventory Days of Supply (IDS)	Yes, to a large extent.	(1) Ensure SI/MTS items have low IDS. (2) Guarantee that IDS is not overestimated since the theoretical calculation in Table 3.4 differs from the company's calculation shown in section 4.7. (3) Remove DFG (SIP) from the IDS calculation.
Days of Finished Goods (DFG)	Yes, in the form of IDS	(1) Calculate DFG separately from IDS to better understand how DFG influences the business. (2) Bring it as close as possible to zero since Alfa Laval is an MTO company.
Obsolete inventory	Yes, takes a financial view	(1) Bring as close as possible to zero by having the correct items stocked.
Service level	Yes	(1) Ensure high service level for high running items.
Inventory turnover	Yes	(1) Ensure SI/MTS items have high inventory turnover. Negatively correlated with IDS; therefore, the calculation of only one of these KPIs is necessary.
Total inventory investment (TII)	Yes	(1) Create TII as a KPI, adding DFG and IDS. (2) Ensure the connection of TII and ROCE, clarifying how the reduction of TII affects the ROCE. (3) Balance TII and service level, reduce until it negatively impacts responsiveness (create graph/scatter plot to show the trade-off).
Return on capital employed (ROCE)	Yes, to a large extent.	(1) Ensure the connection of ROCE and TII, clarifying how the reduction of TII affects the ROCE.
Forecast Accuracy or Forecast error	Yes, to a large extent	(1) Monitor forecast accuracy and error for product and component levels. (2) Ensure high forecast accuracy for SI/MTS items as it impacts service level.
Supply lead time and Order lead time	Yes	(1) Decrease as much as possible, until costs outweigh the benefits in terms of responsiveness and service level.

Furthermore, Figure 5.7 shows a hypothetical example of how Alfa Laval could create a graphic to analyze the trade-off between total inventory investment and service level, as suggested in Table 5.2.

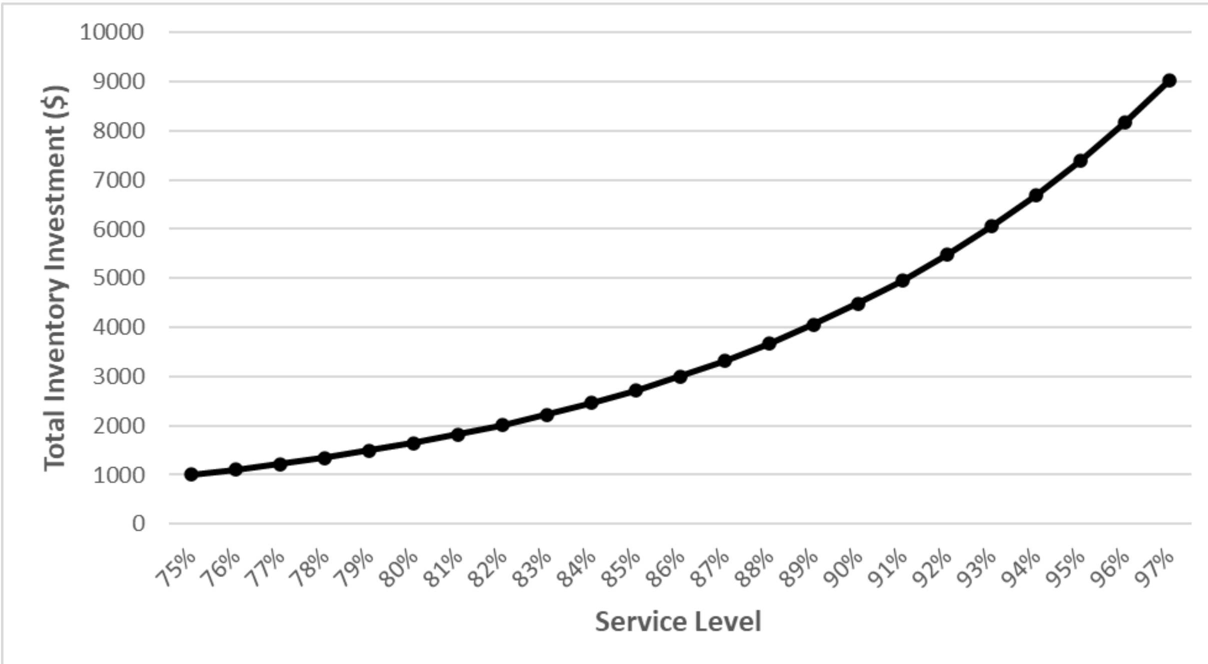

Figure 5.7: Hypothetical graph to show trade-offs (Created by the authors)

Finally, tools such as DuPont are not applied to fully grasp the interconnections between various levels of KPIs, particularly at the operational level. As a result, it might be challenging to establish a definitive link between reducing inventory and achieving KPI targets, so further improved visibility is required. Therefore, Figure 5.8 shows an example of how Alfa Laval could integrate the DuPont analysis using the suggested KPIs in Table 5.2 to grasp the interconnections between various levels of KPIs comprehensively.

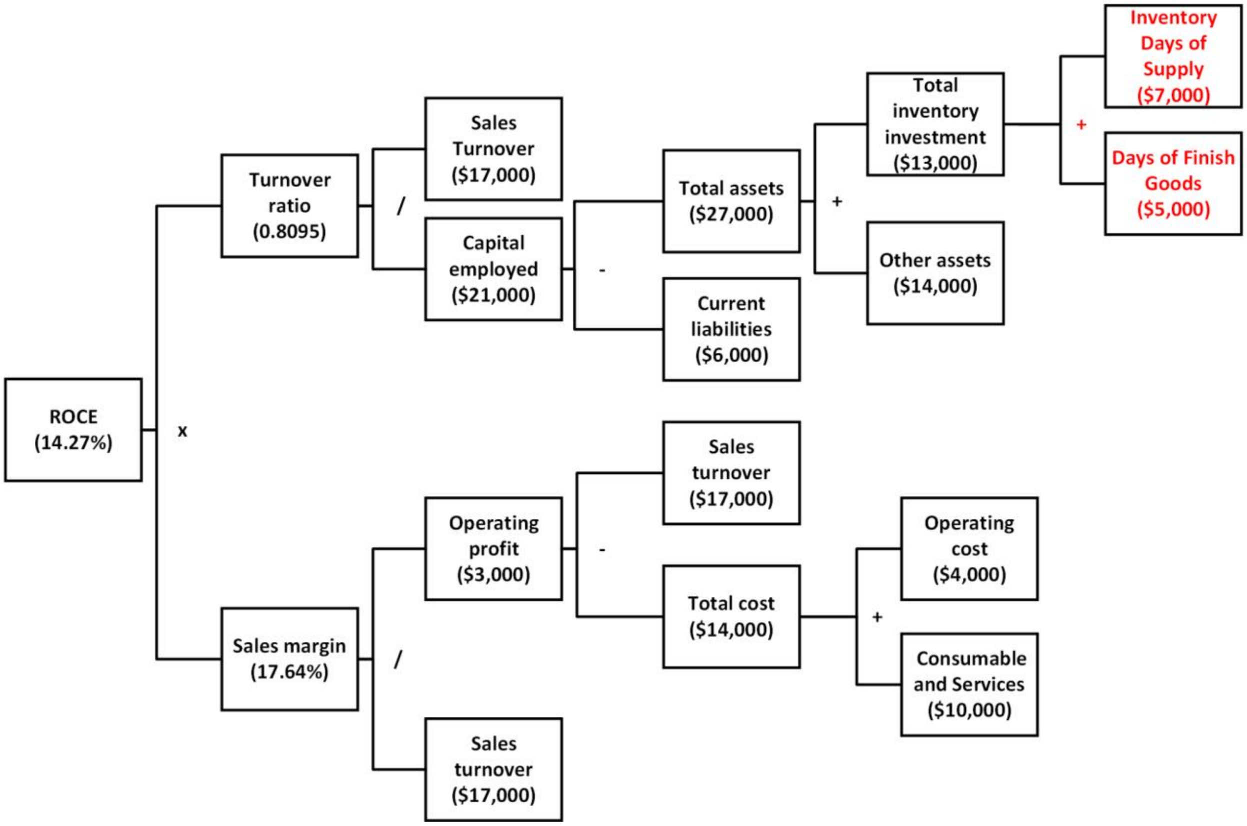

Figure 5.8: Hypothetical DuPont analysis for Alfa Laval (Created by the authors)

The DuPont analysis highlights the importance of considering IDS and DFG as separate KPIs adding up to the TII. This is because reducing TII and increasing ROCE require different efforts from various parts of the company. For instance, the ATHENA initiative has no impact on DFG inventory, which can affect the visibility of the initiative's success as the goal is to decrease IDS, which currently includes DFG.

5.7 Organizational structures

The restructuring in 2017, as well as the introduction of S&OP has shifted Alfa Laval’s placement along the centralized versus decentralized spectrum. Previously, according to interviewees, Alfa Laval was considered to operate in a decentralized manner, therefore, as these processes have brought more influence back to the central office, they now fall under a more hybrid approach. Figure 5.9 shows the placement of Alfa Laval along the spectrum today.

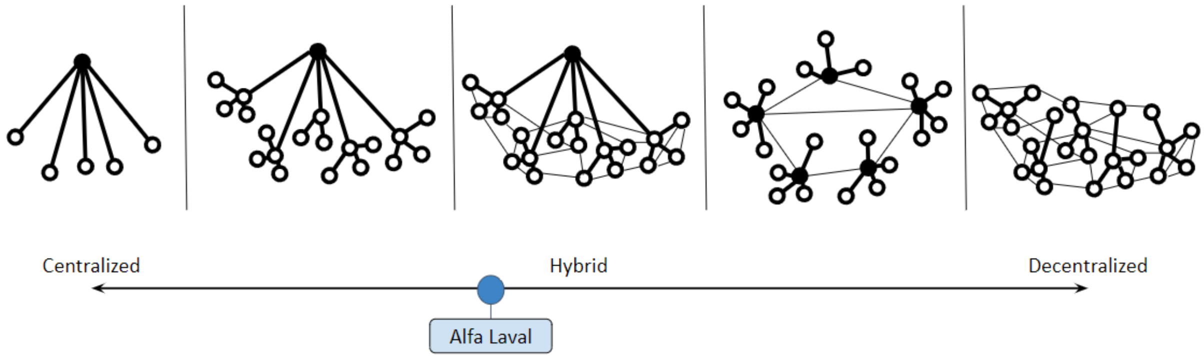

Figure 5.9: Alfa Laval's placement on the centralization spectrum (Created by the authors)

The placement of Alfa Laval is justified by the fact that ownership and high-level decision-making is the responsibility of the central office, and they provide clear guidelines and directives to more local actors. The addition of the S&OP process has also created a global process criterion, and ATHENA will add onto this with a standard set of operational policies and planning principles. These circumstances point towards centralization; however, Alfa Laval also encourages both formal and informal communication between functional departments and different factories when needed. Additionally, the individual locations still have freedom to add additional helpful tools and practices if they find them helpful which allows for independent decision-making. Therefore, this combined approach allows for a connection to the central office but also links between other factories. This mix of strategy is supported by contingency theory which states that there is no one size fits all approach to designing organizational structures (Boute, Dierdonck & Vereecke, 2011).

However, the shift towards centralization also makes sense as Sahin & Powell Robinson Jr. (2005) state that it has been tied to supply chain performance improvements when organizations operate in an MTO setting, as does Alfa Laval. This change has allowed Alfa Laval to gain benefits in terms of standardization, strategic alignment, and maintenance of expert knowledge as outlined and expected by Johnson et al. (2014) and van Weele (2014, p. 286).

Yet, some benefits might diminish as they shift closer to the centralized side, and these changes should be considered in relation to Alfa Laval's organizational strategy. Prime advantages of decentralization include better external relationships and service levels, as well as decreased costs (Johnson et al., 2014; van Weele, 2014, p. 286). Considering the fact that Alfa Laval's goal is to provide the number one experience to their customers, these advantages are very important, as they are competitive factors that set the company apart from their competitors. For example, the BU GPHE operates in several regions with varying market needs. While on a high level the structured and cyclical nature of centralized processes is beneficial, it can create difficulties on a local level where flexibility and fast-paced decision-making are essential to staying relevant in the market. This should be considered if the BU implements a component forecast, as mentioned in Section 5.4, as this process should be decentralized, while the expected outcome and follow up procedures could be centralized (Olhager, 2023). This approach would balance the benefits of standardization with flexibility and the importance of market specific processes.

It is recommended that the organization continue using a hybrid approach to their organizational structure. In the future, however, if they continue to standardize processes and move closer to a strict centralized structure, a cost benefit analysis should be done to ensure that the advantages outweigh losses in terms of flexibility. For example, the future change to the KPI structure will remove flexibility of local measures as more operational KPI reports will be introduced. These will outline on a more detailed level what should be measured and how. Yet, this might ignore the benefits of certain measures on a more operational level, and this balance is particularly important for Alfa Laval given the uniqueness of their operations and market particularities around the world.

5.8 Recommendation summary

By analyzing the theoretical topics against the empirical information collected, gaps were found and recommended changes to the inventory management processes and impacting elements were made. These recommendations aim to align Alfa Laval's operations more closely with the discussed theoretical topics. An overview of the recommendations for each topic area has been compiled and is shown in Table 5.3. The practicality of the implementation of some of the recommendations by the case company, Alfa Laval, will be further discussed in Section 5.9.

Table 5.3. Recommendations for each topic area related to inventory management

Topic area	**Theoretical recommendations**
Strategic alignment	Maintain two supply chain strategies (GCC = efficient; LA = responsive)
	Enhance clarity at GCC regarding two different operation lines: MTO and MTS
	Consider the impact of introducing more modularization
Inventory management	Partially shift SIP responsibility to sales
	Remove SIP & WIP from pipeline stock
	Compare classification methods (ABC-XYZ & *ATHENA's* ABC-XYZ)
Inventory control	Ensure control parameters describe Alfa Laval's situation
	Add additional parameters

Forecasting	Stop trying to break down the product forecast into components
	Create component forecast independent from product forecast
	Monitor forecast accuracy
	Decentralize component forecast process, centralize outcomes
Collaboration	Create value chain visibility for inventory monitoring across locations
	Increase data accuracy (better forecasting)
	Open key customers channels
	Maintain supplier collaboration
KPIs	Table 5.2
	Implement DuPont modeling
Organizational structure	Continue with hybrid structure
	Weigh benefits of standardization versus flexibility in local markets

Additionally, the order in which the recommendations should be implemented and prioritized was out of the scope of this thesis. A comparison on the importance of each recommendation and the impact of implementation should be made.

Chapter 6 - Discussion

This chapter will provide a discussion on the theoretical recommendations in the context of the case company, Alfa Laval. It will include practical insights regarding implementation barriers, necessity of the recommendations, and reasoning behind the company's current ways of working.

Select recommendations were chosen for further discussion. The discussions take a practical, more context specific view from the case company, rather than purely theoretical.

6.1 Strategic alignment

Currently, the BU GPHE uses a mixed strategy of efficiency at the GCC (global core component) where there are make-to-stock (MTS) processes, and more customization is performed at the local assembly (LA) where make-to-order (MTO) production is done. While on a strategic level, the company is overall categorized as MTO, the order penetration point (OPP) creates a division between the factories and operations which impacts product characteristics. Therefore, on an operational level the supply chain should become more tailored by distributing uncertainty and responsiveness to places where it makes sense and implementing more stability where possible.

As Alfa Laval's organizational strategy evolves, it will have a small impact on the process approach of ATHENA since it is an iterative, continuous improvement process. However, having an understanding of the implications of changing strategy aspects on the operational decisions made through ATHENA is important because these will change with the organization's strategy. For example, depending on the organization's goals, attributes including the expected service levels can change which will impact the planning principles of different item classifications. Therefore, these changes impact the governing rules which can overall impact the level of inventory and what constitutes proper management.

This is similarly true if subcategorization of products is done between the GCC and LA, or through the line separation of MTO and MTS processes at the GCC. Functional products with efficient supply chain strategies have different expectations than innovative products which require increased responsiveness. The same goes for MTO versus MTS processes, and since they have different expectations, the governing principles of ATHENA should be different.

6.2 Inventory management

The definition and classification of pipeline stock within the BU (business unit) centers around the idea that all inventory that is out of the control of the planners should be included in the category. This has been said to be influenced by benchmarking the organization against IKEA.

However, IKEA and Alfa Laval operate very differently given that IKEA is an MTS company with a cost focused business model, while Alfa Laval is an MTO company focused on customer prioritization.

While the classification of pipeline stock is incorrect, work-in-process (WIP) inventory has been discussed as being much more flexible than sales-in-process (SIP) in terms of what could be considered the correct classification. Also, when considering the benchmarking process, an MTO company should not even have SIP inventory. Therefore, a prioritization should be placed on separately and correctly categorizing SIP. In addition to this, ownership should be moved outside of operations, to sales, as operations cannot impact SIP levels. It is also worth mentioning that although Alfa Laval is an MTO company, their customers often order in batches, which creates an acceptable category of SIP as orders are waiting to be completed. Additionally, the company takes a customer centric approach and the implementation of strict contracting rules to try to fully remove SIP would decrease their responsiveness which goes against the organization's ethos. Contract changes can also present a big issue as many of their industrial customers, for example shipyards, often have strict delivery requirements based on a Just-In-Time approach, which makes it hard for Alfa Laval to control. Nevertheless, including incentives for both sales and customers to deliver according to the original delivery date or charging for holding SIP inventory for additional time is relevant. Another possible solution might be to work towards higher levels of inventory turnover in the category. With this approach, they could maintain their customer focused flexibility, but not at the cost of having large amounts of tied up capital in unnecessary inventory.

During interviews, one typical question that arose was whether the BU GPHE possesses the competencies to improve and implement inventory management practices. BU GPHE's team showed excellent process knowledge and analytical capabilities, so the relevant questions to consider now are whether there are enough employees to handle the workload and how tasks will be effectively divided among the teams.

6.3 Inventory control

Alfa Laval has automated their inventory control system, but the current enterprise resource planning (ERP) system, lacks in providing all the necessary parameters to make effective decisions. The new ERP system, is expected to address this gap in the next few years, so no further recommendations have been made regarding inventory control.

6.4 Forecasting

Alfa Laval might encounter difficulties implementing an independent component forecast due to certain circumstances. The Alfa Laval inventory component list is quite extensive, with hundreds of items that can be challenging to analyze individually. Having available consumption data for each item in the last 12 or 24 months would be necessary. Consequently, the classification method can reduce the number of analyzed items, making the task less complex. Moreover, it can be challenging to identify the demand patterns for each item in stock. Many companies have conducted academic studies on developing and implementing component-level forecasts. In some cases, it may be hard to find the most suitable method without software and algorithms. Therefore, it depends on Alfa Laval to decide if having an accurate forecast on the component level is a priority and a necessity. This would require them to allocate financial resources to acquire new software or allocate human resources to examine items individually. Although essential, this task can be expensive and time-consuming.

6.5 Collaboration & information sharing

One recommendation was that the BU GPHE should increase information visibility across the different locations so that they could share slow-moving inventory. However, this option is already readily available through a simplified process, using the S&OP team, sharing extra components and raw materials through an Excel spreadsheet, and reaching out to each other via email or a phone call. While this approach is not very advanced, the different locations have various ERP systems and it is not very often that a substantial amount of goods is available, needed by another location, and has financial or responsive benefits that outweigh the costs. Additionally, there has been a reported lack of use of the current process, therefore, in order to implement a more advanced solution, it is likely that the implementation costs would not be able to justify the project. However, this might be a possibility once all locations have transitioned to the new ERP system, as they will have more visibility when using a single ERP system.

An additional recommendation was for the BU GPHE to try to select a category of key customers. Many companies rely on building strong connections with their customers in order to gain insight into marketing trends, create new products, improve forecast accuracy, and streamline relationships. However, for BU GPHE, this could be challenging due to the decentralized nature of sales, with multiple clients involved. Therefore, instead of analyzing each customer separately, the BU could explore the market by segments and create a list of key verticals, such as the maritime industry.

6.6 Key performance indicators

Alfa Laval is currently using all the necessary key performance indicators (KPIs) mentioned in Table 3.3. However, the company's present challenge is standardizing these KPIs and tracking them centrally across multiple locations. Moreover, Alfa Laval must ensure a balance between financial benefits and responsiveness levels while setting specific KPI targets. For instance, achieving zero days of finished goods (DFG), likewise called SIP, is unrealistic, but what would be an acceptable trade-off? Can a 50% reduction be considered as a reasonable goal?

Moreover, it is important for Alfa Laval to improve the way they categorize their KPIs. Currently, inventory days of supply (IDS) includes DFG and operates similarly to total inventory investment (TII). By following the recommended guidelines and separating the KPIs more effectively, Alfa Laval can enhance their understanding of how each individual KPI impacts their business and follow up ATHENA success with more clarity.

Alfa Laval currently uses IDS as a strategic KPI to assess the organization's overall performance. While IDS is usually applied to the entire company or a single plant, it can also be used to assess department level inventory, but only those that are responsible (accountable) for the inventory. For example, if the purchasing department is accountable for the purchase and storage of raw materials inventory until it goes to production, they can use IDS to measure their inventory performance during this period of time. Therefore, a department must be responsible (accountable) for the inventory to be evaluated using IDS otherwise the measure cannot be used, and there should be a clear segmentation of when the responsibilities for inventories shift between the departments. Consequently, Alfa Laval can use IDS to evaluate the performance of their departments separately. This division of the KPIs and segmentation of responsibilities can be used to break down additional measures as well. For example, once the KPI of DFG is established and the responsibility of SIP is shared, they can utilize DFG to measure the operations and sales departments' accountability for finished goods. This will allow for a more effective evaluation of departmental performance.

Even further, Alfa Laval can analyze days of supply for specific items in stock. Moreover, analyzing IDS at the item level can provide valuable insights into inventory management and supply chain performance. It would enable Alfa Laval to manage their inventory by identifying items that are being stocked for too long or not long enough. Additionally, they can determine which items have excess inventory, tying up valuable working capital, and which items have insufficient inventory, causing production delays or stockouts. Moreover, the company can also consider other KPIs, such as inventory turnover, for a more comprehensive understanding of their inventory management performance on the items/departments level. Analyzing multiple metrics in combination can provide a better view of inventory management and help make better-informed decisions to improve operations.

Furthermore, the DuPont model presented in Figure 5.8 considers total inventory investment as a major part of current assets, which is part of total assets, along with fixed assets. Nevertheless, total inventory investment includes IDS and DFG. On the other hand, consumables also often include raw materials. So, inventory is also included in the “total cost.” However, only the cost of holding inventory is included, not the value or investment in the inventories. Therefore, a reduction in inventory investment should only be analyzed as part of the total assets.

In addition to the Dupont model, it's beneficial to understand the relationship between financial and non-financial KPIs, Figure 6.1 shows an example of the relationships between all studied KPIs. Primarily because there is always a tradeoff between cost efficiency and responsiveness, so even if a decision seems to support the strategic goals, there can be additional direct or indirect impacts that are not strategically aligned. For instance, if you reduce the IDS, it will reduce the TII and increase ROCE, but there is also a chance of reducing the service level. Moreover, lower order lead time can reduce DFG, or shift the responsibility of finished goods to the sales department more quickly, while lower supply lead time can reduce the level of uncertainty, which reduces the need for safety stock and leads to lower level of IDS.

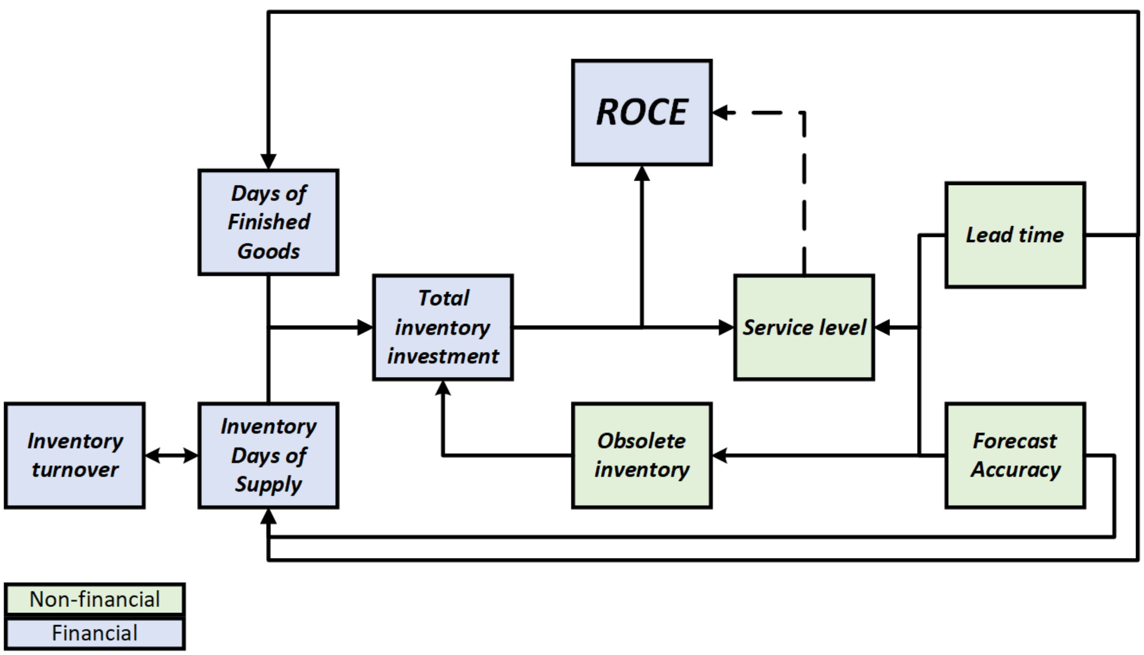

Figure 6.1: Financial and non-financial KPIs relationship (Created by the author)

6.7 Organizational structures

It was recommended that Alfa Laval continue using a hybrid approach within the organization, and carefully consider future decisions to continue to move towards a more centralized structure. However, this would require them to measure the benefits of increased standardization against the decreasing levels of flexibility, which is extremely difficult to estimate prior to implementation. Additionally, even if the BU GPHE begins to see that increased centralization is showing diminishing rewards, these changes and directives typically come from top management as it represents an overall organizational shift, so it will be up to them to decide to halt increased centralization. This can create a gap because inefficiencies are typically noticed at an operational level to start, and take a bottom-up approach, which can create a delay in the effects actually reaching those with the decision-making power.

Overall, however, if possible, it is recommended that Alfa Laval use a hybrid approach, and Figure 6.1 shows the ideal range of hybridity for the organization in green. Along this portion of the spectrum, there is a balance between structure and standardization, as well as some level of informal, local connections between the various factories which can enable inventory sharing as well as knowledge sharing on best practices. The limited decentralization also allows local actors to implement market specific approaches which is ideal when you have very different market scenarios and needs, while still being monitored on a global level to ensure they are operating in line with the organization's strategic goals.

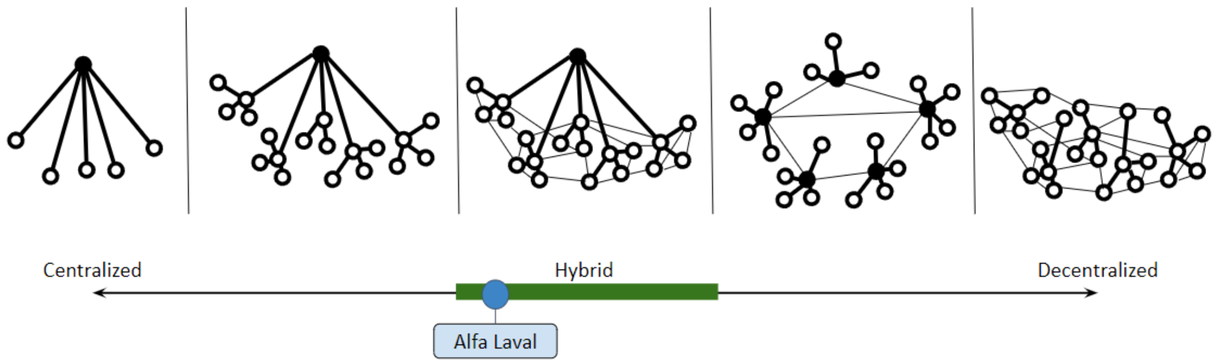

Figure 6.2: Recommended organizational structure (Created by the author)

In the future, if increased information sharing capabilities are implemented across the various factories, this would push the organizational structure slightly towards the decentralized side. Additionally, if component forecasting is implemented but the method is decided by local actors, this again would move the BU towards a more decentralized structure. However, if the component forecast is followed up by central KPIs, these decisions would be balanced, and the organization's position would likely not move much. Lastly, by providing local factories with more operational KPI reports, they take some decision-making away from local actors pushing the organization's placement further towards centralization. If all of these processes are implemented in combination, Alfa Laval's position would remain essentially the same. Yet, if only the processes which increase standardization and bring decision-making back to the central office, the organization risks losing the benefits of decentralized processes and being pushed outside of the ideal area on the spectrum.

Chapter 7 - Conclusion

This chapter will provide our concluding remarks, including a revisitation to the purpose of this study and the research questions. An explanation of how the research questions were answered will be provided. Additionally, both the practical and theoretical contributions will be outlined, as well as recommendations for future research studies.

The purpose of this thesis was to increase the effectiveness of the case company, Alfa Laval's, inventory management by finding potential challenges, opportunities, and gaps in their current inventory management practices. The main objective of this study was to compare the company's current inventory process with the best practices outlined in the literature and develop recommendations for improving their inventory management. By conducting a thorough analysis of their current inventory process, it was aimed to identify areas of improvement that will help Alfa Laval optimize their inventory management and enhance their operational efficiency. This study was process-oriented and provided valuable insights into how Alfa Laval can adopt best practices in inventory management to enhance their overall performance.

7.1 Research question 1

Research question 1: *How is the company currently working with inventory management?*

At Alfa Laval, the primary approach to inventory management is through an initiative ATHENA. It includes inventory classification, item classification, planning principles, and replenishment policies. The inventory classification method divides the inventory into six categories: *overstock, cycle stock, safety stock, pipeline stock, anticipation stock, and hedge stock*. The item classification uses an adaptation of the ABC-XYZ based on the number of times an item is picked over a 52-week period. The plan is followed up with a set list of performance measurements which are provided by the central BU and related to the company’s financial scorecard. The ATHENA initiative is strategically aligned with the organizational and BU targets and goals. Moreover, the BU GPHE uses an automated software system for managing relevant inventory control parameters.

In addition to ATHENA, to better understand Alfa Laval’s inventory management practices, additional selected process elements and practices that impact plan performance were chosen by the authors. These topics were included based on insights from the company, expert professors, and relevant literature that was found. The topics that were considered are shown below in Figure 7.1.

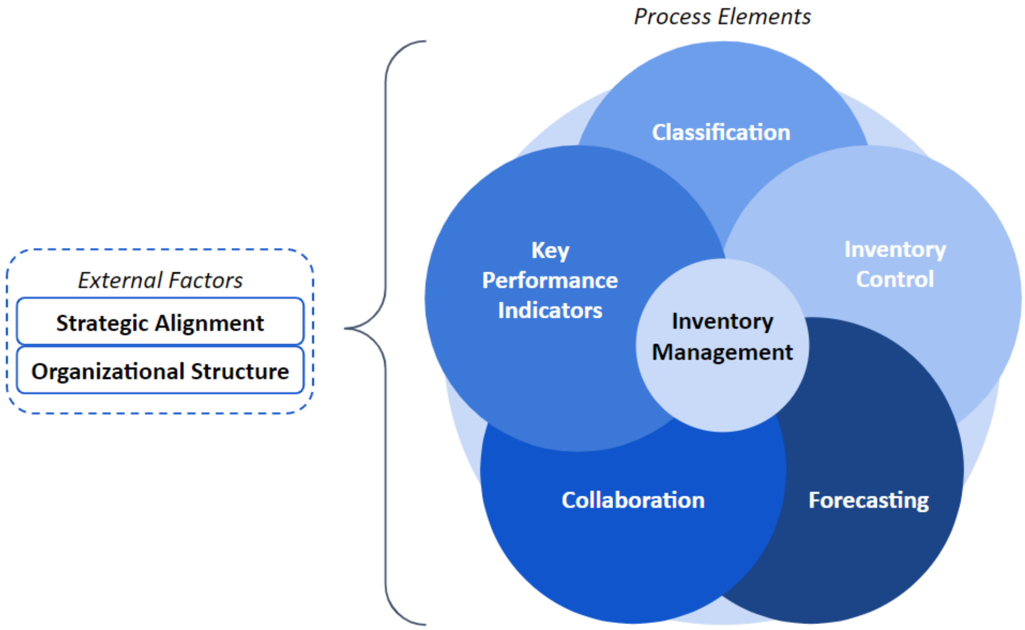

Figure 7.1: Revisiting selected topics found to have a connection to inventory management (Created by the authors)

Factors and elements that were not previously mentioned include: *forecasting, collaboration, and organizational structure.* In terms of forecasting, S&OP is used to create a product level forecast. The forecast is done automatically through an advanced demand planning software that includes insights from various managers and sales. The output is used to make informed planning decisions on a tactical level and is then broken down into a component forecast and used on an operational level in the factories. The BU GPHE also collaborates externally with key raw material and component suppliers and uses S&OP to drive collaboration across the value chain. Lastly, Alfa Laval's organizational structure has shifted from decentralized to more centralized in recent years. This has mainly been done through the standardization of processes and procedures, including S&OP.

7.2 Research question 2

Research Question 2: *How can the company fulfill gaps relative to the selected theory and improve their inventory management practices?*

A gap analysis was performed using the empirical findings from the case company, Alfa Laval, and the theoretical information compiled in the literature review. Based on this analysis, recommendations were made where practices and theory were disconnected. The full list of recommendations can be seen in Table 5.3. These recommendations were made from a strictly theoretical point of view. However, the applicability and company context were further considered in Chapter 6.

A selected list of recommendations is shown below in Table 7.1. This list excludes suggestions to maintain current practices and includes only actions that could improve Alfa Laval's inventory management in relation to the company's current operations.

Table 7.1. Selected list for each topic area related to inventory management

Topic area	**Theoretical recommendations**
Strategic alignment	Consider the impact of introducing more modularization: Alfa Laval can improve efficiency by increasing modularization. This would simplify inventory management and shift them to an ATO approach.
Inventory management	Partially shift sales-in-process (SIP) responsibility to sales: Alfa Laval should optimize their SIP processes to reduce costs. However, SIP is currently under the operations' control, so the sales team should assume partial responsibility for optimizing the process.
	Remove SIP & WIP from pipeline stock: The pipeline category should only consist of inventory being transported from the suppliers to the company. This will create more transparency in the category.
Inventory control	Ensure control parameters describe Alfa Laval's situation: Alfa Laval should examine formulas used to calculate inventory control parameters to ensure accuracy, as assumptions may lead to potential inaccuracies.
Forecasting	Stop trying to break down the product forecast into components: MTO companies should primarily forecast raw materials and purchased components. These items have an "independent demand," not directly linked to the final product's demand.
	Create component forecasts independent from product forecast: There are different ways to achieve this. One option is to use models like moving average and exponential smoothing. Using Excel, the company can gather previous demand data for each item and apply these techniques. However, more advanced software may be needed for items with complex demand patterns at the component level accurately.
	Monitor forecast accuracy: The company must incorporate component level forecast accuracy to avoid issues such as the bullwhip effect and to optimize inventory levels.
	Decentralize component forecast process, centralize outcomes: The forecasting process for individual components should be decentralized because demand patterns can vary depending on the specific market. However, the outcome and follow up procedures can be centralized.

Collaboration	Create value chain visibility for inventory monitoring across locations: It would benefit BU GPHE to establish a system for sharing information about slow-moving but expensive items between locations. This system should consider the financial and non-financial implications of transferring inventory and should coordinate stock removal accordingly.
	Increase data accuracy (better forecasting): Sharing inaccurate information can misguide suppliers in procurement and production. Collaborative component level forecasting can minimize distortions, reduce lead times and inventories, and improve responsiveness.
	Open key customers channels: The BU GPHE can focus on core customers and collaborate closely with them to enhance customer service, delivery accuracy, lead time, quality, and flexibility.
KPIs	Implement days of finished goods (DFG): Currently, the company calculates inventory days of supply (IDS), including SIP. Therefore, it is recommended to implement DFG (SIP) as a separate KPI from the IDS calculation to better understand how DFG influences the business.
	Create total inventory investment (TII) as a KPI: It is done by adding DFG and IDS. Also, it is recommended to ensure the connection of return of capital employed (ROCE) and TII, clarifying how the reduction of TII affects the ROCE.
	Monitor forecast accuracy and error for component levels: It would improve visibility, follow up and avoid the sharing of inaccurate data with suppliers.
	Implement DuPont modeling: It can establish a definitive link between reducing inventory and achieving KPI targets, improving visibility and follow up.
Organizational structure	Weigh benefits of standardization versus flexibility in local markets: It is suggested that the organization maintains its hybrid organizational structure. However, if they plan to standardize processes and adopt a strict centralized structure, they should conduct a cost-benefit analysis to determine if the benefits outweigh the loss of flexibility.

7.3 Theoretical contributions

In terms of theoretical contributions, the conclusions of this thesis are specific to the context of the case company, Alfa Laval, as they are dependent on the empirical analysis relative to the outlined literature on inventory management. However, organizations with enough similarities could benefit from the information and conclusions that have been made. Additionally, while the conclusions are not generalizable, the holistic nature of this thesis can inspire future research.

Particularly studies which aim to assess the interconnectedness of topics related to inventory management and how they relate to the processes at case companies.

Additionally, very little research could be found on the connection between collaboration and inventory management. The authors could also not find any papers or models that aimed to show the relationship of several topics and inventory management, but rather the papers and models found typically researched very deeply a singular topic related to the phenomenon. Consequently, this holistic approach, including enablers and other impactful variables, is less common in the research community on inventory management. Therefore, this thesis provides a large theoretical contribution as the authors made a high-level analysis of selected process elements and factors impacting plan performance.

7.4 Practical contributions

This case study was performed at Alfa Laval with the aim of finding improvements for the BU GPHE's inventory management processes. From a practical perspective, the work in this thesis provides vital insights into the current processes and functional aspects of the BU GPHE's current practices. Yet, this information allowed the authors to find places where improvements are possible through a comparative analysis with relevant literature on the various topics related to inventory management. Not only do these topics include inventory management practices like classification and control, but also two enabling factors of collaboration and forecasting methods that should be prioritized by the BU. In addition to enabling factors, adequate follow up measures were identified to monitor the progress of the implementation of the inventory management initiative. The comprehensiveness of the selected KPIs provides a linkage between the department's inventory initiative and the strategic goals of the company. Although the goal is to reduce stock levels, by taking a holistic approach to understanding the interconnectedness of different decisions across the organization, the company can have a better grasp of whether or not the inventory in stock is correct and actually serving the organization.

7.5 Future research

Some areas of interest were found that were out of the scope of this thesis but touched upon briefly. Two of the areas are specific to the context of the case company, Alfa Laval: Improving the SIP process, and developing component level forecast models. A third area of interest has potential for future academic study: A holistic study which assesses relevant inventory practices and implementation tactics at MTO companies with a focus on component and raw material management. These topics could inspire future studies and will be outlined in the following sections.

Improving SIP process

Alfa Laval operates as a Make-To-Order (MTO) company and can enhance their competitiveness by improving the Sales-in-Progress (SIP) process. Currently, two areas of improvement can be addressed. Firstly, the company places a high priority on customer relationships, resulting in a significant buildup of finished goods awaiting delivery. Secondly, the production of larger orders can commence several months in advance, and the completed units must wait until the order is finalized before being invoiced and delivered to customers. Consequently, Alfa Laval can create a project to address the accumulation of SIP from both the production and sales perspectives. The goal would be to reduce the total amount of finished goods by a predetermined target.

Developing forecast models at a component level

Moreover, forecasting at a component level was identified as a current burning platform at BU GPHE. Companies, in general, have been struggling to find appropriate and accurate forecasting models, and diverse organizations have developed studies and master's theses focusing on finding suitable and applicable forecasting models for their specific cases. Developing an accurate forecasting model for all items at the component level can be a challenging task, especially when patterns are difficult to identify. To gain valuable insights, Alfa Laval can conduct a study to develop forecasts at the component level and follow up accuracy.

Academic perspective

From an academic perspective, inventory is a widely studied topic. However, the authors of this study encountered difficulties when searching for relevant articles and journals applicable to MTO companies' processes. Therefore, it is suggested the development of more studies relating inventory management practices and implementing these practices from an MTO company perspective, showing the importance of shifting the attention from a finished product to a component standpoint.

References

Alfa Laval. (2021). Close at hand - Heat exchangers for Hygienic Fluid Handling Equipment. *Alfa Laval*, 114.

Alfa Laval. (2023). Alfa Laval: Sweden. Retrieved January 17, 2023, from https://www.alfalaval.se/

ASCM. (2022). *ASCM Supply Chain Dictionary* (17th Edition ed.) [Association for Supply Chain Management]. Retrieved April 14, 2023, from https://ascm.force.com/community/apex/scormanywhere__SCORM_Player?KVl6EsrtbQUlSoTWyZBmMUcnVKQgD3VWsQa5lLlKPeItTsQjRBG6bg1NwM85Uggg

Axsäter, S. (2006). *Inventory Control*. Springer.

Baker, P. (2007). An exploratory framework of the role of inventory and warehousing in international supply chains. *International Journal of Logistics Management*, *18*(1), 64-80. DOI 10.1108/09574090710748171

Bayraktar, E., Lenny Koh, S.C., Gunasekaran, A., Sari, K., & Tatoglu, E. (2008). The role of forecasting on bullwhip effect for E-SCM applications. *Int. J. Production Economics*, *113*, 193–204.

Berling, P. (2022). *Guest Lecture: Using production/inventory models in practice: Principles for determining cost parameters* [07-02-2022]. Lund University, Lund, Sweden.

Bialas, C., Revanoglou, A., & Manthou, V. (2020). Improving hospital pharmacy inventory management using data segmentation. *American Journal of Health-System Pharmacy*, *77*(5), 371–377.

Bongsug, C. K. (2009). Developing key performance indicators for supply chain: an industry perspective. *Supply Chain Management: An International Journal*, *14*(6), 422-428.

Boros, S., van Gorp, L., Cadeon, B., & Boute, R. (2017). Breaking Silos: A Field Experiment on Relational Conflict Management in Cross-Functional Teams. *Group Decis Negot*, *26*, 327-356. 10.1007/s10726-016-9487-5

Boute, R., Van Dierdonck, R., & Vereecke, A. (2011). Organising for supply chain management. *International Journal of Logistics Research and Applications*, *14*(5), 297-315. 10.1080/13675567.2011.636347

Buliński, J., Waszkiewicz, C., & Buraczewski, P. (2013). Utilization of ABC/XYZ analysis in stock planning in the enterprise. *Agriculture (Agricultural and Forest Engineering)*, *61*, 89–96.

Cannas, V. G., Gosling, J., Pero, M., & Rossi, T. (2019). Engineering and production decoupling configurations: An empirical study in the machinery industry. *International Journal of Production Economics*, *216*, 173–189.

Capkun, V., Mameri, A.-P., & Weiss, L. (2009). On the relationship between inventory and financial performance in manufacturing companies. *International Journal of Operations & Production Management*, *29*(7-8), 789-806. 10.1108/01443570910977698

Chae, B. K. (2009). Developing key performance indicators for supply chain: an industry perspective. *Supply Chain Management: An International Journal*, *14*(6), 422–428.

Chen, H., Frank, M. Z., & Wu, O. Q. (2005). What Actually Happened to the Inventories of American Companies Between 1981 and 2000? *Management Science*, *51*(7), 1015-1031. 10.1287/mnsc.1050.0368

Chen, Y., Li, K.W., Kilgour, D.M., & Hipel, K.W. (2008). A case-based distance model for multiple criteria ABC analysis. *Computers and Operations Research*, *35*(3), 776 – 796.

Chinello, E., Herbert-Hansen, Z., & Khalid, W. (2020). Assessment of the impact of inventory optimization drivers in a multi-echelon supply chain: Case of a toy manufacturer. *Computers & Industrial Engineering*, *141*. 10.1016/j.cie.2019.106232

Chod, J. (2017). Inventory, Risk Shifting, and Trade Credit. *Management Science*, *63*(10), 3207–3225.

D'Alessandro, A.J., & Baveja, A. (2000). Divide and Conquer: Rohm and Haas' Response to a Changing Specialty Chemicals Market. *Interfaces*, *30*(6), 1–16.

Demeter, K., & Golini, R. (2014). Inventory configurations and drivers: An international study of assembling industries. *International Journal of Production Economics*, *157*, 62-73. 10.1016/j.ijpe.2013.10.018

Douissa, M.R., & Jabeur, K. (2016). A New Model for Multi-criteria ABC Inventory Classification: PROAFTN Method. *Procedia Computer Science*, *96*, 550–559.

Eccles, R. G. (1995). The Performance Measurement Manifesto. *Harvard Business Review*, *69*(1), 131–137.

Feller, A., Shunk, D., & Callarman, T. (2006). *Value Chains Versus Supply Chains* [BPTrends].

Fisher, M. L. (1997). What is the Right Supply Chain for Your Product? *Harvard Business Review*, *March-April*, 105-116.

Galankashi, M. R., & Rafiei, F. M. (2022). Financial performance measurement of supply chains: a review. *International Journal of Productivity and Performance Management*, *71*(5), 1674-1707.

Gansterer, M. (2015). Aggregate planning and forecasting in make-to-order production systems. *Int. J. Production Economics*, *170*, 521-528.

Ghorabaee, M., Zavadskas, E. K., Olfat, L., & Turskis, Z. (2015). Multi-Criteria Inventory Classification Using a New Method of Evaluation Based on Distance from Average Solution (EDAS). *Informatica*, *26*(3), 435–451.

Gibson, B., Coyle, J. J., Suzuki, Y., & Novack, R. A. (2018). *Transportation: A Global Supply Chain Perspective*. Cengage Learning.

Handfield, R. B., & Bozarth, C. C. (2015). *Introduction to Operations and Supply Chain Management*. Pearson.

Hu, Q., Boylan, J. E., Chen, H., & Labib, A. (2018). OR in spare parts management: A review. *European Journal of Operational Research*, *266*(2), 395–414.

Jacobs, R. F., Berry, W. L., Whybark, D. C., & Vollman, T. E. (2011). Chapter 4: Sales and Operations Planning. In R. F. Jacobs (Ed.), *Manufacturing Planning and Control* (pp. 88-111).

Johnson, P. F., Shafiq, A., Awaysheh, A., & Leenders, M. (2014). Supply organizations in North America: A 24 year perspective on roles and responsibilities 1987–2011. *Journal of Purchasing & Supply Management*, *20*, 130-141. 10.1016/j.pursup.2014.01.003

Kalaiarasan, R., Olhager, J., Agrawal, T. K., & Wiktorsson, M. (2022). The ABCDE of supply chain visibility: A systematic literature review and framework. *International Journal of Production Economics*, *248*. 10.1016/j.ijpe.2022.108464

Kembro, J., & Selviaridis, K. (2015). Exploring information sharing in the extended supply chain: an interdependence perspective. *Supply Chain Management: An International Journal*, *20*(4), 455-470. 10.1108/SCM-07-2014-0252

Lee, H., & Whang, S. (1999). Decentralized Multi-Echelon Supply Chains: Incentives and Information. *Management Science*, *45*(5), 633-640.

Lolli, F., Balugani, E., Gamberini, R., Rimini, B., Ishizaka, A., & Regattieri, A. (2019). Machine learning for multi-criteria inventory classification applied to intermittent demand. *Production Planning and Control*, *30*(1), 76-89.

Longo, F. (2011). *Supply Chain Management Based on Modeling & Simulation: State of the Art and Application Examples in Inventory and Warehouse Management* (P. Li, Ed.). IntechOpen. DOI: 10.5772/15103

Meindl, P., & Chopra, S. (2016). *Supply Chain Management: Strategy, Planning, and Operation*. Pearson.

Mentzer, J. T., DeWitt, W., Keeber, J. S., Min, S., Nix, N. W., & Smith, C. D. (2001). Defining Supply Chain Management. *Journal of Business Logistics*, *22*(2), 1-25.

Michalski, G. (2008). Value-based inventory management. *Romanian Journal of Economic Forecasting*, *9*(1), 82-90.

Min, S., Roath, A. S., Daugherty, P. J., Genchev, S. E., Chen, H., Arndt, A. D., & Glenn Richey, R. (2005). Supply chain collaboration: what's happening? *The International Journal of Logistics Management*, *16*(2), 237-256. 10.1108/09574090510634539

Neely, A., Gregory, M., & Platts, K. (1995). Performance measurement systems design: a literature review and research agenda. *International Journal of Operations & Production Management*, *15*(4), 80-116.

Nenes, G., Panagiotidou, S., & Tagaras, G. (2010). Inventory management of multiple items with irregular demand: A case study. *European Journal of Operational Research*, *205*(2), 313-324. 10.1016/j.ejor.2009.12.022

Norrman, A., & Näslund, D. (2019). Supply Chain Incentive Alignment: The Gap between Perceived Importance and Actual Practice. *Operations and Supply Chain Management*, *12*(3), 129-142.

Olhager, J. (2003). Strategic positioning of the order penetration point. *International Journal of Production Economics*, *85*, 319–329.

Olhager, J. (2010). The role of the customer order decoupling point in production and supply chain management. *Computers in Industry*, *61*(9), 863–868.

Olhager, J. (2019). *Supply Chain Management - Produktion och logistik i försörjningskedjor*. Studentlitteratur AB.

Olhager, J. (2021). *Sales & Operations Planning* [Lecture notes, Business Process Management MTTN60, Lund University].

Olhager, J. (2022). *Lecture 1-2: Introduction* [Lecture notes, Project Management & Research Methodologies MTTN85]. Lund University, Lund, Sweden.

Olhager, J. (2023). *Personal interview* [31-01-2023]. Lund University, Lund, Sweden.

Olhager, J., & Prajogo, D. (2012). The impact of manufacturing and supply chain improvement initiatives: A survey comparing make-to-order and make-to-stock firms. *Omega*, *40*, 159 - 165.

Olhager, J., & Selldin, E. (2007). Manufacturing planning and control approaches: market alignment and performance. *International Journal of Production Research*, *45*(6), 1469-1484.

Pawlak, M., & Malyszek, E. (2008). A local collaboration as the most successful co-ordination scenario in the supply chain. *Industrial Management & Data Systems*, *108*(1-2), 22-42. 10.1108/02635570810844061

Perona, M., Saccani, N., & Zanoni, S. (2009). Combining make-to-order and make-to-stock inventory policies: an empirical application to manufacturing SME. *Production Planning and Control*, *20*(7), 559-575. 10.1080/09537280903034271

Porter, M. (1985). Competitive Advantage: Creating and Sustaining Superior Performance. *The Free Press, New York.*

Rădăşanu, A. (2016). Inventory Management, Service Level and Safety Stock. *Journal of Public Administration, Finance and Law, 5*(9), 145–153.

Rummler, G. A., & Brache, A. P. (1991). Managing the White Space. *Training*, *28*(1), 55-70.

Sahin, F., & Powell Robinson Jr., E. (2005). Information sharing and coordination in make-to-order supply chains. *Journal of Operations Management*, *23,* 579-598.

Sánchez-Rodríguez, C., Hemsworth, D., Martínez-Lorente, A. R., & Clavel, J. G. (2006). An empirical study on the impact of standardization of materials and purchasing procedures on purchasing and business performance. *Supply Chain Management*, *11*(1), 56-64. 10.1108/13598540610642475

Saunders, M., Lewis, P., & Thornhill, A. (2012). *Research Methods for Business Students*. Pearson.

Scholz-Reiter, B., Heger, J., Meinecke, C., & Bergmann, J. (2012). Integration of demand forecasts in ABC-XYZ analysis: Practical investigation at an industrial company. *International Journal of Productivity and Performance Management, 61*(4), 445-451.

Seuring, S., & Müller, M. (2008). From a literature review to a conceptual framework for sustainable supply chain management. *Journal of Cleaner Production, 16,* 1699–1710.

Sharman, G. (1984). The rediscovery of logistics. *Harvard Business Review*, *62*(5), 71–80.

Shepherd, C., & Günter, H. (2006). Measuring supply chain performance: current research and future directions. *International Journal of Productivity and Performance Management*, *55*(3-4), 242-258.

Småros, J. (2003). Collaborative forecasting: a selection of practical approaches. *International Journal of Logistics: Research and Applications*, *6*(4), 245-258. 10.1080/13675560310001626981

Song, J.-S., van Houtum, G.-J., & Van Mieghem, J. A. (2020). Capacity and Inventory Management: Review, Trends, and Projections. *Manufacturing & Service Operations Management*, *22*(1), 36-46. https://doi.org/10.1287/msom.2019.0798

Stojanović, M., & Regodić, D. (2017). The Significance of the Integrated Multicriteria ABC-XYZ Method for the Inventory Management Process. *Acta Polytechnica Hungarica*, *14*(5), 28 - 48.

Stone, F. (2004). Deconstructing Silos and Supporting Collaboration. *Wiley InterScience*, 11-18.

Tsai, S. C., & Zheng, Y. X. (2013). A simulation optimization approach for a two-echelon inventory system with service level constraints. *European Journal of Operational Research*, *229*(2), 364–374.

Vanpoucke, E., Vereecke, A., & Muylle, S. (2017). Leveraging the impact of supply chain integration through information technology. *International Journal of Operations & Production Management*, *37*(4), 510-530. 10.1108/IJOPM-07-2015-0441

van Weele, A. J. (2014). *Purchasing & Supply Chain Management: Analysis, Strategy, Planning and Practice*. Cengage Learning.

Voss, C., Tsikriktsis, N., & Frohlich, M. (2002). Case research in operations management. *International Journal of Operations & Production Management*, *22*(2), 195-219.

Williams, B. D., & Tokar, T. (2008). A review of inventory management research in major logistics journals. *International Journal of Logistics Management*, *19*(2), 212-232. 10.1108/09574090810895960

Woodruff, R. (2003). Alternative paths to marketing knowledge. *Qualitative methods doctoral seminar: University of Tennessee*.

Yin, R. K. (1994). *Case Study Research: Design and Methods*. SAGE Publications.

Appendix

Appendix A - Interview Guide

Disclosure: Questions were selected according to the participant's position.

Introduction - explain the thesis and introduce ourselves.
Ask selected questions:

1. What is your current role at Alfa Laval? How long have you worked there?
    a. What previous experiences do you have?

2. Can you define what your role entails at Alfa Laval?
    a. Who is involved? What decisions are made?
    b. What challenges are there?

3. What are Alfa Laval's strategic goals and how do you relate this to your role?

4. What production strategy does ___ factory use? For instance, MTS, MTO, ATO.
    a. Is anything standardized?
    b. If not, is there something that could be standardized?

5. How does the S&OP process influence your role in the organization?
    a. What information do you receive? How does it affect/help your position?

6. Does your department work in collaboration with another company department?
    a. If yes, how is this cross-functional work done?
    b. How often does it happen?

7. Do you share/receive information from/to other departments or external actors?
    a. What kind of information?
    b. How do you share information?
    c. How do you use shared information?

8. What is the relationship between the ___ planners and inventory management? What is the ___ planner's role in inventory management?
    a. What type of inventory is held at the LA/GCC?

9. How is the ___ plan being executed?
    a. What are the constraints that are considered when creating the ___ plan?
    a. How is the plan followed up? And how is the plan's success measured?

    b. Is the initial plan usually successful?

10. How is the forecasting process made? Who makes it? Who is it shared with?
    a. What is actually forecasted? (orders, raw materials?)
    b. How do you use it?

11. Who sets the reorder points, order quantities, and SS?
    a. How often are purchasing policies updated for different goods/materials?
    b. How are these calculated?

12. Do you classify the type of stock (Safety stock, cycle stock,...)

13. How does the company classify stock items? Does it use ABC analysis or any other classification method? Does it influence the decision to keep them in stock or produce them in large quantities? Or vice versa.

14. How is the implementation of ATHENA?
    a. Successes?
    b. Challenges?

15. How do you define metrics to be measured to control the business?
    a. Do you focus primarily on financial KPIs?
        i. Which ones?
        ii. Do you help translate these into more operational measures?

16. What KPI structure is recommended by central, particularly connecting inventory control and Alfa Laval's strategic goals?
    a. Do you use a scorecard (operational or financial)?
    b. Are the measures standardized in their formulation?

17. Would you say that Alfa Laval operates in a centralized or decentralized manner?
    a. If hybrid, what type of decisions are made at each level?
    b. Does this work? Or does it create a disconnect?
    c. Does this affect your role? If so, how?

18. In general, do you see improvement potential in current work and processes?
    a. If so, where? How would the ideal process look to you?
    b. What do you think needs to happen to get there? How can you overcome the previously mentioned challenges?