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DETERMINING PRODUCTS FOR ASSEMBLE-TO-ORDER INVENTORY

Development of a calculation model and an implementation process

Master of Science Thesis
Faculty of Management of Business
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ABSTRACT

Oskar Heinonen: Determining products for Assemble-to-Order inventory: Development of a calculation model and an implementation process
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Determining which items and materials to stock is an important aspect of inventory management. In this study, ATO (Assemble-to-Order) offering management refers to defining which materials are stocked to enable short lead times for end-products. A calculated ATO offering is a computationally defined set of materials and components that ensure sufficient availability of end products while minimizing inventory costs. Defining a calculated ATO offering is important across the organization, as it impacts manufacturing, operations, inventory costs, customer satisfaction, and overall business performance.

The objective of this study was to identify the key criteria for determining which items and materials should be stocked in an ATO environment, and how these criteria can be formed into a calculation logic for a computational model. The study also examines how computational suggestions of materials to be added to or remove from stock should be implemented in practice. For the case company, the goal of this study was to create a way to challenge and evaluate the current ATO offering, by developing and implementing a historical demand-based calculation model. This model is used to evaluate and suggest changes to the ATO offering on an annual basis within the case company. Optimizing the ATO offering improves availability for high-demand items and reduces unnecessary inventory to free up inventory-tied capital. This systematic approach to reviewing the ATO offering enables holistic management, allowing adjustments to be made before issues such as low availability or low warehouse consumption become apparent.

The study includes a literature review, and industry expert interviews which provide a foundation for the quantitative analysis. The quantitative section utilizes the Action Design Research framework for developing the calculation model, where iterative versions are produced, evaluated, and modified according to practical considerations of the case organization. The aim is to produce a solution that solves a real-life challenge of evaluating the current ATO offering, calculating suggested changes and implementing these suggestions in practice. Results of the calculation model were evaluated by industry experts in workshops, to highlight challenges in the implementation phase.

The key findings of this study are both theoretical and practical. The theoretical findings highlight the parameters to be considered when defining a calculated offering, and the importance of defining the key parameters which are used to determine which items to stock. The practical findings highlight the many factors which need to be considered when implementing such a tool in practice. These include tacit knowledge, data reliability, manual reviews associated workload, as well as the ease using and understanding the final solution and its results in practice.

A key outcome of this study is the practical calculation model and its implementation process for the case company. The calculation model is a comprehensive tool for ATO offering management: Calculated suggestions are manually reviewed to ensure changes implemented are feasible. From the academic perspective, the conclusions of this study underscore the combination of theoretical and practical considerations for ATO offering management: To successfully develop and implement a solution to manage ATO offering in a practical context, theoretical ideas need to be applied, practically tested, evaluated, and developed iteratively.

Keywords: Assemble-to-Order, ATO, Inventory management, Offering management

TIIVISTELMÄ

Oskar Heinonen: Assemble-to-Order-tarjonnassa olevien tuotteiden määrittäminen: Laskentamallin ja implementaatioprosessin kehittäminen
Diplomityö
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Varastoitavien tuotteiden ja materiaalinen määrittely on tärkeä osa varastonhallintaa. ATO (Assemble-to-Order) -tarjonnan hallinta viittaa tässä tutkimuksessa siihen, mitä materiaaleja päätetään varastoida lopputuotteiden lyhyen toimitusajan varmistamiseksi. Laskennallinen ATO-tarjonta on laskennallisesti määritelty joukko materiaaleja ja komponentteja, jotka mahdollistavat hyvän saatavuuden minimoiden varastokustannukset. Laskennallisen ATO-tarjonnan määrittely on tärkeää koko organisaation kannalta, sillä se vaikuttaa tehtaan toimintaan, operaatioihin, varastointikustannuksiin, asiakastyytyväisyyteen, sekä liiketoimintaan.

Tämän tutkimuksen tavoitteena oli tunnistaa keskeiset kriteerit, joiden perusteella voidaan määrittää, mitkä tuotteet ja materiaalit olisi varastoitava ATO-ympäristössä, ja miten näistä kriteereistä voidaan muodostaa laskennallisen mallin laskentalogiikka. Tutkimuksessa tarkastellaan myös sitä, miten materiaalien laskennalliset ehdotukset tai varastosta poistaminen tulisi toteuttaa käytännössä. Case-yrityksen kannalta tämän tutkimuksen tavoitteena oli luoda tapa haastaa ja arvioida nykyistä ATO-tarjontaa kehittämällä ja toteuttamalla historialliseen kysyntään perustuva laskentamalli. Tätä mallia voidaan käyttää arvioimaan ja ehdottamaan muutoksia ATO-tarjontaan vuosittaisella tasolla case-yrityksessä. ATO-tarjonnan optimointi parantaa saatavuutta suhteessa varastoon sitoutuneeseen pääomaan. Tämä systemaattinen lähestymistapa ATO-tarjonnan tarkasteluun mahdollistaa kokonaisvaltaisen hallinnan, jolloin mukautuksia voidaan tehdä ennen kuin ongelmat, kuten heikko saatavuus tai varaston alhainen kulutus, tulevat muuten ilmi.

Tutkimuksessa suoritetaan kirjallisuuskatsaus ja alan asiantuntijoiden haastatteluja, jotka muodostavat perustan kvantitatiiviselle analyysille. Kvantitatiivisessa osiossa laskentamallin kehittämisessä hyödynnetään Action Design Research -viitekehystä, jossa iteratiivisia versioita kehitetään, arvioidaan ja muokataan case-yrityksen käytännön tarpeiden mukaisesti. Tavoitteena on tuottaa ratkaisu, joka ratkaisee tosielämän haasteen, joka koostuu nykyisen ATO-tarjonnan arvioinnista, laskennallisten muutosten ehdotuksista ja näiden ehdotusten toteuttamisesta käytännössä. Laskentamallin tuloksia arvioitiin työpajoissa alan asiantuntijoiden toimesta käytännön toteutukseen liittyvien haasteiden kartoittamiseksi.

Tutkimuksen keskeiset tulokset ovat sekä teoreettisia että käytännönläheisiä. Teoreettisissa tuloksissa korostetaan laskennallisen tarjonnan määrittelyssä huomioon otettavia parametreja ja keskeisten parametrien määrittelyn tärkeyttä varastoitavien tuotteiden määrittämiseksi. Käytännön havainnot osoittavat, millaisia tekijöitä on otettava huomioon tällaisen työkalun käytännön implementoinnissa. Näihin kuuluvat hiljainen tieto, tietojen luotettavuus, manuaaliset tarkistukset ja niihin liittyvä työmäärä sekä lopullisen ratkaisun ja sen tulosten käytön ja ymmärtämisen helppous käytännössä.

Tämän tutkimuksen keskeinen tulos on käytännöllinen laskentamalli ja sen käyttöönottoprosessi case-yrityksessä. Laskentamalli on kokonaisvaltainen työkalu ATO-tarjonnan hallintaan: Lasketut ehdotukset tarkistetaan manuaalisesti sen varmistamiseksi, että ehdotetut muutokset ovat toteutettavissa. Akateemisesta näkökulmasta katsottuna tämän tutkimuksen päätelmät korostavat teoreettisten ja käytännön näkökohtien yhdistämistä ATO-tarjonnan hallinnassa: Jotta ATO-tarjonnan hallintaan voidaan onnistuneesti kehittää ja ottaa käyttöön ratkaisu, teoreettisia ideoita on sovellettava, testattava käytännössä, arvioitava ja kehitettävä iteratiivisesti.

Avainsanat: Assemble-to-Order, ATO, varastonhallinta, tarjonnanhallinta

USE OF ARTIFICIAL INTELLIGENCE IN THIS THESIS

I have utilized AI tools in my thesis.

Tool name and version: ChatGPT, versions 4 and 4o.

ChatGPT was used to enhance the structure and clarity of some sentences and for translating interview quotations. All content-related decisions where AI was used were reviewed by the author.

I am aware that I am fully responsible for the content of my thesis, including sections produced with AI, and I accept my responsibility for any potential violations of ethical guidelines.

PREFACE

Writing a master's thesis is a big step in the academic journey of any student, as it is the final chapter of all studies all the way from pre-school. It has been a pleasure to study at Tampere University, and I am especially grateful for all the amazing people I have met along the way. The first big thank you goes to my partner Emma for the encouragement and support during my entire studies. Thank you to my thesis supervisor Aki for helpful and valuable feedback along the way, they really helped me get the thesis over the finish line.

I also want to thank the case company for allowing me to write my thesis on such a practice-related topic and for great support throughout the process. Special thanks to my thesis supervisor at the case company, Sakari, for the easy collaboration and continuous support during the development of the calculation model and the related process. Another big thank you to Rene, who is now taking over the responsibility of running the calculations and initiation of the implementation process.

I quoted the recipe of a sausage sauce in the preface of my bachelor's thesis, which I will refrain from due to the more professional nature of a master's thesis. However, the analogy from my bachelor's thesis is also relevant in this study: In both cooking and inventory optimization, the best results are often achieved through iteration and continuous improvement.

Helsinki, 15.3.2025

Oskar Heinonen

SISÄLLYSLUETTELO

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ABBREVIATIONS AND NOTATIONS

ATO	Assemble-to-Order
ATO offering	Items and materials, which can be assembled in a short lead time. A valve is in ATO offering, if all of its materials are in ATO offering.
BOM	Bill of Materials
LT	Lead time
Material	For the purposes of this study, “material” refers to the parts or components a valve consists of. Materials consist of sub-materials.
Topwork	A final product consisting of a valve and other components combined with it, for example a positioner and an actuator.
TypeCode	An ID for a valve

1. INTRODUCTION

1.1 Background and purpose of thesis

Inventory is a crucial aspect of almost any manufacturing company. Inventories provide a possibility to store items for later use, to cover fluctuations in supply or demand (Saxena, 2009, p. 3). In the manufacturing industry, managing inventory is a crucial aspect of overall operational success. Successful inventory management enables efficient use of resources and maintains availability despite varying supply or demand. On the other hand, poor inventory management can lead to excessive capital tied up in stock, inefficient use of resources, and, ultimately, reduced profitability. (Chan et al., 2017) Underestimating inventory needs can result in missed customer orders, delayed deliveries, and reputational damage (Bah, 2023).

Inventories can be held for example as end products or as materials from which the end-products are assembled. In this study, the focus is on Assemble-to-Order (ATO) environments, where materials of end-products are stocked, rather than warehousing complete end-products. In ATO environments, when a customer order is received, materials are assembled into an end-product according to the order specifications. Compared to Make-to-Stock (MTS or Make-to-Order (MTO), ATO enables high customizability of end products, while maintaining short lead times (Tsai et al., 2014).

Managing which material items to stock is often more complex in ATO environments compared to stocking end-products. In ATO, end-products are assembled using multiple materials, and materials can often be used for multiple different end-products. This interconnectedness is at the core of a complex network of relations, where the availability of one material can affect the availability of entire sets of end-products: A product cannot be assembled if all materials are not available. In an extreme situation, one missing screw can lead to the delay of an entire order. Understanding and being able to evaluate which products or materials should be in stocked offering is important. In ATO environments, striking the right balance of maximum availability and minimum inventory costs is particularly challenging. The ability to offer customized products with short lead times is a key competitive advantage (Spring & Dalrymple, 2000).

The purpose of this thesis is to increase the understanding of how to computationally define which products and materials should be stocked in an ATO environment. Defining

a calculated inventory is complex, as it involves numerous parameters and criteria, including availability and inventory costs but also qualitative factors such as customer relations. This study provides a review of what the main factors and parameters are to be considered, and how to form a calculation logic for computationally defining which products to stock. This study also provides insights into what kind of factors should be considered when implementing calculation results in a practical process.

1.2 Objectives and research questions

The objective of this research is to define how a calculated inventory can be determined by a calculation model, and how the calculated results of which items and materials should be in stock can be implemented in practice. The challenge includes examining relevant criteria for such a calculation model and determining how they can be evaluated computationally. This quantitative, calculation-based point of view is combined with an implementation process, where practical considerations of running and evaluating workload, ease of use, and availability of data, among other factors, need to be considered.

From the case company point of view, the challenge is practical in nature: Case company faces the challenge of managing a large inventory and seeks to find a way to evaluate and challenge the current ATO offering by determining a calculated inventory of products and materials. The core challenges from an inventory management point of view are to minimize tied-up capital and improve the availability of key products. The solution is to create a historical demand-based calculation model and a process where the calculation results of the tool are implemented, to determine the products to be stocked. This is in practice done by developing a calculation model which outputs a list of valve materials to be added to or removed from stocked materials. Once a computational inventory is defined, the suggestions of the calculation model are reviewed in a process involving relevant stakeholders, who evaluate the feasibility of these change suggestions. Key performance indicators (KPI) are developed to evaluate the calculation results in terms of how much they improve different inventory management parameters. At the end of the implementation process, materials are added to or removed from ATO inventory based on the combination of quantitative calculations and qualitative evaluations.

The planned output of this study from case company point of view is a dynamic tool to determine the optimal offering for products and components stocked in short-term ATO inventory. ATO warehoused items are defined as items whose materials are warehoused, i.e. they can be assembled into a complete "topwork" in a short time. In addition, a process will be developed in the thesis on how to implement the calculation results into practice with a recurring process. In the process plan, the practical steps from data input

to implementation are defined, as well as how different stakeholders participate in the process.

The objective of this study is to review how to computationally define products to stock in an ATO environment, what kind of inventory management -related parameters should be considered, and what should be taken into consideration when implementing such calculation results in practice. Therefore, the objectives can be divided into the following research questions:

- *RQ1: How can a calculation model be developed to determine the materials and products to be in stock in an ATO environment?*
    - *RQ1a: What are the main parameters to include when defining which materials to stock?*
    - *RQ1b: How can the parameters be formed into a calculation logic, where both theoretical and practical factors are considered?*

Research question 1 and its sub-questions focus on reviewing how an ATO inventory can be defined computationally, and which parameters and criteria should be considered. The aim is to form a calculation logic based on the selected criteria, which defines whether a material should be stocked or not.

- *RQ2: How can the results obtained in the calculation model be implemented in a practical process?*

Research question 2 examines how results from a calculation model (which determines computationally whether a material is stocked or not) can be implemented in a practical process. This includes defining the relevant stakeholders who can evaluate the feasibility of implementing results, as well as practical considerations on how to drive the process from calculation results to implemented inventory changes.

Through increased availability of high-demand products, decreased excessive inventory, and a clearer understanding of stocked offering, this research supports the case company optimizing its short lead time inventory globally. This study also aims at helping the company implement these optimizations by providing a transparent, repeatable process for ATO offering management. A computational model helps to systematically challenge the need for a strategically determined inventory, in case sales forecasts have not materialized. A computational model could also highlight instances where major offering expansions can be made with low inventory investment.

1.3 Case context

The case company operates in the industrial valve manufacturing sector, providing flow control solutions to various industries. The focus of the thesis is on the whole Flow Control business unit and its benefits, optimizing cost, availability and other criteria identified in the study. The thesis will be carried out from the pricing and availability team's perspective but will seek to consider the whole organization and other relevant stakeholders. However, as the researcher has been working in the pricing and availability team, there is a risk for biases, which should be mitigated.

Valves are a core piece of equipment in many industrial processes, and mission-critical to ensure successful regulation of liquid, gas, and slurry flow. Valves are important in a wide range of sectors, including oil and gas, water treatment, chemical processing, and manufacturing. Both operational efficiency as well as safety are highly affected by the performance of valves, highlighting the importance of high-quality products, and the desire for solutions which have a proven track record. (Zhang et al., 2024) There is also a high number of different kinds of technical requirements in the form of certificates which need to be considered. These vary between customers and need to be considered when defining product offering. The valve industry is stable, and contrary to many other industries, the products do not change much over time. There are new innovations regularly, but a large part of business is based on well-established, reliable, products.

The valve business is very complex due to multiple factors, including regional regulation differences, the criticality of the valve as a part of processes, and the variety of customer demands and requests when it comes to the requirements of the flow control solutions. This can cause the number of end-products to be very high, as there are almost infinite possibilities to customize solutions. Due to this large offering of products, it is crucial to manage the inventory effectively, and to avoid unnecessary inventory, while maintaining or improving availability. Determining which materials and end products to stock requires consideration of quantitative and qualitative aspects. Finding which criteria are the most important and should be considered in the calculation logic is one of the main challenges in the study. The criteria are combined in the form of a calculation logic which determines materials and items to stock.

The geographical scope of the study from the point of view of the case company includes the entire global business unit and its entire offering, excluding North America, due to the same type of data not being used there. The test runs of the calculation model and the process are done with a focus on the Helsinki warehouse for all valve series. However, the model is constructed in a way where it can easily accommodate calculations

for other warehouses as well. One of the targets of the calculation model developed in this study is to be able to run the process for all valve series globally, including North America. The process developed to implement the calculation results includes a plan to run the calculations for the entire organization. This is important to ensure the entire offering is evaluated using a computational model, and to enable global comparison between plants and product series.

1.4 Structure of the study

The structure of a thesis can be divided into four core categories: Introduction, background, core, and synthesis according to Evans et al. (2014). These four categories must be connected to form a structured approach to a stated problem. This thesis is divided into according to these four categories: The introduction chapter functions as the introduction, the literature review is the background, research methodology and analysis and findings are the core of the study, and the conclusions chapter is the synthesis.

The literature review forms the theoretical background for the study. It focuses theoretical points of view for defining a calculated ATO inventory, and the practical process of implementing the results. The literature review is divided into an introduction of inventory management and ATO in general, trade-offs in inventory management, factors to consider when defining an ATO offering, the implications of ATO offering selection, and the process considerations for implementing calculation results in an ATO context.

The findings in the literature review are utilized in the core of the study, which is the analysis and findings chapter. According to Evans et al. (2014), the core of a study includes the hypotheses, design, interviews, results and analysis. In this chapter, the literature review, interview, workshop, and discussion findings, and iterative calculation model development are combined. The analysis and findings chapter begins with the analysis of the interviews and workshops, which examine the requirements, as well as practical and theoretical understanding of industry experts regarding ATO offering definition. The knowledge of the literature review and the qualitative data collection are utilized in the iterative calculation model development phase. The result of the calculation model development is a calculation logic, which encompasses the criteria and parameters defined in the earlier stages. At the end of the analysis and findings chapter, the implementation process of the calculation results is described.

The chapter conclusions synthesizes the findings of the study both from the point of view of the case company as well as research in general. The research questions are answered, and an evaluation of considerations, limitations, and future development are

examined. In the conclusion chapter, the contribution to research is examined and compared to earlier research (Evans et al., 2014).

An additional chapter, recommendations for case company, is added as requested by case company. It is a synthesis of how case company can leverage the findings in this study in the best way possible according to the author's subjective perspective. The recommendations chapter includes an action plan for the following three years, as well as a ranked list of the most important future developments of the calculation model.

2. LITERATURE REVIEW

The literature review lays a theoretical foundation for the calculation model and its implementation process developed in this thesis. The literature review includes chapters on inventory management in general, ATO offering, ABC and XYZ analyses, trade-offs in inventory management, factors to consider when defining an ATO offering, implications of ATO offering selection, and process design.

The theories presented in this thesis will be applied to the specific context of the case company. Aspects that require special attention are the large number of unique products of the case company, and other industry-specific aspects of a highly quality-focused manufacturer of specialized and customized products. There is also a lot of tacit knowledge used when defining offering, which needs to be considered when implementing the calculation results in practice. Understanding and combining both the historical demand -based parameters as well as the more qualitative aspects of offering management is important for successful development and implementation of the calculation model and its results.

2.1 Introduction to inventory management

The goal of this thesis is to optimize the product offering, making it essential to understand the fundamental principles of inventory management related to this challenge. The key objectives of inventory management are to ensure optimal stock levels and thus reduce tied up capital, while maintaining sufficient product availability (Eroglu & Hofer, 2011). These challenges have existed since the very beginning of the industrial revolution and businesses are continually seeking to balance efficiency with responsiveness to market needs (Munyaka & Yadavalli, 2022). Inventory management has been influenced by a variety of economic and operational ideas. The lean production philosophy of the late 20th century emphasizes the reduction of waste, including excess inventory, as a way to improve operational efficiency (Eroglu & Hofer, 2011). The lean way of thinking led to ideas such as just-in-time (JIT) and Economic Order Quantity (EOQ). These theories have highlighted the importance of effective inventory management and its effect on the financials.

Inventory can be defined as “the accumulations of materials, customers or information as they flow through processes or networks” (Slack et al., 2022, p 598). According to this

definition, inventory can be seen as a variety of available resources ready to be processed in one way or another. In this study, the focus is on physical inventory, which is also called stock. Physical inventory, or stock, can be defined as “accumulation of physical materials such as components, parts, finished goods or physical (paper) information records”. Managing the accumulation of inventory is what can be defined as inventory management. (Slack et al., 2022, p. 598).

As supply and demand do not occur simultaneously, there is a need for inventory. Inventory management is where this required stock is controlled and optimized. The benefits of having inventory (as opposed to manufacturing everything based on customer orders) include predictability, the ability to tackle fluctuations in demand and unreliability of supply, price protection, quantity discounts and lower ordering costs (Muller, 2011, p. 13). The costs that occur in inventory management include the costs of order placing, price discount, stock-out, working capital, storage, obsolescence, and operating inefficiency. (Slack et al., 2010, pp 340-348). The focus of this thesis, in terms of costs, is on tied-up capital in inventory and the costs associated with lost sales due to stockouts. Additionally, costs related to order quantities are addressed, particularly concerning minimum order quantities for lower-priced items. Storage costs are not considered in this study, and they are assumed to be negligible in the scope of this thesis.

2.2 ATO inventory

Production environments can be categorized into four categories: make-to-stock (MTS), make-to-order (MTO), engineer-to-order (ETO), and assemble-to-order (ATO). In MTS, inventory is kept ahead of customer demand as end-products. In MTO, components and engineering design are available, but the product to be made is defined by the customer order. ETO can be seen as an extension of MTO, where the customer specifications define the product almost entirely. (Ari Samadhi & Hoang, 1995)

This thesis focuses on Assemble-to-Order (ATO) inventory. In practice, ATO is an approach to inventory management, where stock is maintained on component level, rather than stocking end-products. In an ATO environment, end-products can be produced by assembling a set of the stocked components. In ATO environments, when a customer makes an order, the components are collected from inventory and assembled into valves and further to the end product. (Atan et al, 2017) In industries where customers require highly customized and specialized solutions, stocking all possible end products would make the inventory sub-optimally large. The solution is stocking materials which can be assembled in many constellations to form a wide selection of possible end-products while keeping inventory on a moderate level. (Atan et al., 2017) One of the main benefits of

ATO inventory is the ability to offer customizable products with relatively low lead times and low cost (Lee & Tang, 1997). ATO also protects against demand variability, as components can be used for multiple different end products. (Akcay et al., 2004)

ATO inventory works well for products with long component replenishment times, while final assembly lead times are relatively short (Akcay et al., 2004). Most companies in the fabricated metal and other manufacturing industries requiring high customizability and having relatively low profit margins and high competition, have high material inventory compared to finished goods inventory (Nag et al., 2014).

The ATO approach to inventory allows manufacturing companies to respond quicky to fluctuating customer demand without the burden of excessive stock of end products. This can be particularly beneficial in industries with high demand variability or rapid changes in end-product life cycles. (Nadar et al., 2014) The ability to manufacture highly customized products while maintaining low inventories improve the customer service while reducing operating expenses (Atan et al., 2017).

2.3 ABC and XYZ analysis

The fundamental idea of ABC analysis is that different products in inventory are not equal when it comes to importance. In ABC analysis, products and components are categorized into classes depending on how important and valuable they are. Items in class A have the biggest impact on inventory investment, while items in group C have the smallest impact. Roughly stated, A class items account for 20 % of inventory items but 80 % of total inventory investment. (Saracoglu, 2022)

According to Kaabi et al. (2015) A level products account for 5 % of inventory items but account for 40 % of the value of inventory. B level products account for 15 % of inventory items and account for 40 % of inventory value. C level products account for 80 % of inventory items but account for only 20 % of inventory value. (Kaabi et al., 2015) This highlights the importance of not analyzing inventory solely based on units in inventory but rather using relevant weights to determine the importance of a stocked item.

Despite A level items being at the core of many inventory efforts, the lower-level items should not be overlooked: C level items can be more important than their share in the ABC analysis, as they can enable the sales of A and B level products as customers value being able to buy everything from one vendor. (M.K.I.A et al., 2018) This is especially relevant for case company, where a large share of sales come from large customers who appreciate reliability and a high service level.

A traditional view of the ABC analysis classifies items by the Analytic Hierarchic Process (AHP) (Flores & Clay, 1986). In AHP, items are listed according to scores based on annual dollar usage, average unit cost, criticality, and lead time. The different criteria then received weights according to the AHP method. The scores combined with the weights were then used to classify items to A, B, or C class. Despite AHB being almost 40 years old, these criteria are very similar to the ones considered in this thesis, due to their fundamental nature.

There are also more recent studies on multi-criteria analyses of inventory optimization. Multi-criteria classification was originally developed by Partovi and Burton (1993) and Partovi and Hopton (1994). Ramanthan (2006) and Ng (2007) created their own versions of the weighted linear optimization model which were based on earlier studies. Ramanthan (2006) used a weighted linear optimization for classification and Ng (2007) added automatic updating of criteria weights. The user was able to enter weights in Ng's model, to try out the effects on inventory of different scenarios. This is very similar to the initial idea of the calculation model created in this thesis. Users can simulate different scenarios and assumptions by entering their preferred input values, and the results will reflect these parameter values.

Despite ABC analysis not directly applicable to this study, it highlights the importance of evaluating the importance of different items in inventory, focusing warehousing efforts to the class of products which have the biggest effect on inventory performance.

As ABC analysis focused on the value of items in inventory, XYZ analysis focuses on the deviation of usage of the items. Deviation affects the needed inventory levels significantly, as a highly varying demand requires a higher maximum level of inventory, which is balanced by inventory being less utilized at other times (Dhoka, 2013). Theoretically, a fully stable demand does not require any safety stock, as all demand can be covered by products which are coming straight from manufacturing or from the supplier. No inventory is accumulated as all demand is covered by a perfectly functioning just-in-time system. (Kros et al., 2006) However, this does not work in practice, as there is always some fluctuation in demand. The theoretical example highlights the impact of a variation in demand, which the XYZ analysis is designed to capture. (Sweeney, 2022) This means that products with higher variability require a higher level of stock to reach the same availability level compared to products with lower variability, even in situations where the annual demand would be similar for X and Z level products.

The XYZ classification is done based on the coefficient of variation, which is the ratio between standard deviation of item consumption and average consumption during a certain period of time. (Schönsleben, 2007). Products can be classified into X, Y, and Z categories according to Table 1 (Wassermann, 2001; Scholz-Reiter et. al., 2011).

Table 1: XYZ classification (modified from Wassermann, 2001 and Scholz-Reiter et. al., 2011)

Category	Description of products
X	Fairly constant consumption, fluctuations are quite rare
Y	Stronger fluctuation due to e.g., seasonal demand or other similar reasons
Z	Completely irregular consumption

The XYZ analysis adds another dimension for evaluating the need for inventory. In an environment with fully stable demand, the inventories should be used to cover the lead times of production cycles. The XYZ analysis highlights the importance of including demand variability in warehousing evaluation: Items with steady consumption can be covered by a low stock and steady consumption, while items with more fluctuating demand need to have more stock to cover demand spikes.

XYZ analysis can be combined with ABC analysis to form a 9-square matrix. This matrix shows the top class of AX, where the most valuable, low variance products are. On the other side of the matrix are the CZ products, which are low value and highly fluctuating. (Schönsleben, 2007) This matrix enables an easy way to categorize and evaluate different kinds of materials in stock. AX items should be ensured to be in stock, as they require little inventory as their demand variability is low and they are critical to operations. On the opposite side, CZ products pose the greatest risk of excess inventory and should be managed carefully. (Scholz-Reiter et al., 2012, Schönsleben, 2007)

2.4 Trade-offs in inventory management

As with any optimization, there are several trade-offs that need to be considered in inventory management. According to Merriam-Webster (2025), a trade-off is “a balancing of factors all of which are not attainable at the same time”. In inventory management, the trade-offs can be related to, for example, inventory holding costs vs. stockout risk, order size vs. ordering frequency, service level or lead time reduction vs. inventory investment,

centralized vs. decentralized inventory, standardization vs. customization, forecast reliance vs. responsiveness, or automation vs. flexibility. This study aims to determine which items and materials should be stocked, emphasizing the trade-offs between inventory investment, stockout risk, service level, lead time, demand forecasting, responsiveness, automation, and flexibility.

As a major factor in inventory management is cost reduction, one of the major challenges is what kind of trade-offs or compromises need to be made to achieve an optimal solution. The main trade-off decisions when it comes to inventory management are stock investments versus service level and lead time reduction versus operational efficiency. (Sbai & Berrado, 2018) In a hypothetical optimal world, there is no need for inventory as supply and demand meet at the customer order point. Realistically, however, to ensure product availability, a company needs to have inventory. Inventory ensures availability, and in the case of ATO products, a shorter lead time compared to products that need to be assembled from components not in inventory. According to Glasserman & Wang (1998) the trade-off between the amount of inventory held versus the lead time for delivery is linear. This tradeoff is especially relevant in ATO systems, in which the need for quick deliveries must be balanced with the amount of component inventory held.

The tradeoffs in inventory management can be analyzed from a business case point of view. The value of availability can be analyzed through the cost of stockouts versus the cost of excess inventory. Analyzing the costs of stockouts can be further analyzed by examining all costs related to poor availability. (Kourentzes et al., 2020) These can include lost sales due to long lead times, but also more qualitative factors such as customer satisfaction, reliability, and company brand and reputation (Ray & Millman, 1979). Inventory costs can be monetarily evaluated more easily: The costs of inventory include inventory tied capital, rent, depreciation, and potential maintenance during warehousing. (Azzi et al, 2014)

The physical location of inventory can also affect availability and inventory costs. Organizations must decide whether to hold inventory centrally or in multiple locations (Fadwa, 2025). Central inventories can lead to lower costs due to economies of scale and a broader offering due to a larger customer base. On the other hand, centralized inventories can reduce responsiveness and cause long lead times or high transportation costs due to long distances between the warehouse and the customer (Fadwa, 2025). Localized inventories benefit less from economies of scale, but benefit from increased responsiveness, shorter lead times and a more geographically focused offering. (Fadwa, 2025)

2.5 Factors to consider when defining ATO offering

When determining which products to stock, the most obvious factor to consider is demand. Demand can be forecasted by using historical demand and assuming that it continues steadily, or in a growing business, grows linearly. For the case company, the business is steady, and there is rarely a situation where demand is growing year-on-year. However, there are major fluctuations in demand on lower levels of the BOM hierarchy. The demand is highly variable in the project business of the case company, but in that case ATO offering is not a key factor, as products can be manufactured and delivered with longer lead times. There are some demand forecasts, but they are not readily available and cannot be generalized for the entire product series or larger entities. Thus, only historical demand-based forecasting is used in this study.

Besides demand, also other factors need to be considered when determining which items or materials to stock. According to Ruiz-Torres & Mahmoodi (2010), lead time variability should be considered when defining stocked offering and safety stock levels to achieve reasonable service levels. Several studies have shown that safety stock levels should be derived from average demand and variability of demand, combined with desired service level (Chase et al. 2001, Stevenson 2018). One risk with increasing inventories based on safety stock calculations is an unnecessarily high service level, which is accompanied by high inventory costs (Ruiz-Torres & Mahmoodi, 2010). Inventory holding costs should thus be a major factor when determining which materials should be stocked and which should not. There can also be a significant difference in cost between two materials that improve availability similarly. If the inventory budget only allows one of these to be stocked, the material which causes less inventory costs should be stocked. (Kolawole et al., 2019) The main factors to consider when defining and calculating ATO offering can thus be defined as demand, cost, and lead time. All these components consist of many subcategories, such as demand based on historical demand or forecasting, and lead time including lead time length, as well as variability. Cost can include factors such as tied-up capital, reorder costs and other holding costs due to e.g. the physical size of inventory. To generalize, the smaller the cost, and the larger the demand and lead time values are, the more likely a material is to be stocked.

2.5.1 Customer orders and offers as a basis for ATO offering

Defining ATO offering is an important decision both from an operational efficiency and a business point of view. Availability of products is often important for customers in the manufacturing and machinery industries, and managing ATO inventory is in the center of enabling availability for the right materials and products (Xiao et al., 2010).

From a business point of view, both won and lost offers are important to consider in specific contexts. Won orders should be covered by ATO offering as that is the core business which needs to be addressed, and improving availability and lead times of sold offers directly affect customer experience and the service provided. (Rahman & Rahman, 2020) On the other hand, focusing availability and lead time improvement efforts on lost offers can pose a major avenue for growth. If an offer is lost due to availability reasons, adding those materials or products to the ATO offering can directly turn lost offers into sales. (Moudio et al., 2022) However, a too intense focus on lost offers can cause inventory expansions for unnecessary items, especially if availability is improved for offers which have not been lost due to long lead times. Data and analysis on why offers are lost are key to understanding the effects of adding materials and products from lost offers to ATO offering.

Viewing historical demand from an offer point of view also highlights an important aspect compared to looking only at individual material or product consumptions: Products which are sold together form bundles which can be analyzed through market basket analysis (Neupane, 2023). These entities of product sold together reflect customer preferences and behaviors, which have significance both from a manufacturing and a business point of view. Despite high customization possibilities, there are often certain customer order patterns to be found in large data sets, where certain products are more often sold with a set of certain other products. (Shin et al., 2016) This connection is important to consider when defining optimal ATO offering, as these entities form the offered availability from the customer's point of view. There is little to no benefit to improving the availability of one product in an offer if there is another product with worse availability or a longer lead time. (Xu et al., 2018) Managing these connections is crucial for the business case of optimizing ATO offering.

The aspects mentioned above focus on the effects of improving availability and thus creating value when adding materials or products to ATO offering. On the other hand, there are also of course significant and obvious business benefits of reducing inventories. If customers do not perceive the increased value of increased availability, there is no use of using resources to increase availability by adding materials to stock. (Kurata & Nam, 2013) Similarly to when adding materials to offering, offers or other entities which

include subsections with long lead times are bottle necks, and thus the availability of other subsections can be lowered to match the bottle neck. The logic is very similar in both improving availability and reducing inventory costs from a business point of view. The offers should be considered as entities, the desired service levels should be identified, and the subsections of the order should be modified to match the desired service level while minimizing inventory costs.

2.5.2 Component commonality

As fulfillment of orders requires availability of multiple components, and as components can be required for multiple products, optimizing inventory levels becomes quite complicated. In case one component is unavailable, it could affect the availability of multiple products. This challenge is defined as component commonality. (Lu & Song, 2005) Solving this problem analytically is theoretically possible but becomes computationally difficult due to the complex structure of the problem (Akcay et al., 2004; Lu & Song, 2005).

As stated in chapter 2.4, when defining ATO inventory, there is always a tradeoff between cost of inventory and lead times of final products. One way to optimize which products to stock in this kind of environment is to analyze the commonality of materials. Commonality means the use of the same components across multiple products, which enables more flexibility with smaller inventories. (Colllier, 1981) However, too strict a focus on commonality could lead to the increased use of high-performance products in situations where they are not needed, increasing product cost with limited benefits (Takai & Sengupta, 2017). In the scope of this thesis, this commonality could be used to evaluate which materials should be warehoused based on how many products they are part of, instead of modifying the offering by combining multiple needs into one product. Many products in the ATO system use the same materials, and multiple materials are needed for a single product. Understanding the interdependencies between warehoused components, materials and products is important, as it affects the optimal inventory levels and the need to warehouse a material: If a material is only used in one product, it is less likely to be stocked in an optimized inventory system. (Agrawal & Cohen, 2001)

One way to analyze this challenge is the commonality index to determine which materials should be stocked. (Banarjee & Yadav, 2010) The commonality index can be used for multiple levels in a Bill of Materials (BOM) hierarchy, but as the scope of this thesis is the material level, the analysis is only done based on the material level in combination with the typeCode level. However, component commonality is important despite only being used for one level in the BOM hierarchy. Component commonality can be used to

determine the importance of a material: It is more likely that an item should be stocked if it is part of many important end products.

Component commonality can also be used to manage demand. For customers, the main target is solving the problem they face. It does not often matter to them which exact product is used, as long as it solves their problem. (Simpson et al., 2012) There are of course exceptions to this, but this describes a large share of customers. According to Bernestein et al. (2011), in component commonality theory, the number of products can be optimized by creating an offering which contains products that are unique enough to solve all different kinds of problems, while being small enough to have sufficient demand for each product. As the case company has a large number of products in offering, which do not necessarily have a lot of demand, it could be beneficial to reduce the number of products to solve multiple problems with fewer unique products.

2.5.3 Demand uncertainty

Historical demand is generally the biggest indicator for inventory levels in stable businesses, where demand does not fluctuate much on a year-to-year basis (Stoilov & Stoilova, 2024). However, there are many instances where demand can have high variability even in stable business environments. For example, project business can cause major demand for a certain type of product or material, which is not highly demanded before or after the project. Strictly looking at historical demand can in these situations lead to inaccurate forecasts, and sub-optimal inventory levels. (Fortuin & Martin, 1999) Additionally, products which are more likely to receive bulk orders have higher variability compared to products which are sold individually throughout the year. It is difficult to determine the optimal inventory levels or make warehousing decisions of materials with high demand variability. (Karaarslan et al., 2018) A decision of whether this kind of an item should be warehoused or not can be further analyzed by combining this with customer and order priority (Chen & Dong, 2014). If the material is highly profitable and is strategically important, it is more likely to be stocked.

2.5.4 Dependent demand

Dependent demand refers to the indirect demand of a material or component which is based on the demand of its parent item. The demand for materials or components is not directly based on customer demand, but rather on the consumption of the parent components. The demand for dependent demand materials is highly predictable if the production cycles of the end-products are determined beforehand, as the consumption can be calculated based on BOM structures, quantity, and timing of higher-level products.

(Jacobs & Chase, 2010, p. 354) In the ATO environment of case company, the demand of an ATO-warehoused valve material is based on the consumption of its parent valves. The consumption of valves is based on market demand, and the demand for the materials is based on the demand of the valves. Evaluating the effect of warehousing materials and optimizing this can become complicated due to the many relations between end products and materials: One material can be part of multiple end products, and one end product can consist of multiple materials. However, the demand for a material is still indirectly based on the market demand. These relations are visualized in Figure 1.

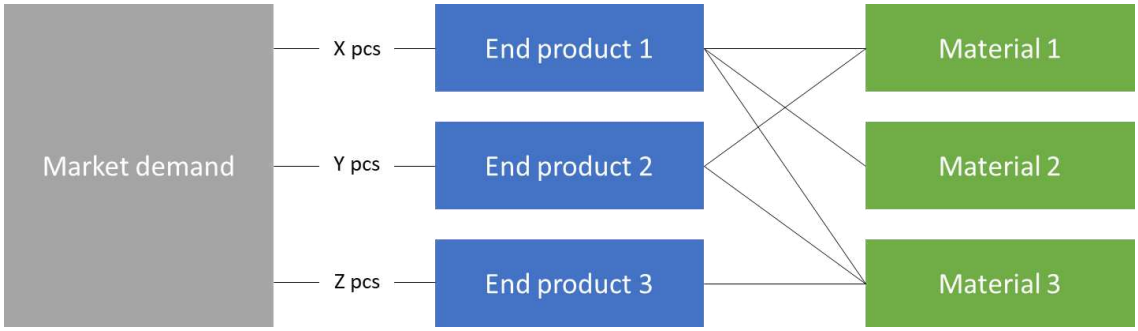

Figure 1: Dependent demand in the ATO context of case company (based on Jacobs & Chase, 2010)

Managing dependent demand is important, as excessive stocking leads to unnecessary inventory, while too little inventory can lead to stockouts or longer lead times. Dependent demand can be managed by Material Requirements Planning (MRP) systems, which are based on increasing product or component availability, reducing inventory, and planning manufacturing, delivery and purchasing activities. (Vollmann et al., 2005, p. 237) The calculation model developed in this study has some similar functionalities as an MRP system, as the aim is to improve availability and reduce inventory based on historical demand of both components and end-products.

2.6 Implications of ATO offering selection

When determining which products or materials should be in stocked offering, it is important to understand the implications these decisions have. For example, increasing inventory increases inventory costs but improves availability. Costs can be further divided into for example inventory holding costs, procurement costs, shipping costs, and manufacturing setup costs (Azzi et al., 2014; Maleyeff, 2014). A reduced availability on the other hand can lead to lost business, stockout penalties, or long-term consequences regarding customer satisfaction and relationships. Additionally, non-optimized availability can lead to losing a lot more than the business for that particular product: One missing product can cause the loss of an entire project and through that a profitable customer

relationship can be lost. (Bah, 2023) Defining availability in ATO offering should thus focus on stocking entities of products instead of just stocking the materials with the most consumption, longest lead times or smallest cost (Maleyeff, 2014).

Defining ATO offering can also be analyzed from another perspective. A common way of determining stocked offering is by analyzing historical demand or demand forecasts (Yang et al., 2020). However, offering can also be analyzed by turning this upside down, by first determining which products case company wants to have demand for, and then modifying the offering to match this desired state. This approach works well if the offering affects demand and customers are flexible enough to accept alternative solutions to their needs. (Dong & Liu, 2022) In the case of case company, this would most likely not be going to work as is, but it is an important consideration that could shift focus from outdated practices to an offering which is more viable financially and strategically.

ATO offering is generally based on the historical demand or demand forecasts of items, as it is logical that the most used items are offered with shorter lead times. However, it is also important to understand the effects of having material in ATO offering. From a customer point of view, a product with a shorter lead time is often more attractive than a product with a longer one (Bah, 2023). This means that a product which is in ATO offering is likely going to have more demand than a similar item which is not in ATO offering (Maleyeff, 2014). Adding a product or a material to ATO offering does not only affect the availability of the product, but also the demand of it. This analysis highlights the importance of selecting products to be in offering not only based on historical data or forecasts, but also on the target state of demand. (Yang et al., 2020) From the point of view of the manufacturing company, products with higher profit margins (or products which the company wants to sell more of due to other reasons) should be included in ATO offering, while products with lower profit margins should be excluded from ATO offering (Maleyeff, 2014).

2.7 Process design for ATO offering management

When planning a calculation model which aims to optimize offering, it is crucial to also plan an accompanying process which ensures these theoretical results lead to practical changes. As a minimum, a process needs ownership, something or someone to initiate the process, and someone to run the operative tasks. (Lee et al., 2021) This process role division can be analyzed with the RACI framework. RACI is an abbreviation of the roles: Responsible, Accountable, Consulted, and Informed. These roles can be divided across the process steps and stakeholders to highlight who has which role in each of the process steps. Defining the roles of stakeholders for each step ensures a transparent way

of dividing tasks related to the process and ensures a collective understanding of responsibilities related to the process. (Cabanillas et al., 2012, p. 59) The person responsible (R) performs the work and is responsible for the activity until it is approved by an accountable. The number of Rs should be limited to one or two, to reduce the risk of no one taking ownership of moving the process forward. Accountable (A) approves the work once the person responsible has performed it. There should only be one accountable for each activity. Consulted (C) includes people whose opinions are requested during the process. Two-way communication is needed to ensure information flows to the consulted, and feedback is received. Informed (I) includes people who might be affected by the work, but their feedback is not needed. Information flows from the work to the informed, but feedback from them is not required. (Jacka et al., 2009) An additional role wo the RACI matrix is Support (S), creating the RASCI matrix. The support role includes people who assist in completing the activity but are not directly responsible. (Cabanillas, 2012, p. 59-60) To ensure the practical implementation of changes, the importance of a holistic process needs to be highlighted: It should be clear who or what initiates the process and how the actual inventory changes are made. Challenges and disruptions in the process should also be considered to accommodate obstacles that might occur in a practical context.

The quality and performance of the calculation model and its results should be evaluated continuously. As the offering change decisions are an important part of the business of any manufacturing organization, the results of the calculation model also need to be correct, and the correctness of the results should be validated to ensure that no suboptimal actions are taken due to a bug in the calculations. In software development, the job of verification and validation (V&V) is to ensure that requirements are complete, consistent and valid (Sujatha et al., 2001) In practice, this validation needs to be added as a part of the implementation process, where the responsibility of some stakeholder is to ensure that the results are correct, and the logic is accurate (Sujatha et al., 2001).

When implementing a calculation model such as the one in this thesis, there is a risk for high intensity of manual labor related to it. There can be a lot of tacit knowledge that should be transferred to the results, which requires time from industry experts. According to Osvalder et al. (2016), Interest and resources from the organization, and motivated and experienced experts with interest in knowledge sharing are needed for optimal tacit knowledge sharing. Process scheduling and a clear division of responsibilities is also an integral part of running the recurring process of offering change implementations. There is a need for a clear overview of when and by whom actions are done. (Dubinsky et al.,

2010) Failure to plan for these matters might lead to the process falling in between priorities that are well established in the calendars of the stakeholders.

2.8 Synthesis of the literature review

The literature review establishes the theoretical foundation for the development and implementation of a calculation model, which determines a computational ATO inventory. The literature review examined the basic concepts of inventory management, which can be adapted when forming a calculation model to determine which items and materials to stock in an ATO environment. The results of the literature review are divided into themes, and the key findings and implications for this study are compiled in Table 2.

ATO inventories have certain characteristics which makes the challenge of evaluating which materials to stock a bit complicated. ATO inventory enables the company to offer highly customized end-products with a limited number of components in stock, while maintaining moderate lead times. (Atan et al., 2017; Lee & Tang, 1997) ATO environment works well for organizations where component replenishment times are long, while final assembly lead times are relatively short (Akcay et al., 2004). These factors highlight why ATO inventory is common in the valve industry, but also the importance of optimizing stock to improve availability and reduce inventory costs.

ABC and XYZ analyses highlight the prioritization of items in inventory. ABC analysis focuses on the importance of items in stock based on cost and volume (Kaabi et al., 2015), while XYZ is a categorization of the demand variability of items (Dhoka, 2013). ABC and XYZ analyses can be combined into a 9-square matrix, where important, low-variance items are in square AX, while low-importance, high-variability products are in square CZ. (Scholz-Reiter et al., 2012, Schönsleben, 2007) The categorization of products according to their importance and demand variability is especially interesting from the point of view of ATO offering, where the effect of stocking a component can have significant effect on multiple end-products. According to Akcay et al. (2014), ATO inventory can protect against demand variability, as components can be used in many end-products.

As with any optimization, there are many trade-offs in inventory management that should be considered when determining which products to stock. According to Sbai & Berrado (2018), there are two sides to stocking materials or products: Availability and inventory costs. Kourentzes et al. (2020), discuss the matter from a business point of view, examining the costs of stockouts versus the costs of poor availability. Fadwa (2025) highlights the trade-off between holding inventory centrally or in multiple locations. These trade-

offs are very relevant when constructing the calculation model and its parameters: Clear cases could be highlighted by the model by default, but it would be optimal that a major share of the decision could be transferred to the user of the model in the form of modifiable parameters. This way management could test different scenarios and make decisions on where the balance should be placed between cost reduction and availability. This is of course accompanied by a set of informative KPIs that indicate other important results of each scenario, including the number of materials stocked, share of orders covered and the safety stock increase of decrease. The special characteristics of the ATO environment pose additional challenges when it comes to the trade-offs related to stocking decisions of materials, as customer demand is indirectly connected to material demand. The trade-offs in inventory management are particularly prevalent in ATO environments: A small addition in inventory investment can yield significant availability improvements, if it is targeted to a bottleneck component.

The items which are in ATO inventory can be assembled into finished products on short notice, which enables customers to get customized products with a relatively short lead time. There are many factors that need to be considered when determining which products should be in ATO inventory. According to the literature (Ruiz-Torres & Mahmoodi, 2010; Chase et al., 2001; Stevenson, 2018; Kolawole et al., 2019), the main criteria when determining stocked ATO offering are demand, cost, and lead time. If a product is in high demand, costs little and has a long lead time, it is high on the priority list to be in ATO inventory. On the other hand, if a product has little demand, costs a lot, and can be obtained on a short lead time, it is likely not warehoused. This study introduces a conceptual model, which can be referred to as the cost-demand-lead time triangle. These three criteria are visualized in a triangle, in Figure 2, where minimal cost and maximal demand and lead time lead to warehousing. There are also other industry-specific parameters to consider, and these are highlighted in more depth in the interview and workshop analyses.

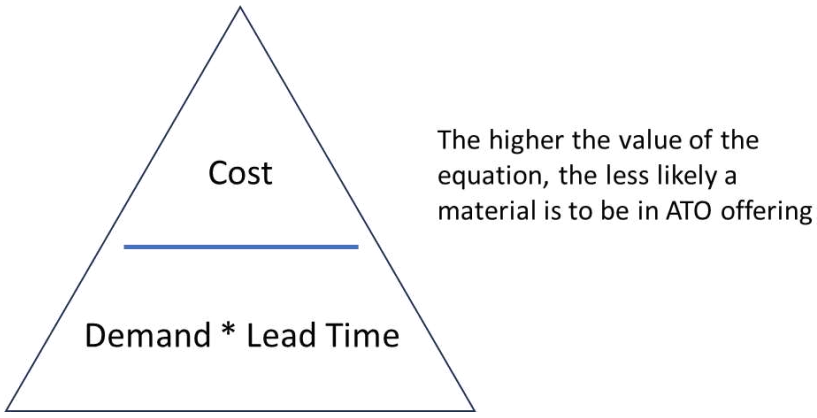

Figure 2: The three main quantifiable factors for whether a material should be stocked for an ATO offering, introduced in this study

Component commonality theory can be used to evaluate the importance of certain materials when making stocking decisions: If a material is a part of many products, which are highly demanded, those should be stocked, while materials not part of important offerings do not necessarily need to be stocked. (Agrawal & Cohen, 2001) This is a good basis for the logic of the calculation model, which determines whether a valve material should be stocked or not. Component commonality can also be used to reduce the number of unique items in offering. According to Bernstein et al. (2011), inventory can be reduced by creating an offering which contains products that are unique enough to solve all different problems, while being small enough to have significant demand.

A question that can be posed in the development of the calculation model in this study is if historical demand can be used as a forecast for future consumption. According to Stoilov & Stoilova (2024), historical demand is a big factor for future demand in businesses with low demand variability. However, strictly evaluating future demand based on historical consumption can cause inaccurate forecasts (Fortuin & Martin, 1999). According to Karaarslan et al. (2018), optimal inventory levels are difficult to estimate for items with high variability. This should be considered when determining a calculated offering: Material warehousing decisions should be made as a combination of calculation and qualitative analysis to ensure sensible changes are made. Project demand can affect historical consumption, despite reduced demand after the end of the project.

Demand for materials in an ATO environment is dependent, meaning the demand of a material is dependent on the demand for its parent item (Jacobs & Chase, 2010). Dependent demand can be managed by MRP systems, which are based on increasing product or component availability, reducing inventory, among other things (Vollman et al., 2005, p. 237). The logics of different MRP systems to optimize inventory could be

utilized in the calculation model logic, to enable efficient use of materials depending on their relations to end-products.

The effects of defining which items and materials to stock were examined in the literature review. The decisions made when defining a short lead time offering affects not only the offering, but also customer demand: Products with shorter lead times are more appealing to customers, potentially increasing the demand for items added to ATO offering. (Bah, 2023; Maleyeff, 2014) If an item is in stock, it is more likely to have higher customer demand. This highlights the importance of not only following customer demand as a basis for inventory decisions, but managerial decisions should be made on which products the organization wants to sell more of: If these are added to stock, they are likely to sell more. Similarly, products which are wanted to be phased out can be removed from stock to shift consumption to other products. (Yang et al., 2020; Maleyeff, 2014)

When warehousing decisions are made on a material level, the importance of bottle-neck material is highlighted: One missing material can lead to an increased lead time of the entire product or set of products. (Bah, 2023) This should be considered when suggesting changes to current offering, highlighting the need for evaluating inventory decisions based on entities of products rather than just looking at the demand, cost or lead time of individual items (Maleyeff, 2014).

The process of implementing the results should be clear and concise, with roles and responsibilities clearly defined (Lee et al., 2021). A challenge in practical implementation of calculation results can be the definition of responsibilities. The RACI matrix is helpful with this and could be used to define who is responsible for which part in the process. (Jacka et al., 2009) When implementing calculation results, it is important to evaluate the correctness of the results. This should be done already during the development process as well as after, to ensure that requirements are fulfilled and that results are consistent and valid. (Sujatha et al., 2001) In this study, this means evaluating results during the development process but also examining the correctness of calculation model suggestions during the implementation process. When implementing results, tacit knowledge should be transferred from industry experts' tacit knowledge to the calculation model parameters and logic. Interest and resources from the organization and motivation and experience from experts sharing knowledge is needed for optimal tacit knowledge sharing (Osvalder et al., 2016)

Table 2: Literature review results

Theme	Key findings	Implications for this study	Research question	Source
ABC and XYZ analyses	Items should be categorized according to their importance and demand variability	Importance and demand variability of items should be considered in the calculation logic.	RQ1	Kaabi et al. (2015), Dhoka (2013), Akcay et al. (2014)
Trade-offs in inventory management	A core challenge is to strike a balance between availability with inventory costs.	Calculation model should include modifiable parameters to allow scenario testing and trade-off evaluation between cost reduction and availability.	RQ1	Sbai & Berrado (2018), Kourentzed et al. (2020), Fadwa (2025)
Criteria for defining ATO offering	Primary factors: demand, cost, lead time.	Calculation model should prioritize high-demand, low-cost, and long-lead-time items for ATO inventory.	RQ1	Ruiz-Torres & Mahmoodi (2010), Chase et al. (2001), Stevenson (2018), Kolawole et al. (2019)
Component commonality	Commonality reduces inventory needs by enabling shared components across multiple products.	The calculation model should evaluate materials based on their importance to multiple products, prioritizing those that impact key offerings.	RQ1	Agrawal & Cohen (2001), Bernstein et al. (2011)
Demand uncertainty	Historical demand is a reliable baseline but may not account for variability (e.g., project-based spikes).	Calculation model or implementation should account for items with high variability by combining demand data with qualitative analysis.	RQ1	Stoilov & Stoilova (2024), Fortuin & Martin (1999), Karaarslan et al. (2018)
Dependent demand	Material demand is indirectly driven by demand from parent components	The relations between materials and components is crucial when calculating which materials to stock	RQ1	Jacobs & Chase (2010), Vollmann et al. (2005)

Implications of ATO offering selection	Stocking certain items can influence demand by improving availability and reducing lead times.	The model should consider the potential for increased demand when adding items to ATO inventory. Similarly, considerations regarding reduced demand for removed items.	RQ1	Maleyeff (2014), Bah (2023), Yang et al. (2020)
Process Design	Effective process implementation requires role clarity.	Use of RACI matrix to assign roles and responsibilities.	RQ2	Cabanillas et al., (2012), Jacka et al. (2009)
	Results should be evaluated to ensure requirements are fulfilled and that results are consistent	Result validation should be done during both development and implementation	RQ2	Sujatha et al. (2001)
	Tacit knowledge transfer requires interest, resources and experienced experts	Tacit knowledge transfer to be implemented in the result evaluation process	RQ2	Osvalder et al. (2016)

3. RESEARCH METHODOLOGY

This chapter presents the research methodology of this thesis. The situation of case company and its challenges are discussed, and the applied process steps during the research process are presented. The methodology of the thesis is divided into two parts according to the research questions: A qualitative analysis of the challenge, where a literature review and interviews with industry experts are conducted, and a developing part, where a calculation model is developed to solve the real-life challenge of defining ATO warehoused materials and components.

3.1 Case company and its status

The challenge for case company is with understanding and managing which materials to stock in short lead time inventory. Current stocked inventory has emerged largely as a result of manual additions during several years. In practice, this means that materials, which have had high consumption, have been forecasted to see increased demand or were wanted to be added due to other qualitative reasons have been added to ATO offering individually and manually. There has not been a comprehensive analysis of the entire ATO offering as a whole, but the current offering is rather a collection of individual materials that have at some point been evaluated to be stocked. One of the main targets of this thesis is to establish a comprehensive, calculated evaluation of the current ATO offering. Suboptimalities discovered during this evaluation are then implemented by either adding materials to, or removing materials from, ATO offering. The current ATO offering should be challenged with a computational model, which analyzes which products should be removed from or added to offering, based on certain parameters. One of the objectives of the calculation model is to identify materials which can be removed from ATO offering that have low effect on the lead times or availability of valves which there is a demand for. Similarly, materials that improve lead times or availability of important valves at a reasonable cost should be identified.

One of the targets for case company is reducing inventory for products with low to no demand. Removing unnecessary materials from ATO offering reduces inventory levels freeing up tied capital and creating more physical room in the warehouses. However, stocking decisions should not be made simply by evaluating demand. For example, a material which has low demand can be the missing piece of a large quotation, affecting the lead time of the entire order, despite only costing little. On the other hand, a material with high demand should not necessarily be stocked, as it can easily and quickly be

manufactured whenever an order comes in. High customization of the final product can lead to a situation where it is more optimal to stock the sub-materials and assemble the level 1 material once an order arrives, practically creating an ATO layer for the ATO stock.

Forecasting demand based on historical demand is not trivial, as the demand is not necessarily stable. For example, it is unnecessary to stock an item that has been added to the ATO offering due to a project which has already ended. On the other hand, a new product line can have low historical demand but have high consumption in the future.

As the ATO offering management of case company contains a lot of tacit knowledge, the results of the tool cannot be put into practice without manual screening and adjustments. It is thus important that the results of the tool give the user as much information as possible on why the model suggests keeping, adding, or removing the material in ATO offering. Decision makers can then, based on all available information, make informed decisions on which items to include in ATO offering.

An important part of this study, besides crafting the calculation model, is to design a process in which the results of the tool are put into practice. Focus points of this process planning include who is included in the process, who makes suggestions and decisions on which materials are included in offering, who makes the final decision, which concrete steps are needed in the process and when is the process triggered. First runs of the process are also included in the scope of the study, where valuable learnings from practical implementation can take place.

3.1.1 Bill-of-material level scope

Bill of Materials, or BOM, refers to a list of raw materials or components that state what end products comprise of in a hierarchy. The BOM can be visualized as a product structure tree with relations between parent and child components. In many industries, BOMs are constantly changing and evolving according to customer demand. In the valve industry, the BOM stays relatively stable: The product structures do not change, and for the purposes of this thesis, the BOMs can be assumed to stay unchanged.

As the scope of the thesis is the ATO inventory, it is important to understand the item levels and the relations of these levels. These levels and brief explanations are visualized in Figure 3. The case company uses BOM (bill of material) levels to define the level of a particular material used in a product. These levels are defined from level -2 to *n*. The level numbering is derived from the numbering used by case company (0 to *n*), with levels -2 and -1 added in this study to describe their position in the hierarchy.

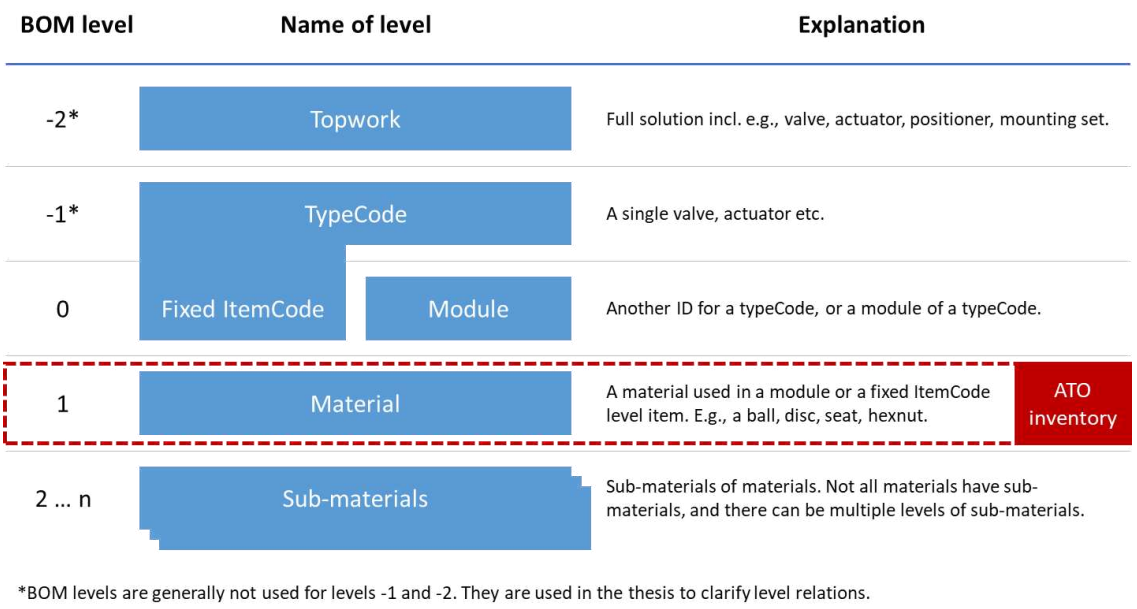

Figure 3: Product and material level descriptions of case company

A complete solution that is sold to a customer is called a *Topwork* (level -2). A *Topwork* includes multiple *TypeCode* level items (level -1). A *TypeCode* level item can be a single valve, actuator, positioner, or other component. *TypeCodes* and *Topworks* have been assigned negative level values to clarify their position in the level hierarchy related to ATO offering inventory level.

Some *TypeCodes* have a fixed ID, while other *TypeCodes* are modular and do not have fixed ID. Modular valves are divided into *Modules* which can be combined into one valve. A *Fixed ItemCode* is essentially another ID for a non-modular *TypeCode*, as modular typeCodes do not have a *Fixed ItemCode*. Therefore, the *Fixed ItemCodes* and *Modules* form level 0. A module is a virtual level which is never physically manufactured but is used to enable the manufacturing of millions of typeCode level items with only some tens of thousands of modules.

Below these is the *Material* level (level 1), which is the main scope of this study. These materials are components of a module or a *Fixed ItemCode*, and these materials can be stocked as ATO items. When an order for a topwork or a *TypeCode* is received, *Materials* are assembled according to order specifications. The topwork assembly includes a lot of testing and other customer specific actions, which is why warehousing finished valves is only possible for very standardized versions of the valves. The enormous variety of customer-specific requirements makes the warehousing of finished topwork level items very difficult. Inventory at material level enables high customization while maintaining high availability and relatively short lead times.

A material can have multiple levels of *Sub-materials*, which are denoted with level numbering 2 to *n*. To achieve optimal levels of inventory holistically, the sub-material level offering management could also be analyzed and improved. However, in this study, it is assumed that all sub-material level items are always in stock without any availability challenges. This assumption can cause inaccuracies in the practical implementation, which is discussed further in the Limitations section.

3.1.2 ATO offering management at case company

ATO offering (Assemble to Order) and ATO offering management are core pieces of terminology in this thesis and defining them is crucial for understanding the core challenges. ATO offering refers to the set of valves and other components, which can be assembled fully from materials which are warehoused. In practice, this means that a valve is considered to be in ATO offering if all its materials are warehoused. ATO offering management refers to the process of defining which products are in ATO offering. Calculated offering refers to an ATO offering (set of products which can be assembled by materials in stock) which is determined by a computational model.

The purpose of ATO offering is to ensure short lead times, high availability and high delivery reliability for the most important valves and other components. The reason for not stocking the final valves and components, but rather having the stock on material level is the high customizability and large number of unique final products available. For the case company, it would not be feasible to stock all possible end products, and the ATO stock has short enough lead times to satisfy customers.

As a valve consists of multiple materials, and a single material can be part of multiple different valves, the optimization of which materials to stock becomes very complex. Even defining historical demand is not straight forward: Both the demand for the finished valves as well as the materials should be considered when deciding which materials should be stocked. The demand and management effects of valve level products and valve materials are compiled in Table 3.

Table 3: ATO offering management from valve and material point of view

	Demand or Consumption	**Management**
Valves (BOM level -1)	Direct customer demand One quotation line contains one valve	Desired ATO offering: Which valves can be offered with short lead times
Valve materials (BOM level 1)	Indirect demand One valve is assembled from multiple materials	Warehousing decisions: Which valve materials are stocked?

Ultimately, the goal of offering management is to establish an offering (set of products and materials in inventory), that effectively fulfills the availability and lead time targets, while minimizing inventory costs. Both qualitative and quantitative factors need to be considered when defining a calculated offering. Defining the ATO offering based solely on quantitative data can cause mismatches with strategic inventory due to low demand figures, or important customer relations where availability of critical items should be prioritized.

3.2 Research strategy and research approach

The research in this thesis has two main parts: One being the qualitative supporting research and the other being the development of the calculation model and its implementation process. The methodology used to develop the solution is ADR research methodology (Sein et al., 2011), where the qualitative research is stage 1 and the development phase is stage 2, as illustrated in Figure 4.

The research method used in this thesis is called the Action Design Research (ADR) methodology, by Sein et al. (2011). This methodology focuses on two main challenges: Addressing an organization-specific problem by intervention and evaluation, as well as “constructing and evaluating an IT artifact that addresses the class of problems typified by the encountered situation” (Sein et al., 2011). When these two aspects of tackling the problem are combined, the result is a method that reflects both the theoretical background of the topic, and the specific context of case company,

The ADR research methodology is divided into four stages, which are visualized in Figure 4: (1) Problem formulation; (2) Building, intervention, and evaluation; (3) Reflection and learning; and (4) Formalization of learning. (Sein et al., 2011). Each step follows certain principles which are at the core of the methodology. In this thesis, stage 1 focuses on

the qualitative aspects of the research, including a literature review and interviews, while stage 2 focuses on calculation model development where the theoretical background is used in practice. Stages 3 and 4 constitute the learning process and the broader implications of the research.

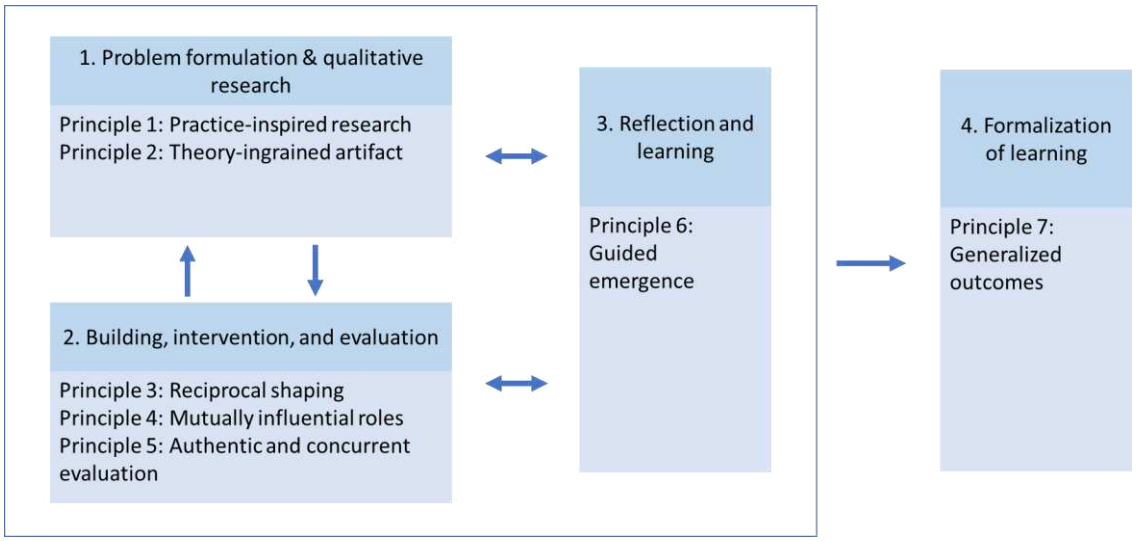

Figure 4: Overview of ADR research methodology, adapted from Sein et al. (2011)

Stage 1, including principles 1 and 2 focus on formulating a problem from a set of challenges faced by the case company, intertwining practice with theory, so that the theoretical research is conducted based on practical challenges but can be applied to a larger set of problems. On the other hand, the artifact which is developed should be based on theoretical knowledge of the subject. (Sein et al., 2011) The research in stage 1 follows a pragmatic approach, as the goal of the thesis is a practical solution for the case company. Theories, concepts, ideas, hypotheses, and research findings are all analyzed by the way they affect practical aspects. Knowledge gathered throughout the research has value due to enabling practical actions to be implemented. Pragmatism also includes the idea that there is no single reality, but rather a collection of points of view that form the entire picture. (Saunders et al., 2016, p. 151) This idea is used in the research, where experts from around the organization are interviewed to form an informed understanding of the different perspectives of the same problem. The research in this study also includes workshops and informal, open-ended discussions as ways of collecting data and feedback of the iterative versions of the calculation model.

Stage 2 in ADR, including principles 3, 4, and 5, focuses on crafting an initial solution to the problem, intervention within the organization and evaluating the results. Principles 3 and 4 highlight the need to include multiple stakeholders and points of view when developing the solution, including the IT solution itself, the context of the organization, and

employees and other individuals participating. Principle 5 highlights the importance of evaluation during the development process. (Sein et al., 2011) According to Remenyi & Sherwood-Smith (1999), the evaluation cycles should be formative and contribute to the refinement of the artifact. During the construction of the calculation model (step 2 in the ADR model), an iterative approach is taken. Uncertainty cannot be eradicated, which means there is a need to master it systematically (Bittner & Spence, 2021, p. 1). In an ideal world, a calculation model could be developed by collecting all requirements, all planning and design, and then doing all the development. However, this is often practically not possible due to uncertainty and difficulty predicting all challenges and new requirements that occur during development. The solution for this is an iterative or incremental approach, where the problem, solution and application are refined and developed throughout a cyclic process. (Bittner & Spence, 2021, p. 3) This cyclicity means that multiple versions of the same application are developed, and ideally each version is closer to the end target than the previous one. This method works well in this case, as there is a lot of uncertainty associated with building the calculation model. As there is currently no process in the case company of evaluating the ATO offering based on historical demand, the achieved interim results affect the following development. In case some flaws are found in the results, or the applied logic does not produce implementable results, a new iteration round is performed. (Sein et al., 2011)

Stage 3, including principle 6, highlights the continuous learning and reflection during the problem formulation and development processes, where focus is shifted from the instance of the case example to a broader class of problems. The research process can be altered during the development of the artifact as the understanding of the context increases. (Sein et al., 2011) Principle 6, guided emergence, highlights the balance between the final product reflecting both the initial design and theoretical background, as well as the organizational context, perspective, and practical considerations (Garud et al., 2008).

Stage 4 including principle 7, as shown in Figure 4, is a separate entity from stages 1-3, and focuses on the general solution and learnings which can be generalized in a broader field of problems. (Sein et al., 2011) As the solution is developed for the specific context of case company, generalization of the outcomes can be challenging. These learnings can include learnings from developing a solution for a given domain, or learnings for a similar problem in a similar context. The generalized findings from this study are discussed in the conclusions chapter.

3.3 Research process

The research process of this thesis is based on the ADR research methodology, which is developed further to match the unique characteristics of the requirements of this thesis. Steps 1 and 2 of the ADR methodology, as shown in Figure 4, form the foundation of the development process. The integration of different sections to form the final calculation model and its implementation process are the core of the research process. This research process is illustrated in Figure 5.

As the first step in writing the thesis, a preliminary study with qualitative methods is conducted. The idea of this analysis is to lay a foundation and to build a theoretical and practical understanding of the topics in this thesis. To ensure that all relevant aspects are considered when defining optimal inventory levels, a two-phased pre-screening is conducted, which consists of a preliminary study with qualitative methods and the development of a first version of the calculation model as a proof of concept.

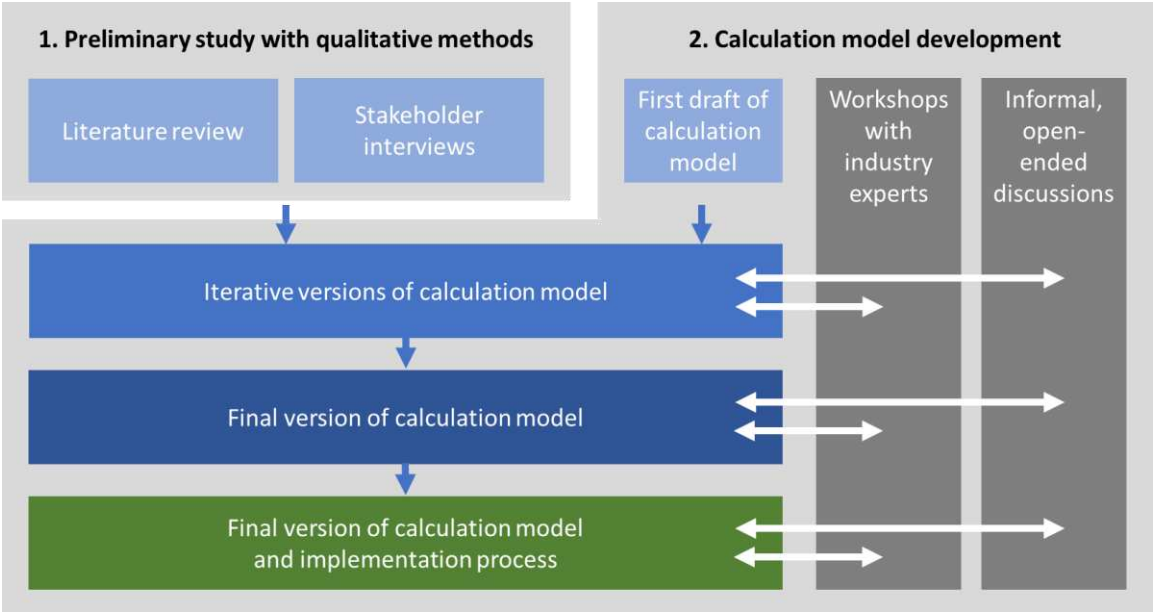

Figure 5: Research process of this study, adapted from ADR (Sein et al., 2011)

3.3.1 Research process of preliminary study with qualitative methods

In the preliminary study with qualitative methods, a literature review of the most important theoretical background is conducted to lay a foundation for the practical development of the calculation model and process development. The literature review focuses on answering questions related to the research topic from an academic point of view, which is then combined with practical considerations from the interviews and workshops.

The second part of the qualitative pre-screening process is a set of interviews, where the most important stakeholders, with extensive and specific knowledge of inventory and availability related matters, are interviewed. The idea of these interviews and workshops is to gather information on what kind of factors, besides numerical data, are, and should be, considered when defining optimal warehoused offering. These factors are important to consider from the very start of the thesis, as the end goal is a practical optimization of the ATO inventory. If calculations are made based on purely mathematical or other theoretical models, the implementation could be hindered by a vast number of manual modifications due to qualitative aspects. The interview stage of the thesis is planned to mitigate as many of these challenges as possible. Of course, it is likely that some of these qualitative aspects are not found in the preliminary study. To mitigate this, a test round of the inventory optimization is planned at the end of the thesis, where new criteria can be considered.

3.3.2 Research process of calculation model development

As the first step of developing the calculation mode, a first draft of the Excel model is developed. The idea of this is to build an understanding of available data, and to create a basis of an iterative process when it comes to optimizing inventory levels. The main goal of the first draft is to get some feasible results of a limited scope regarding what kind of changes should or could be made to current inventory. A first draft including collecting data and creating simple calculations also defines boundaries for the scope of the tool-building process. This helps with building an understanding of the scope, possible parameters, and technical calculation methods of the final product. It also helps with analyzing theoretical models and evaluating their feasibility in this practical use-case: Creating a model based solely on theoretical models and ideas can be quite different and require a lot of application before it can be utilized in a concrete product that can define optimal inventory levels in a real-life organization. To evaluate the results during development, a set of workshops and informal, open-ended discussions are held to evaluate results and to gather ideas for improvements.

3.4 Data collection and analysis

Data collection in this thesis can be divided into two sections as discussed earlier: Preliminary study with qualitative research and calculation model development. The qualitative data used is based on four main components: Literature review, stakeholder interviews, workshops, and informal, open-ended, discussions. These were selected as data collection methods to get a comprehensive understanding of the topic from both a theoretical and practical point of view, while being able to evaluate the iterative versions of the practical development of the calculation model. The literature review and interviews examine different points of view of high-level questions related to the topic, while the workshops and open-ended discussions provide opportunities for discussion on whether interim results work in practice or not, and how to develop them further.

The literature review and stakeholder interviews were conducted based on a predefined plan created at the beginning of the project, while the timing, participants and topics of the workshops and informal discussions were influenced by the practical results during the calculation model development. Due to this, the literature review and the stakeholder interviews are part of the preliminary study with qualitative methods, and the workshops and informal, open-ended discussions are a part of calculation model development, as illustrated in Figure 5 in the previous chapter.

3.4.1 Interviews with stakeholders

The qualitative analysis of the pre-screening includes a literature review and a set of interviews with the most relevant stakeholders. The focus of the qualitative analysis is to identify existing research and best practices in inventory management, while also maintaining close contact with the case company and its practical needs and requirements. The qualitative analysis conducted here is used throughout the thesis to support and build ideas and decisions related to the final tool for defining inventory levels as well as the processes related to translating those discoveries to practical modifications and improvements regarding inventory levels. The primary goal of the interviews was to understand current processes, identify key challenges, and outline expectations for the ATO offering management calculation model.

Interviewees were asked questions on the current state and the target state of ATO offering management, and considerations regarding those. These questions were refined for each interviewee to get as comprehensive, but relevant, answers as possible. The interviews were conducted in a qualitative, semi-structured manner, where interviewees were asked a set of open-ended questions which they could answer as they pleased,

and the interviewer could ask clarifying questions (Saunders et al., 2016, p. 444). This format allowed for findings and considerations to arise that were not known prior to the interviews. This methodology was especially helpful when defining issues with the current system as well as defining the most important factors and parameters when defining warehoused materials.

Even though the interview stage was done early in the thesis, the goal was that all phases of the project were considered in the interview. The target result of the interview was an understanding of the following main concepts or themes:

1. Current state of ATO offering management
2. Target state of ATO offering management
3. Considerations for defining ATO offering
4. Practical and other considerations

The interviewees were selected individually from different operational and managerial positions with a point of view of ATO offering management. Although the interviewees represent different sections of the case company, it cannot be assumed that their opinions reflect those of all professionals within their respective sections. This limitation is acknowledged in the analysis section, where differing opinions are highlighted and discussed to provide a balanced perspective on the findings. The selected interviewees, positions in the organization and focus points of interviews are compiled in Table 4. Participant coding is done from P1 in ascending order, and the participants are in order based on the order of the interviews. Questions related to theme 4, practical and other considerations, were asked from all interviewees, but was not a focus point for any particular interview. A compiled list of the interview questions can be found in Finnish in Appendix D, and translated questions in Appendix E.

Table 4: Interviewees and focus of interviews

Interviewee code & date & duration	**Interviewee position or title**	**Main questions, focus points and themes**
P1 8.10.2024 27 min	Senior manager, Availability and offering management	How well is the current way of managing ATO offering working? (1) Practical targets of thesis. (2) What kind of challenges are there with the current way of working? (1)

P2 11.10.2024 28 min	VP, MRO and service business unit	High-level view of targets of the project and what are the expected results of the thesis. (2) What are the issues with the current way of working? (1)
P3 11.10.2024 57 min	Global demand and inventory planner	How are current calculations done: what kind of formulas should be used to simulate the safety stocks any given ATO offerings cause? (1)
P4 15.10.2024 26 min	Director, Pricing and availability	Targets of project and what are the expected results of the thesis. (2) What are the issues with the current way of working? (1)
P5 21.10.2024 53 min	Director, Global supply chain management	Are the correct items in ATO offering currently? (1) How are current calculations done; what kind of formulas should be used to simulate the safety stocks that any given ATO offering causes? (1 & 3)
P6 21.10.2024 31 min	Director, Pulp & Paper industry management	Criteria for warehousing decisions. (3) Is a historical demand-based view a good way of forecasting demand? (3) Can a product be removed from offering if it does not have consumption? (3)
P7 5.11.2024 28 min	Senior Manager, Control valve product line	Criteria for warehousing decisions from a product manager's point of view. (3) Reasons to not follow historical demand on making warehousing decisions. (3)
P8 30.10.2024 28 min	Director, Renewable Energy and Gases	Criteria for warehousing decisions. (3) Is a historical demand-based view a good way of forecasting demand? (3) Can a product be removed from offering if it does not have consumption? (3)

The interviews were analyzed in a thematic way, where interview questions and answers are divided into collections of themes. Thematic analysis involves identifying, analyzing, and reporting patterns or themes within data. (Saunders et al., 2016, p. 151) Each interview transcript was reviewed to identify recurring topics or concerns that aligned with the four main research themes outlined earlier.

The interviews were first analyzed separately to get an understanding of the interviewees' ideas and points of view. The coding process began with open coding, where responses were categorized based on the specific themes they addressed. For example, comments about challenges with current processes were coded under Theme 1 (Current state of ATO offering management). Similarly, insights into warehousing criteria and decision-making frameworks were coded under Theme 3 (Considerations for defining ATO offering). Answers to different themes were then coded according to the topics they were covering, highlighting the similar and contradicting opinions on topics.

The interviews were transcribed with the help of Microsoft Teams transcribe functionality. According to Hyvärinen et al. (2017), the tone of voice of the interviewees can be a significant factor when an interview concerns the interviewee themselves, but this was not considered in this study. As the interview questions were tailored specifically to each interviewee, the answers to all questions were relevant. The answers were coded based on which topic they covered, and what type of insight they contained. These codes could this way be used to compare similar questions and similar or differing answers to those questions. As the interviewees represented different positions in the organization, the differing opinions were especially valuable insights from the interviews. This highlighted the different priorities and points of view of the different parts of the case company. The insights gathered in the interviews are presented in chapter 4.1.

The purpose of the interviews was to gather practical information from professionals who work with challenges related to this thesis regularly in the case company. The aim was to leverage existing best practices rather than developing solutions from scratch. Offering is already managed actively, and a lot of the challenges mentioned in the thesis have already been faced and tackled previously. As the end goal is a practical optimization of offering, it was also important to get as much approval and support as possible in the organization already at the early stages of the project. This support makes the implementation phase easier as some of the ideas have already been discussed in the interviews, and feedback has been received, and it has had an impact on the result.

3.4.2 Workshops with industry experts

There are major challenges in crafting a calculation model from scratch. In many cases, even the requirements and end goals can be affected by interim results, and it is thus important to evaluate the progress and results of the tool iteratively, to achieve desired results. One important factor in gathering this information is close collaboration with industry experts, who can analyze results and give valuable feedback on what works, and which results are not correct, realistic, or feasible to implement.

A workshop can be defined as “a meeting of people to discuss and/or perform practical work in a subject or activity” (Cambridge dictionary, 2024). The idea of a workshop as a research methodology is to produce reliable and valid data about a specific domain (Baran et al., 2016). Workshops were used in this thesis to validate results and discuss possible improvements in either the calculation logic or result presentation.

The main way of working with a workshop methodology in the research of this thesis included the review of a certain version of the calculation model, or a set of results that the participants were knowledgeable of. This method simulated an actual implementation process, where the participants could immerse themselves in the situation where actual tool results would be implemented. One of the leading questions in the workshops was *Can these results be implemented as is, and if not, why?* This starting point or perspective highlighted the core reasons of the main problems of a calculation logic or a set of results. When these challenges were solved, a new workshop could be held with updated logic or results.

The workshops provided an iterative feedback loop where ideas, knowledge, and feedback were passed back and forth to avoid misunderstandings and to enhance a successful final product. After each workshop, the insights from the discussions were leveraged to either move forward with the current plan or develop a solution to mitigate a challenge faced in the workshop. A total of 24 workshops were conducted with a total duration of 20h 30 min. Workshop details are compiled in Table 5.

Table 5: Conducted workshops: Number, participants, and purpose

Workshop participant code	**Number of work-shops**	**Participant position or title**	**Purpose of workshop**
P7	9 x 60 min	Senior Manager, Control valve product line	Review of calculation logic and results from Product Manager point of view.
P7	2 x 60 min	Senior Manager, Control valve product line	Review of Topwork compo-nents to be added to ATO of-fering
P9	3 x 60 min		Review of calculation logic and results from Product Manager point of view
P3 & P5	3 x 60 min	Global demand and in-ventory planner & Direc-tor, Global supply chain management	Review of suggested addi-tions to and removals from ATO offering from Operations point of view
P10	2 x 30 min	Senior Product Manager FC VC&A Positioners	Review of Topwork compo-nents to be added to ATO of-fering from Product Manager point of view
P11	2 x 30 min	Product Manager, Third Party Valves FC P&S Product Lines VEQ Ball Valves	Review of Topwork compo-nents to be added to ATO of-fering from Product Manager point of view
P5, P12, P13	3 x 30 min	Director, Global supply chain management Superviso, FC GLO Hki Positioner Factory FI Production Planner, FC GLO Hki Positioner Fac-tory FI	Review of Topwork compo-nents to be added to ATO of-fering from Factory point of view

3.4.3 Informal, open-ended discussions

As the calculation model was developed to be an integral part of current processes, there is a lot of tacit knowledge in the organization regarding which products should or should not be in ATO offering. For example, the parameters used in the tool were iteratively developed in a series of informal, open-ended discussions with availability and offering management team members and other industry experts. These sessions were conducted by developing the calculation model based on previous discussions in working sessions and the results from implementing these changes.

Once certain milestones were reached, the calculation model was presented to stakeholders who had industry expertise and knowledge on how the tool should work from their point of view. These changes were again iteratively developed and implemented in the tool. For example, parameter values were first defined based on the current target levels, and for new parameters based on industry expertise. After iteration rounds and analyzing results, parameter values were changed to mitigate problems caused by imbalanced parameter values.

Due to the dynamic nature of business needs and the flexibility of the calculation model, iterative development and parameter value altering can be continued to be done even after this thesis to achieve even better results. As ATO offering definition had not been done systematically in the organization previously, there were no set ways of how calculations should be defined. Due to this, also the target state of the calculation model was adaptable according to the obtained interim results and the experiences from analyzing the interim calculation results. For example, a shift from a mostly material-level based analysis to a more typeCode -level analysis was made based on the results of the tool around half-way through the project.

4. ANALYSIS AND FINDINGS

4.1 Qualitative analysis – Findings from stakeholder interviews and workshops

The qualitative analysis included structured interviews based on pre-determined questions, and workshops, which were less structured and were based on testing and evaluating results with industry experts and relevant stakeholders. In this chapter, the first subchapters analyze findings from the stakeholder interviews, while the findings from the workshops are analyzed in the last subchapter, 4.1.5.

In the interviews, the four main themes of the interviews were the following:

1. Current state of ATO offering management
2. Target state of ATO offering management
3. Considerations for defining ATO offering
4. Practical and other considerations

The four main themes of the interviews were subdivided into specific findings and compiled in Table 6. The findings highlight opinions the interviewees agree on, but there are also differing opinions to be discussed. Each theme and the related questions are discussed in the subchapters below. All interviews were held in Finnish, and the quotations are translated to English to convey the meaning as accurately as possible. For some translations, artificial intelligence (Open AI's ChatGPT-4o) was used to convey the content and feeling of the quotation as accurately as possible. All translations were manually reviewed to ensure accuracy.

Table 6: Findings from stakeholder interviews

Theme	Interview findings
1	ATO offering ambiguity
2	Dynamic tool with modifiable parameters and usable for all series and warehouses.
	Recurring process needed
	Calculation results should be viable, improving lead time and availability
3	Parameters to consider in defining calculated offering: Demand, lead time, cost
	Historical consumption as a basis for forecasting divides opinions
	Projects or other one-time demand cause problems with forecast accuracy
	Demand spikes and other fluctuations
	Self-fulfilling prophecies of ATO offering
	The cyclicity of certain industries is not reflected correctly in a history-based forecasting system
	Challenges simulating safety levels accurately
	Availability as lost reason should be considered in warehousing decisions
	Assumptions of availability on other BOM levels: Risk of lack of availability
	Differing opinions on whether full series should be warehoused or not, despite some sizes not having sufficient consumption
4	Simple usability as a main consideration for tool results and when implementing tool
	Supply chain uncertainty: Lead times in data not always reliable
	Ability to use different products for the same applications (component commonality)

4.1.1 Current state and problems with current state of ATO offering management

ATO offering ambiguity: According to P1, the current ATO offering is not based on a comprehensive analysis of the full offering, but rather a result of individual manual additions made for specific materials. The result is an offering, which seems to reflect the needs of the demand fairly well. However, the performance of the current offering is unclear, as this is the first time an analysis for the entire offering is being conducted at case company.

> *P6: "[ATO offering currently] is in my opinion pretty good, and the lead times have been reasonable"*

It is not clear why certain products are in ATO offering. Presumably, most materials are in offering due to high consumption, but there is no clarity on why materials are in offering currently. If a material has been manually added to ATO offering by someone, it might stay there without a good reason. Suggestions to this challenge were also made in the interviews: According to P8, there should be a clear way to document why a material is added to (or removed from) ATO offering. For most materials, the reason would be high consumption, but especially in cases where consumption does not warrant warehousing on its own, a qualitative reason for warehousing is needed. Every time ATO offering is evaluated, data would be available for why a material was previously in offering. If the reason behind this decision has not changed, the material can continue to be in offering. However, if the reason for warehousing has changed e.g., due to a project ending, warehousing can be evaluated based on other factors. One of the main targets of the thesis is to have a calculation basis for defining ATO inventory. To make calculation results and qualitative input useful throughout the organization, a clear process for documenting why an item is included in ATO offering should be created. Where and in which format the data is gathered and stored is discussed later in this thesis.

> *P2: "[ATO] Offering has not been actively managed during the last twenty years"*

> *P4: "We have stuff which has historically been added for some reason, but we don't really have an understanding why"*

> *P8: "There should definitely be [documentation on why manual changes have been made] because your memory only lasts until the morning. After two years, you're left wondering why things are the way they are in stock. If you can easily check it somewhere, it will clear things up quickly. I certainly don't remember why certain decisions were made two years ago."*

4.1.2 Target state of ATO offering management

Dynamic tool with modifiable parameters and usable for all series and warehouses: The target state of the ATO offering is a very basic question, which is discussed in the interviews to get an understanding of the different expectations stakeholders have for this study, the calculation model developed and the process to implement the results. The target state of the study is to develop and implement a calculation model which can determine which typeCode level items or materials should be added to or removed from ATO offering. The model should be dynamic to accommodate parameter changes. It should also be flexible and usable for all valve series and for all sites, possibly excluding North America due to different data.

> *P7: "I don't have any indicator which would tell me if the ATO offering is appropriate or not. The lack of an indicator is perhaps the biggest problem."*

Recurring process needed: The process of running the calculation model should be done on a regular basis to make sure the ATO offering is up to date and reflects business needs. This process would be owned by the Offering Management team.

> *P4: "First we should run through our [entire] offering, but in the future, it would shift to maintaining the offering. […] Quarterly could be too frequent, maybe a biannual review would be good. It depends on what kind of tools are developed."*

Calculation results should be viable, improving lead times and availability: Lead times and availability should be improved, while capital tied up in inventory should be minimized. The suggested offering changes should reflect the business needs of the case company, and thus improve the offering from a business point of view. Valves and components, whose availability increases business, should be included in offering, while unnecessary items should be removed to lower inventory costs.

> *P2: "[The goal is] to have a harmonized way to determine which products should be in offering based on historical demand on which plants, and that way optimizing availability and reducing excess inventory."*

4.1.3 Considerations for defining ATO offering

Parameters to be considered when defining calculated ATO offering: The most important factor when it comes to defining ATO offering is historical consumption. The interviewees also mentioned the same other factors which are lead time and cost. Additionally, availability and consumption variance should be considered. This is very much in line with the findings in the literature review, which indicate that the calculation model should be based on these factors. Many interviewees also mentioned inventory turnover as an important KPI, which can be calculated with the help of inventory levels and consumption.

> *P4: "From the point of view of availability, we might want to keep some items so that lead times don't become too long compared to customer demand"*
>
> *P2: "I think we should focus on inventory turnover [as the main parameter]"*
>
> *P6: "We are most interested in availability, lead time and cost. Those are the main criteria we have.*

Historical consumption as a basis for forecasting divides opinions: According to the interviews, the scope of this thesis is clearly on evaluating ATO offering based on historical consumption. However, some considerations are needed when it comes to using historical demand as the only source for forecasting consumption. There were also differing opinions on how well historical demand reflects future demand and availability.

> *P7: "Historical demand [as a basis forecast for future demand] is probably accurate. I would say very good."*
>
> *P8: "Predicting availability solely based on historical data is completely impossible. Maybe, in addition to analyzing history, models should be built that somehow rely on different visions of the future."*

Projects or other one-time demand cause problems with forecast accuracy. Projects can cause some products or materials to show significant demand, even though this is not necessarily caused by steady consumption. Project demand should not necessarily be a basis for warehousing, as the demand is not continuous. On the other hand, if a material or a product is needed for projects on a continuous basis, it can be argued that it is worth stocking.

> *P3: "Project demand is a bit different; we should evaluate from the start what the customer needs."*
>
> *P8: "Have all the same item been sold to the same project to the same customer. If there's future demand for these items, then it's fine [to stock these items]."*

Demand fluctuations should be considered: Similarly to projects, material demand might fluctuate. This can lead to sub-optimally large safety stocks, if the entire consumption of a one or two-year period is aggregated evenly onto all months.

> *P5: "Of course, since our demand is so variable, our forecast is always wrong in a way — we're working with averages of averages. […] If you only base the safety stock level on something like average usage, you might end up overshooting significantly."*

Self-fulfilling prophecies of ATO offering: Items which are readily available are more appealing to customers and are easier to sell, leading to high consumption for warehoused materials. This is even used to manage demand: Lead times are sometimes artificially increased to shift demand to alternative products in case an item is intended to be phased out. According to some interviewees, this is the direction in which case company should be moving: Customer demand should be altered by creating an offering where multiple products can be replaced by a single product, increasing component commonality, as discussed in chapter 2.5.2.

> *P6: "So, the product we want to phase out is given a long lead time, while the new replacement product is given a short lead time."*

> *P5: "When we get started, there's a bit of a chicken-egg situation: Which is the limiting factor? Is it availability, meaning we can't sell more because we don't have enough? Or is it that sales are so low that it's not worth keeping more in stock?"*

The cyclicity of certain industries is not reflected correctly in a history-based forecasting system: For example, an industry might be seeing a big interest now but will not be as popular in the coming years. Similarly, a growing industry might not show major demand in the past but could be forecasted with other methods. Not considering future trends in warehousing decisions might have negative effects on expanding the business. This lack of enabling future growth caused concerns, especially with P8.

> *P8: "A certain part of stable business [can be forecasted with historical demand], but then we have strategic targets to grow to new market areas and new businesses. Forecasting availability with historical demand is completely impossible. […] We need to consider different visions for the future and how they account for market cycles. If we analyze data from the past X years during a specific industry cycle, but the next five years look different, we risk drawing conclusions that significantly miss the mark."*

Challenges simulating safety levels accurately: According to P3, the basic formula of the current way for calculating safety levels for products is simple:

$$Safety\ stock = Lead\ time\ *\ Average\ consumption$$

However, in practice, this formula is not a very accurate way of determining actual safety levels for a given material. Safety levels are often modified manually, and can be based on a variety of quantitative, tacit knowledge, factors. Minimum order quantities also play a role in determining safety levels. The effect of demand variability should also be considered for accurate safety stock simulation. In case of one high demand peak, safety levels should be set according to the regular level, and peak consumption should not be considered.

> *P3: "A new product might have been launched several years ago, but as sales gradually shift to new products, we've built the inventory readiness and offering, even without historical data. We've tracked new product inventories with product management and the availability team, defining starting inventories and which items are included. There may also be individual cases where we've agreed on a sales forecast with a customer to build availability specifically for them."*

> *P5: "Due to our high variability, mathematical models tend to overshoot or undershoot, causing fluctuations in the supply chain. For instance, if we start selling a lot of a specific product line or size, the parts will arrive six months later, by which time the demand situation may have completely changed. […] When we have those demand spikes, if you base it solely on average usage, you might end up overshooting significantly."*

Availability as lost reason should be considered in warehousing decisions: Offers sent but lost due to availability would be a valuable addition to the data analyzed in this thesis. These lost offers highlight the core issue of warehousing decisions. Lost reason analysis is difficult to include in the analysis, as the data is of poor quality currently. Materials which have been the reason for lost offers due to long lead times should be considered to be added to the warehoused offering to prevent this from happening again. The business case aspect of warehousing decisions was also highlighted and should be a core focus of this project.

> *P8: "We should also look at the offers we've made, not just the ones that resulted in sales, and maybe also focus on the ones we lost and if they were due to availability. […] Forecasting based on historical demand tells us where we have succeeded, but if we want to grow […] then we have to understand more clearly what we are losing and why we are losing."*

> *P1: "Why have we lost some offers, there should be data. However, the data is very poor quality."*

P2: “We should, through some process, gather input from sales to identify which product areas they think we’re losing business in due to a narrow offering and then base actions on those business cases.”

Assumptions of availability on other BOM levels: Risk of lack of availability: Even though the systems show that a certain product is stocked with a short lead time and there is enough of it in stock, it might be that multiple salespeople are negotiating deals on the same products. In this case, if many of these deals go through, there will be a lack of availability even though stock levels show sufficient inventory and low lead times. Another risk regarding availability is that the emphasis of the calculation model is on the material level (level 1), and it is assumed that there is an unlimited availability of level 2 materials. This can lead to incorrect results, as availability at lower levels is not guaranteed in practice. A balance between availability and large inventories needs to be achieved.

P5: “Maintaining availability is either very expensive because inventory doesn’t turn over, or we’re constantly facing availability issues. It’s a bit of a balancing act.”

Differing opinions on whether full series should be warehoused or not, despite some sizes not having sufficient consumption: The results of the tool show in many cases certain sizes of items which are part of a series, but which have limited consumption. From the point of view of sales, it would be beneficial to have all sizes in offering, despite not all of them having consumption. However, according to the idea of reducing inventory based on actual consumption, these low-demand sizes would not be warehoused. There is a need to understand the reasons behind decisions regarding this, and the balance between the savings and the ease of having an entire series warehoused.

P5: “The goal isn't necessarily to focus on that, but rather on the product line strategy for the offering. However, the information should be available and easily accessible, such as what products are in the offering and which sizes are missing.

P6: “Since there’s quite a bit of variation, I do believe that the entire product range should be in the offering.”

P8: “That’s a really good question. I think it’s more impact-based — if keeping it on the shelf costs 5 euros, it doesn’t matter, but if it costs 5 million euros, then there definitely needs to be a serious reason to keep it. But ideally, the whole range should be available, without any gaps in between.”

4.1.4 Practical and other considerations

Simple usability as a main consideration for tool results and when implementing tool: Theses often create sophisticated theoretical models, but the usability is often lacking, according to P8. The usability and simplicity of both the tool and the implementation process should be a main factor. Results will more likely not be implemented, if the users need to use a lot of time to understand how to use the tool or to interpret the results. This simplicity should also be considered when planning where to store information on why certain items are in ATO offering, despite not having sufficient historical demand.

> *P2: "On the psychology side, it [the calculation model] needs to be simple enough. There should be a clear description of the model that can be easily explained to a human being."*
>
> *P8: "Unfortunately, these kinds of theses and calculation models often remain theoretical, and the data isn't directly useful to the people who are actually working with it."*
>
> *P8: "If there's no good suggestion, it needs to be something that makes the information easily accessible — click and filter, without sifting through a million things. If it's too difficult to use, like a database that takes half a year to learn, it ends up being unused."*

Uncertainty of supply chains: The calculation model could suggest reducing inventory based on not getting lead time improvements for any typeCode. This might, however, lead to lower on-time delivery, as the supply chains, especially in Asia, might cause delays and problems with availability. The data that the calculation model is based on does not always consider these supply chain risks, and there are instances where the lead times stated in the data are too optimistic. This data inaccuracy, caused by supply chain problems or erroneous data, can cause inaccuracies in the calculation results.

> *P5: "At best, before COVID and the war in Ukraine, we were able to get shipments from China via rail in 35 days. Now, we're looking at around 90 days, which is more than double the time. "*

Ability to use different products for the same applications (component commonality): According to P5, there are situations where a product could replace another product without affecting the functionality much or even improving functionalities. This could be a source of optimizing offering, as it would reduce the number of unique materials. However, according to P5, customers are conservative and often do not want to make changes if the current valves have been working well for them. This is reflected by the

mission criticality of the products of the case company, where reliability is one of the most important factors.

> *P5: "Our customers are quite conservative, and their existing installed base largely defines which product they use for specific applications, even if there is some overlap in our offerings."*

4.1.5 Findings from workshops with industry experts

The industry expert workshops were a crucial part in gathering data and information on which aspects of the calculation model work, and which needed more attention due to aspects not considered before.

Manual labor should be minimal in offering implementation process (highlighted by P7): According to P7, it is very important to reduce the manual work as much as possible. If a pattern is recognized where multiple materials are not included or excluded according to the calculation model suggestions, these changes should be implemented into the model. For example, it is not worth using a product manager's time to evaluate whether to stock a pin or bolt that has demand and costs little. It might not even be worth removing these items from ATO offering, as the savings would be minimal but the manual labor in removing them still exists. Removing small items could also cause problems in the practical manufacturing or assembly processes and should be avoided. Clear cases should be removed altogether, and similar cases should be grouped so that only one overview and evaluation is needed.

Shift from material to typeCode overview (highlighted by P7 and P2): Product managers can more easily go through results of typeCodes instead of materials, and an evaluation of material level is only possible if typeCodes are also available. This is due to the industry expertise product managers have in typeCodes. Despite the calculations being made on a material level, product managers are significantly more used to dealing with typeCode-level products, as those constitute the offering within their area of responsibility.

Implementing results requires significant manual labor (Highlighted by P3): When testing actual implementation of results with Operations, it was highlighted that the removal or addition of a material is not as easy as pressing a button. Depending on the material, adding or removing a material from offering requires a significant amount of manual work. This highlights the importance of accurate results, which should not be shifted back and forth during different implementation cycles. Of course, if the offering is far from optimal in the first runs, changes need to be made despite causing manual work.

It was also noted that it is worth having stricter criteria for a change suggestion to be presented by the model so that the changes are more likely to be implemented. Even though some possible beneficial changes can be lost this way, it enables a larger share of change suggestions to be implemented, which reduces the required manual work and improves the calculation accuracy, as the relations are not broken by manual changes.

Reasons why materials cannot be added to or removed from ATO (highlighted by P7, P5, and P3): As discussed earlier, despite the calculation model functioning well, there is still a lot of manual work needed to review the results of the calculations. One of the main outcomes of the workshops was to get an understanding why the calculation model results should not be implemented in practice. These results can be divided into two sets:

1. Those results that are caused by flawed logic or other problems with the calculation model
2. Those that could not be identified by a calculation model.

The challenges that were caused by flaws in the calculation model were noted and corrected in the following version. This included challenges such as wrongly balanced parameter values where an expensive, low-demand item was suggested to be added despite not improving lead time much. Another example of this was the consideration of a flag found in the data, which indicated that the product has not yet been defined.

The modifications to calculation suggestions, that could not have been identified by the calculation model were compiled in a separate list which was used as an input file for the following runs of the model. Examples of these reasons are collated in Table 7 and Table 8.

Table 7: Reason why materials should not be removed from ATO offering, despite the calculation model suggesting so, according to P7, P5, P3

"Harmonization, it may not make sense to remove. Needs to be investigated. Others of the same valve type are on the shelf."
"Availability issue. R&D and the factory added it to ATO due to an availability problem. Being manually crafted at the factory."
"Comes as a DO (direct order), so maybe good to keep in stock. Could be sourced from the warehouse in China, as there's enough time compared to other components. Let's ask production; they can decide.

Table 8: Reason why materials should not be added to ATO offering, despite the calculation model suggesting so, according to P7, P5, P3

"Manufactured valve, and only a 3-day lead time benefit"
"Slightly special, but with decent consumption. Too expensive relative to the fact that the typeCode's lead time is already quite short. Parameter values could be reconsidered."
"Special material, not part of the standard offering."
"Meant for a special project, no need to keep it in stock."
"No reason to add it, no cost data either. Rare."
"Improves the lead time of only a few typeCodes, and only 1 consumption."

Very recent data is important (highlighted by P3): In the test runs of implementation, there were several cases of materials suggested to be added to ATO offering, which turned out to already be there. This was caused by using two months old data, and the materials in questions had already been added to ATO offering during that time. This caused unnecessary labor from both the product manager and operations, who had to review these suggestions, despite already implemented.

Qualitative comments are important (highlighted by the author): During a workshop with operations, it was highlighted how important it is to get qualitative comments regarding the product manager's view on whether a material should be stocked. The difference between a Boolean comment such as "to be added" or "not to be added" was highlighted, as it gave more information on the expert opinion of the product manager: If the comment was stated mildly, a border line case was perhaps not implemented. Similarly, if there was a strong feeling in the comment, even more questionable cases were added or removed according to the product managers wished. This method of qualitative comments increases the flow of tacit knowledge from one stakeholder to another.

The need for meetings to evaluate the results (highlighted by P3): According to P3, meetings are a good way of handling the changes in the first runs of the implementation. As processes are stabilized, workload can be reduced by transitioning the phase from a meeting to an email where all necessary information is available. When new people or people are introduced, a meeting can be a good way of transferring information between the stakeholders.

Rate of reviews (highlighted by P5): As the processes of adding a material to ATO offering or removing it are long, it is not practical to evaluate each series often. According

to P5, a review of any given product series could be done approximately once a year or once every two years, but not more often.

4.2 Calculation model development

The calculation model development process was iterative to enable continuous feedback from stakeholders for different alternatives and test scope results. This iterative way of building the calculation model enabled early testing, which was crucial for maintaining the connection to practical use-cases. The algorithm for the calculation model was overhauled based on feedback from interviews and test runs, so that the most important factors were in focus.

The first calculation model was developed at the beginning of the study, as there was a need for practical results quickly regarding which components should be in ATO inventory. The early tool development proved to be a valuable aspect to start an iterative process which would at any given time give feasible results on which items to include in ATO inventory. The first version of the calculation model also enabled feedback regarding matters that needed to be considered when designing the final solution. Moreover, as the thesis is a part of a bigger project to improve visibility of ATO inventory, the iterative versions form a continuous line of iterative versions of the same tool, which can be further developed by whoever proceeds with the project after the thesis. The qualitative and quantitative data gathered in the interviews were utilized during the development of the first draft of the calculation model. The goal of the first draft was *not* to get a completely accurate set of materials to be added to or removed from offering, but rather an understanding of how different parameters and calculations work together to form a coherent result. The first draft of the calculation model served as a foundation for the final version of the calculation model, providing a practical approach to applying initial understanding of the challenge. It also highlighted the practical challenges of obtaining and combining required data.

Due to the practical interest of the calculation model in the case company, there was no concrete finish line point at the initial tool version. The tool was iteratively developed, and whenever a new functionality wanted to be tested, a version of that functionality was implemented. The results were then evaluated and analyzed based on their accuracy and usefulness for the desired result.

4.2.1 Structure of calculation model

A description of the main data sources and data modification steps for the first draft of the valve material section of the calculation model is illustrated in Figure 6. Data is gathered from two main sources:

(1) TypeCode data contains all level -1 items that the case company offers. There is a total of 142000 unique typeCode level items in the active product offering scope, which is used as the scope of the calculations. The active product offering scope includes all items which have been part of an offer during the last two years or are otherwise in active product offering. The TypeCode data is filtered by series (or other column) to only include the selected scope for the tool. This filtered TypeCode file is used as the input file for the Power Query analysis. Some typeCodes are comprised of modules, while other typeCodes have a fixed itemCode. There are up to 10 module types, which are stored in separate columns. These columns are unpivoted in Power Query and a unique row is allocated for each TypeCode – module combination.

A new column, Level 0 ID, is created to store information on the top-level ID for each TypeCode. For items which have a fixed itemCode, the fixed itemCode is used as level 0 ID. For items which do not have a fixed itemCode, the Module ID is used as Level 0 ID.

(2) Supply Chain BOM (Bill of Materials) data contains the structure of each level 0 item or module, material and sub-material. Each row contains information on top item (highest in hierarchy), parent item (one hierarchy level above), and which BOM level the row belongs to. This data can thus be used to show product and component hierarchy. The Supply Chain BOM data contains a total of approximately 800 000 rows.

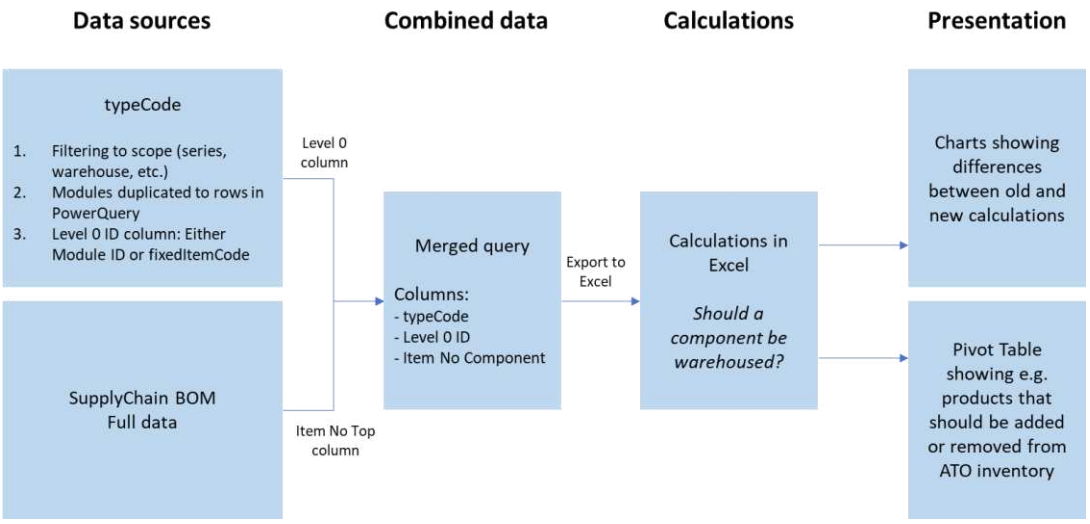

Figure 6: High-level view of data flow in the valve material section of the calculation model

The steps made to combine and modify TypdeCode data and Supply Chain BOM data are visualized in Figure 6. TypeCode data and Supply Chain BOM data are merged in Power Query by Left Outer Joining ‘Level 0 ID’ from TypeCode with ‘Item No Top’ from SupplyChain BOM. The merged data is then modified with the following steps:

1. ‘SupplyChain BOM.BOM Level No’ is filtered to only include Level 1 rows.
2. The data is filtered to only include rows where ‘TypeCode.Level 0 ID’ equals ‘SupplyChain BOM.Item No Top’.
3. Duplicates are removed, where all of the following row values are equal: Type-Code, Level 0 ID, Material ID, 12 Months Demand Total, Lead Time, Costing Type 6 LCUR, QTY.
4. Technical modification including rearranging rows and correcting data types are made.
5. A column with information on when the data was last refreshed is added to enable easier monitoring.

This merged data is then exported to Excel, where further data analysis is conducted. Besides the data from the merged Power Query table, user input values are used in the Excel calculations. The user can dynamically change the values of the parameters, and only a Pivot Table refresh is required to obtain results based on the modified parameter values.

The calculation steps in Excel to evaluate whether a material should be warehoused or not is described in chapter 4.2.4 for the first version of the calculation model, and in chapter 4.2.6 for the final version of the calculation model.

The data table, including the newly added calculated columns are used as the source for the calculation results, including suggested materials to be added to or removed from ATO offering and KPIs before and after calculations. These results are described in more detail in chapter 4.2.9 .

4.2.2 Key parameters

One of the reasons for conducting these interviews was to highlight the qualitative aspects of defining an optimal ATO offering. According to the interviews, there are multiple reasons why items should be in inventory despite not having a large historical consumption, and vice versa (some items should not be in inventory despite having significant historical consumption). The most important factors determining the warehousing of a

material according to both the literature review (chapter 2.5) and the interviews are *Consumption*, *Lead time* and *Cost*. These and their implications are compiled in Table 9, and their relation to each other is visualized in Figure 7.

Table 9: The main three quantifiable factors for whether a material should be in ATO offering, and their implications

Factor	Implication of high value	Description
Cost	Less likely to be included in ATO offering	High cost increases stock capital, which should be avoided.
Consumption	More likely to be included in ATO offering	High consumption indicates more business and faster turnover, indicating that the material should be stocked.
Lead Time	More likely to be included in ATO offering	Long lead time leads to a low ratio value, indicating that the material should be stocked as it cannot be obtained quickly.

The workload caused by redefining the ATO inventory is significant and should remain on a moderate level according to the interviews and workshops. Thus, quantifying the results of the tool and creating measurable KPIs that can be used for data analysis should be a major focus point of the tool. Flagging both unclear and clear cases accordingly enables faster screening of products suggested to be added to or removed from ATO offering. According to the interviews and workshops, a list with a significant number of products to be added to or removed from the ATO offering, without insights on why would create a major workload that would most likely not be feasible to implement in practice. This highlights the importance of creating a tool which not only calculates which products should be in ATO offering but also gives as much information as possible on how likely these products are to be correctly added to or removed from offering.

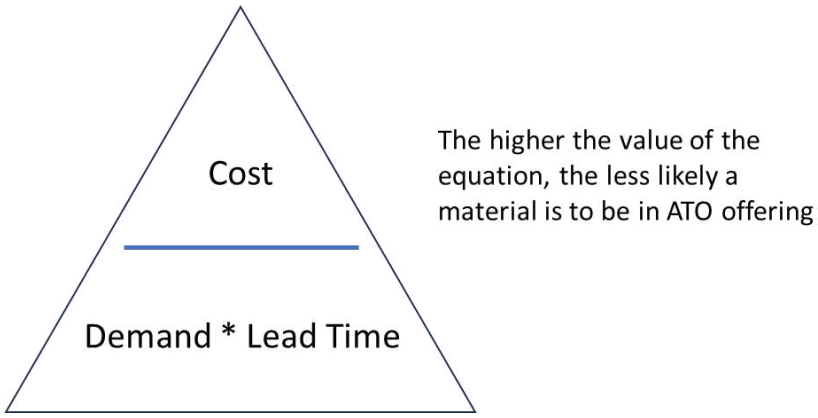

Figure 7: The main three quantifiable factors for whether a material should be in ATO offering

To mitigate the challenge of results without insights, a flagging system was implemented to show which products would most likely be in offering and which not. One option analyzed was to create a single ratio that would contain all three factors, with the formula

$$\frac{Cost}{Lead\ time * Consumption}$$

but the results of this formula were deemed too ambiguous, as the single KPI has little practical connection, and cannot be easily interpreted. Instead, the three main factors were turned into three ratios, that show the impact of these parameters on whether a material is likely to be stocked or not:

1. $\frac{Cost}{Lead\ time}$ 2. $\frac{Cost}{Consumption}$ 3. $\frac{1000}{Lead\ time * Consumption}$

These three ratios are shown on the overview tab in the calculation tool Excel next to each suggested addition to or removal from ATO offering. Additionally, conditional formatting is applied to each ratio to show the implications of the ratio value, as show in Figure 8 (values are blurred due to confidential data). In formula 3, the numerator is 1000 to avoid unpractically small ratio values. The values of the ratios have little use on their own and are mostly only useful when comparing ratio values between items. It was also noted in the workshops, that warehousing decisions of items or materials cannot be made based on only looking at cost, lead time or consumption, but rather a combination of these. This is also why these ratios were implemented in the calculation logic to filter out poor suggestions of additions or removals. In a successful and long-term implementation of the calculation model to optimize ATO offering, these ratios could be used as KPIs to review offering performance.

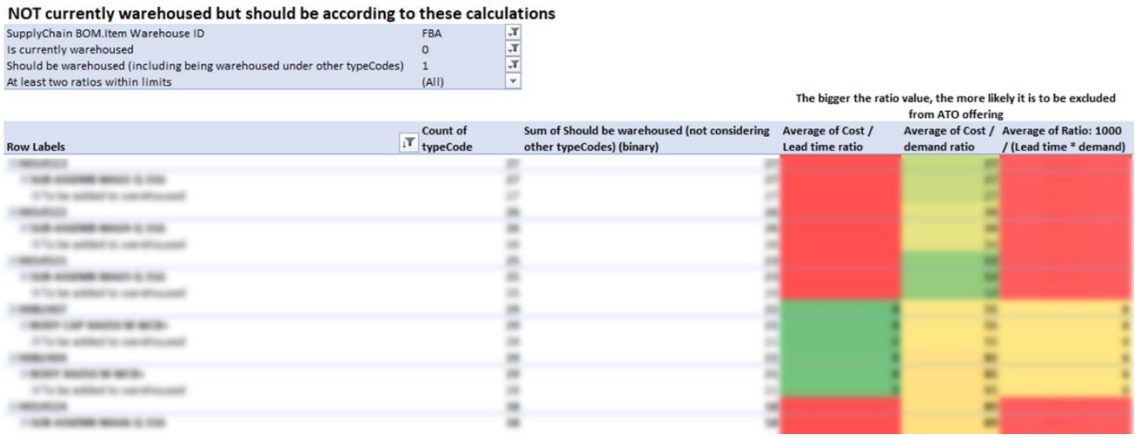

Figure 8: Ratios and their conditional formatting in the calculation tool

Ratios 1, 2, and 3 receive their acceptance levels as user-input parameters. The default values for the ratios were defined in informal, open-ended discussions with P1. Different parameter values were tested and evaluated based on results obtained using them. It was important to strike a balance between accuracy, simplicity, getting all beneficial suggestions but keeping irrelevant suggestions out. Equal values of 50 for all three ratios created a clean and streamlined ratio system, where results were balanced and fairly precise. The alteration of these parameter values can be easily done due to the dynamic nature of the calculation model.

4.2.3 Parameter value definition

The parameter values selected for implementation were based on workshops with industry experts. The ratio values, discussed in the previous chapter (4.2.2), were based on example scope values, where certain products were identified to be in scope or out of scope. The parameter values were then adjusted to include and exclude clear cases of materials which should or should not be included in ATO offering.

As the ratios and their values were new KPIs which had not been used before, it was difficult to find correct values for them. One solution to this challenge was to make the parameter values lenient, where a lot of materials are suggested to be reviewed, and the product managers can then make decisions on which of the edge cases should be implemented.

The parameter value definition is very much related to the manual work of product managers. The more lenient the parameter values are (more results to be implemented), the more manual work the product manager must do to review the results, and the less likely a material is to be implemented. On the other hand, if the parameter values are very

strict, only a few materials are suggested to be added to or removed from scope, which reduces the need for manual reviews and improves the chances of suggestions to be implemented. However, this increases the chance of the calculation model missing some good alterations to ATO scope. This balance is visualized in Figure 9.

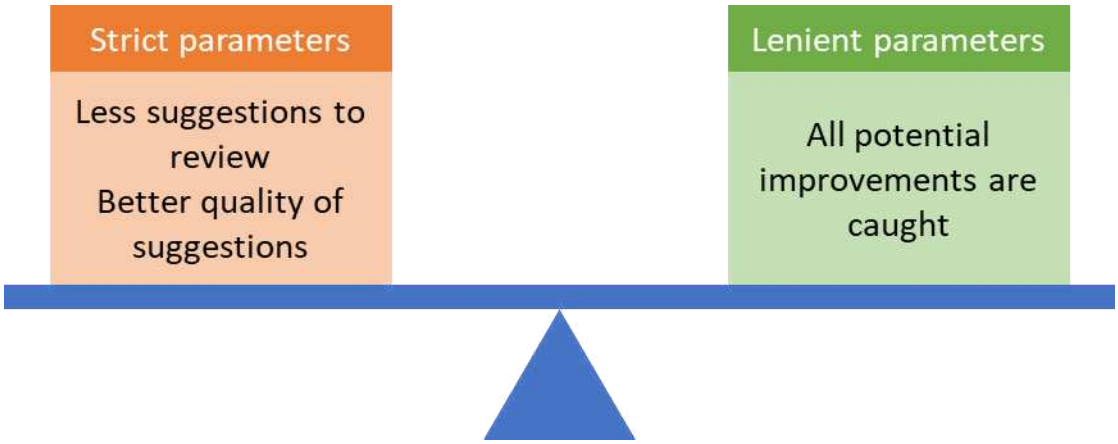

Figure 9: Balance in parameter selection between strict and lenient parameters

It is practically impossible to define objectively optimal parameter values, as they are indicators of the balance required in inventory management. The balance between availability, which consists of demand and lead time, and inventory costs is always a balancing act, as discussed in the literature review chapter 2.4. Increasing availability is good from the customer's point of view but should be evaluated based on a cost-benefit analysis. Minimizing inventory reduces costs in the short term but is likely to lead to less business due to poor availability.

Parameters are defined based on findings in the literature review and expert interviews. The parameter values were defined in workshops with P1. The method for arriving at these values was to identify products which were (1) clearly included in ATO offering, (2) clearly excluded from ATO offering and (3) unclear cases. These examples were then evaluated to determine which characteristics were contributing to these opinions and thus affecting the warehousing decisions. Inventory turnover rate of 2 rounds per year is a standard KPI within case company. The modifiable parameters and their default values are compiled in Table 10.

Table 10: Parameters and their default values in the calculation model

Parameter description		**Default value**	**Unit**
Annual consumption for typeCode to be important	At least	1	pcs/year
Inventory turnover rate	At least	2	rounds/year
The share of warehoused materials that make all other materials also warehoused	At least	80 %	of typeCode value
Safety percentage to cover demand fluctuations		30 %	over required
Minimun safety levels for materials in ATO offering	At least	5	pcs
Consumption that leads to warehousing regardless of other factors	At least	25	pcs / year
Max cost / LT ratio for warehousing	ratio value	50	€ / LT days
Max cost / Demand ratio for warehousing	ratio value	50	€ / (pcs/year)
Max 1000 / (LT * Demand) ratio for warehousing	ratio value	50	1000 / (LT days * (pcs/year))
Consumption limit (Cheap items with consumption)	Over	5	pcs / year
Cost limit (Cheap items with consumption)	Under	100	€
Consumption limit 2 (Cheap items with consumption)	Over	1	pcs / year
Cost limit 2 (Cheap items with consumption)	Under	15	€
Minimum demand for topwork component to be stocked	At least	4	pcs
LT weeks for Topwork components to still be considered ATO	At least	5	weeks
Number of LT days for valve material to still be considered ATO	Maximum	21	days

During the implementation of the calculation model results, it was noted that the definition of which materials and components are in ATO offering was not completely clear, and at least that a modification needed to be made to achieve desirable results. The ATO offering definition was earlier in the study defined as materials or components which are defined to have a safety stock based on their *Forecast method* -data field. However, when presenting interim results to management, it was noted that it would be more beneficial to determine ATO offering as all offering which can be obtained within five weeks from an order. This way significant effort is not invested in improving lead times for products

which are already available with a short lead time. On the other hand, this point of view reduces the improvement effect on availability of important products. However, as this change was implemented as a dynamic parameter, it can be switched to the original ATO offering definition by simply entering 0 days as the minimum lead time for a material and valve to be considered ATO.

4.2.4 Algorithm for whether a valve material should be warehoused in the first version

This chapter focuses on the logic of the first version of the calculation model. The idea was to determine the main materials of all typeCode level products, evaluate the historical criteria for those materials, and based on that make the warehousing decisions for the entire typeCode-level product. In more detail, the calculation steps, as presented in Figure 10, are the following.

Main materials are defined for each typeCode: The main drivers of an item's cost are defined, to focus the analysis on the most important materials of items. If a material constitutes over 10 % (or user input parameter value) of the cost of a typeCode, it is defined as a main material.

The annual demand, inventory turnover and lead time of materials are compared to parameters (default or user input) to determine whether a material should be warehoused or not based on historical data. This step gives a Boolean (True/False) value for whether the historical consumption meets requirements for warehousing.

As the focus of availability is on the typeCode level items (not the materials), warehousing decisions of materials are based on availability requirements of entire typeCode products instead of individual materials: If all typeCode *main materials* are warehoused, then all typeCode materials are warehoused. Additionally, if over 50% (or user input parameter value) of materials are warehoused, then all materials are warehoused.

To ensure that items are not warehoused despite having no demand, a step to remove no-demand items is conducted: If a a typeCode contains a material with no annual consumption, then none of the materials of the typeCode are warehoused.

Materials are often a part of multiple items, and there is of course no separate inventory for the materials of every typeCode. Thus, if a material is to be warehoused under any typeCode, the material is automatically warehoused under all typeCodes containing that material.

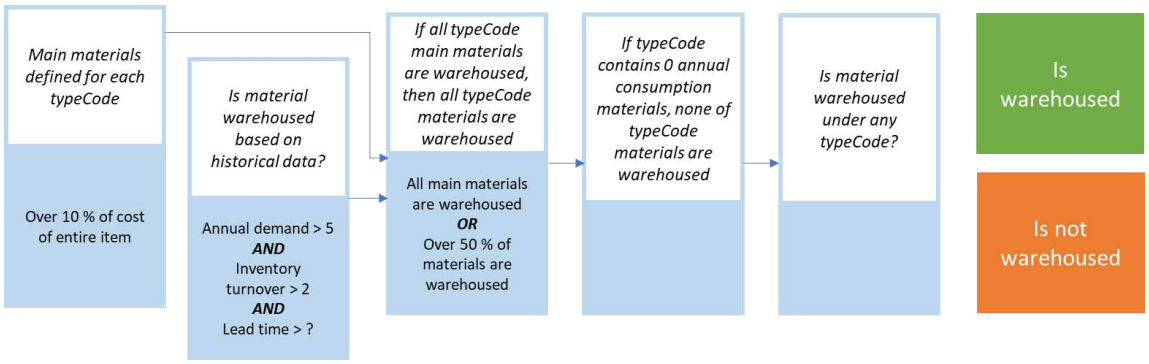

Figure 10: Algorithm in first draft for whether a material should be warehoused or not

The result of this algorithm is a Boolean value for whether or not a material should be warehoused. In test scopes, the result was that around 60 % of materials should be warehoused, which was similar to the share of products previously warehoused.
The user input parameters and their default values for the first version of the calculation model are compiled in Table 11

Table 11: Parameters and default values of first draft of tool

Parameter description	**Default value**
Minimum annual consumption for warehousing	5 pcs / year
Minimum inventory turnover rate for warehousing	2 rounds / year
Minimum material share of typeCode value to be main material	10 %
Minimum share of warehoused materials that make all other materials also warehoused	50 %
Safety percentage to cover demand fluctuations	30 %
Minimum safety of warehoused items	5 pcs

4.2.5 Results and learnings from the first version of tool

The results obtained from the first draft of the inventory optimization tool indicate that most items that are currently warehoused should continue to be so. Compared to the current ATO offering, some items should be removed, while others should be added according to the results of the tool. Depending on the product series, around 10 – 20 % of items should be removed from ATO offering, while a similar percentage of items should be added to ATO offering. This calculation leads to a very similar offering size compared to the earlier level. However, it is worth considering that these results are

based on simple calculations and do not contain much qualitative insight on other factors that should be considered when defining optimal warehoused ATO offering. Another consideration is regarding the used parameter values. If the parameter values are changed, it of course also affects which items are suggested to be included in ATO offering by the tool.

A problem with the calculation that was recognized was that the calculation did not consider items, materials, or components which were warehoused due to other reasons besides ATO inventory. There was a situation where in step 5 of the algorithm in Figure 10, a material was not considered warehoused as it was not part of the ATO inventory of any typeCode. This led to all typeCodes containing that material to not being in ATO inventory. However, the item was warehoused due to other reasons, leading to an incorrect result of the tool. This flaw in the logic ruins the results, as one material can be part of hundreds of typeCodes. This error would cause all of these typeCodes to be suggested to be excluded from ATO offering, which is unacceptable.

Another problem with the first draft is the lack of lead time analysis. If a material has a very long lead time, it can affect the availability of an entire typeCode level item or even a topwork. Lead time values of materials could also be utilized to minimize the total lead time of a typeCode: Even if a material should not be warehoused, the warehousing of it could improve the lead times of one or many typeCodes. One suggestion for tackling these lead time challenges is to add a “LT could be improved by warehousing” calculation and column to the tool. This value would function as a flag, encouraging decision-makers to double-check those materials before removing them from the ATO offering.

During a validation workshop with P1 and P7, A problem was discovered with the first draft of the tool, where materials that had a major effect on lead time was wrongly suggested to be either removed from or added to warehoused offering. The algorithm also suggested that typeCodes, which had low or no demand, were to be warehoused.

It was noted that the calculation model results were far from what product managers deemed sensible, to the point where the calculation model was not very useful. These issues, combined with a stronger focus on lead time, were analyzed, and utilized for the development of a completely overhauled algorithm for defining warehoused materials.

4.2.6 Algorithm for whether a valve material should be warehoused in the final version

There were several challenges with the first version of the calculation model, as discussed in chapter 4.2.5. These aspects, and learnings from the literature review, interviews, workshops were combined into a new calculation logic for determining which materials should be added to or removed from ATO offering. The leading thought of the logic is to focus on adding materials, which improve the lead time significantly of valves with historical demand, while costing little. These aspects are derived from the key parameters defined in chapter 2.5. It was noted in the workshops that materials, which do not affect the lead time of valves, should not be added to ATO offering, as they do not affect the availability of the offering from a customer point of view. This comment initiated the idea of finding the material lead time bottleneck for each valve which has demand and determining the warehousing for those items. This way efforts and investments of adding materials to ATO offering are always improving the lead times of a valve, meaning no unnecessary additions are made. Regarding removals, the logic works similarly: If the material lead time bottleneck of a valve is not warehoused, the shorter lead time materials do not need to be in ATO offering either. This way materials, which do not improve availability of valves can be removed from inventory, without affecting lead times or availability from a customer point of view.

The algorithm for the final version of the calculation model is visualized in Figure 11. This new model is based on lead time improvement of typeCodes with demand. A typeCode with demand is defined based on having over X amount of annual demand, with a default value of 0. If a typeCode does not have demand, a material is not warehoused due to that typeCode, except if the material is currently warehoused and has significant consumption or is cheap enough not to be worth removing. Significant consumption is defined as over X pcs per year, with a default value of 24, equaling 2 per month.

Materials under typeCodes marked important are ranked descending by lead time. All materials are then checked whether they qualify to be in offering based on historical consumption and ratios (ratios explained in chapter 4.2.2) or based on being currently warehoused. All materials are then checked to determine the longest lead time material for each product which is not warehoused (lead time bottleneck). If a material with a longer lead time under the same typeCode is not warehoused, then none of the shorter lead time materials are warehoused due to that typeCode. All materials which have passed the ratio check and improve the lead time of an important typeCode are *approved* and thus warehoused. If a material is *approved* under any typeCode, it gets approval under all typeCodes. All unapproved materials then go through a check whether they are

currently warehoused and have sufficient consumption (default 25 pcs / year) for warehousing, regardless of other factors. If they have sufficient consumption, they are warehoused, otherwise not. Affordable materials which have some consumption (default values: Cost < 100€ and annual demand > 5 pcs) are warehoused if they are currently warehoused, to avoid spending valuable time to review materials which have little effect on inventory value and could affect the availability of valves. This criterion was added based on workshop findings discussed in chapter 4.1.5. Another reason to not remove low-cost items is the relation to other valve series: As the analysis is run for one valve series at a time, there might be situations where a material is used for multiple valve series. A material can have low consumption for material A but have significant consumption for valve series B. Validating these relations requires significant manual labor, which is not justified for inexpensive materials.

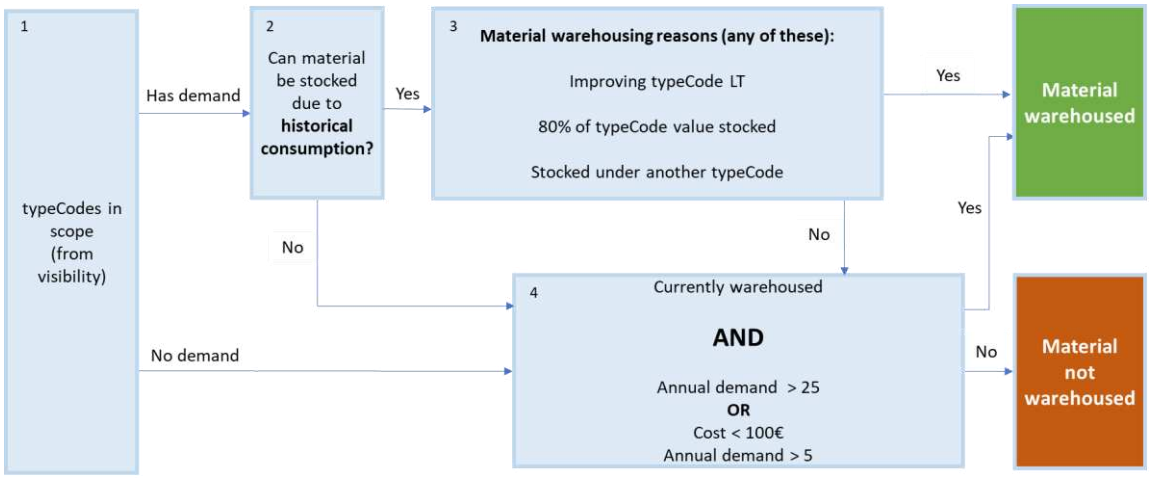

Figure 11: Algorithm for whether a valve material is suggested to be warehoused in the final version of the calculation model

4.2.7 Topwork component analysis

Besides evaluating the materials to be added to or removed from ATO offering, a following analysis are the other components sold with valves. From a customer and business point of view, the lead time and availability consist of the lead time and availability of an entire order, and not just a valve. That is why it is crucial to not only optimize which valves are in ATO offering but also include as many components sold with ATO valves as feasible.

The logic of suggesting topwork components to be added to ATO offering developed in this study is not as complex as with defining ATO valve material warehousing. The logic

is dependent on two statements, which both need to be true for a topwork component to be suggested to be added to ATO offering:

1. Topwork component is sold with ATO valve on 4 different order rows during the last 12 months, excluding project orders.
2. Topwork component lead time is over 4 weeks.

All topwork components fulfilling these two criteria are suggested to be added to ATO offering, and similarly to the process of evaluating valves suggested to be added to ATO offering, as presented in chapter 4.3.2, product managers and operations are consulted to determine which of these suggestions should be implemented.

The process of evaluating other components only includes additions in the scope of this thesis. The reason why it is not feasible to evaluate which topwork components to remove from ATO offering is due to no visibility of the required topwork components across all series: A topwork component might not have been sold a single time with example series 1 but could be commonly sold with example series 5. The development of calculations evaluating the entire topwork offering is to be done shortly after this study and is discussed further in chapter 5.7.

4.2.8 Calculation logic and data flow of calculation model

Due to large amounts of data and the complexity of the calculation model, it is important to understand the calculation data flow of the model. Additionally, as the aim is to transfer this model into a database solution, a documentation on what has been done is needed.

The original data sources used in the calculation model are compiled in Table 12. These are exported from internal sources within the case company, and all are in the form of an Excel file.

Table 12: Data sources used in the calculation model

Data source	Description
Visibility typeCode list	All valves sold in the last two years and data about them.
SupplyChain BOM	BOM hierarchy of all products and modules in offering tool, including related data.
Order export Topwork (All components of a topwork)	Customer orders (won, lost, open) including quotation numbers and price data for each component sold with a valve in scope, and which valve it was sold with.
Order export Valves (All valves sold)	Customer orders (won and lost), including quotation numbers and data for each valve in scope sold.
Manual change list	Modifications to tool suggestions, which is also an input file for future runs. These include product manager and operations comments.
Currency list	Data on exchange rates between currencies found in other data
Product Line responsible person list	Data on who is responsible for each product line. This is used to determine who to contact regarding results.
Safety stock notes	Details about the modifications to safety stock levels, including the context of how, when, why, and by whom changes were made. This data provides additional information on historical management of the materials, including their previous statuses and actions taken.
Project or not	Table on which 'Opportunity Business Type Name' field values indicate that an offer was sold in a project
Won/Open/Lost offer status	Table on which "Status Name" field values indicate that an offer is won, lost or still open.

The combined data sources generated in the calculation model are compiled in Table 13. These datasets are used in the calculations to reach results on which materials should be added to or removed from ATO offering, what implications that has on the offering, and how well the offering matches past quotations.

Table 13: Combined datasets, used as sources for Excel calculations

Combined data	Type	Description
TypeCode & SCBOM Merge	PowerQuery Query exported to Excel sheet	All BOM level 1 materials for in-scope valves
Helper calculation sheet	Excel sheet	Summarized data for each unique valve typeCode, material ID and order quotation number.
Stock valves data	PowerQuery Query exported to Excel sheet	Data on which valves are stocked in non-modular form.
Dashboard (Valves)	Excel sheet	Combined calculated results for which valve materials should be added to or removed from ATO offering. Parameter input for calculation model.
Dashboard (Topwork)	Excel sheet	Combined calculated results for topwork analysis. List of suggested topwork components to be added to ATO offering.

The relations between the different sheets of the master Excel file are visualized in Figure 12. The Dashboard sheets present information calculated in the other sheets and combine data for ease of use. All sheets are dynamic, and the data for each sheet is refreshed by updating the input file in the source folder. As in the requirements from the interviews (chapter 4.1.4), this way the calculations can be easily run for different plants or valve series, with no changes needed to be made to the calculation model.

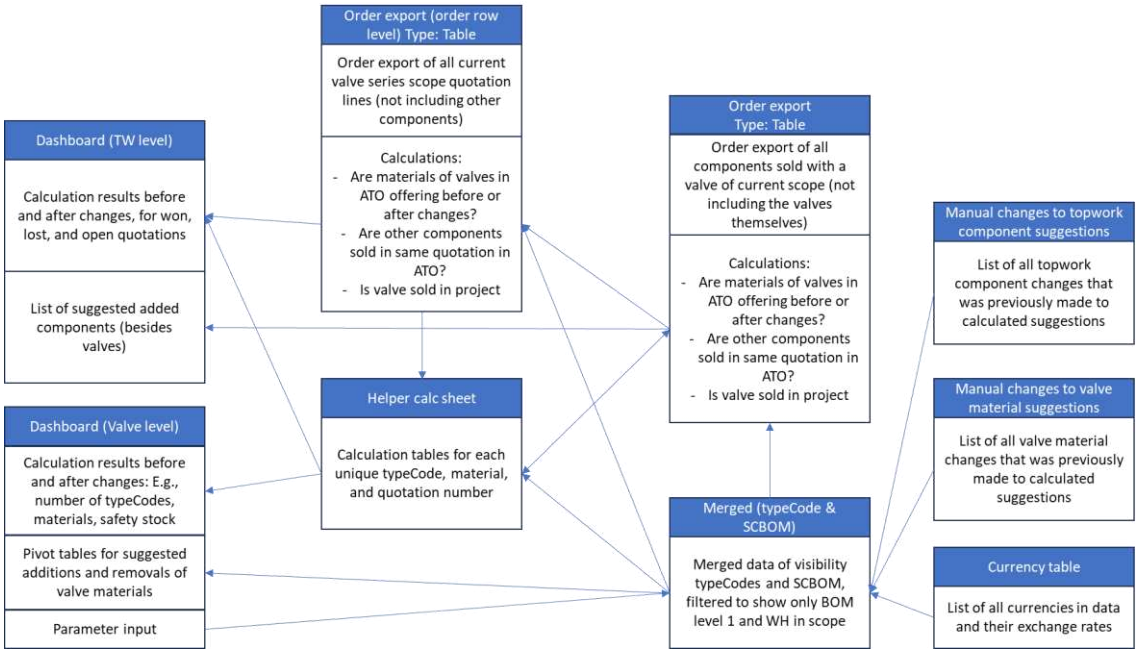

Figure 12: Relations between Excel sheets of calculation model

4.2.9 Calculation results

After the valve material calculations are completed, the results are compiled and visualized in the Excel Dashboard sheets. The sheet 'Dasboard (Valves)' includes separate Pivot tables for materials suggested to be added to and removed from ATO offering. The sheet 'Dasboard (Topwork)' includes a list of topwork components suggested to be added to ATO offering.

The results also include KPIs, including ratio KPIs discussed in chapter 4.2.3. Other KPIs include before and after -values of the number of typeCodes and materials in ATO offering, simulated safety stock, and offer coverage for won, lost, and open quotations. The calculation results are compiled in tables and visualized in charts, shown in Appendix B and Appendix C.

Besides the KPIs, the results include the number of typeCodes affected by the material additions and removals, as well as other qualitative results. One of the result values that is added for qualitative review of calculation model results is *effect on typeCode lead time*. This value shows how much the total lead time of a typeCode is increased in case a material is removed from ATO offering. In practice, this means that if a material is the longest lead time material of a typeCode that is not warehoused, it is the bottleneck regarding lead time for that typeCode. In case such an item is removed from ATO offering, it affects the lead time of the entire typeCode. For example, item X is expensive, has low consumption and an acceptable lead time. However, if this material is removed from ATO offering, it increases the lead time for that typeCode by Y. Before such a material

is removed from offering, this e*ffect on typeCode lead time* value flags this material, and an educated decision can be made regarding its warehousing. A similar *effect on typeCode lead time* value is used to analyze whether a material should be added to ATO offering. In case the material is the longest not previously warehoused material of a typeCode, the lead time improvement is shown in the column. It is to be noted that the values for e*ffect on typeCode lead time* is calculated differently, based on if it is used for products to be added to or removed from ATO offering.

4.2.10 Insights from calculation model development

The calculation model development highlighted a variety of challenges along the development process. Most importantly, faulty hypotheses could quickly be discarded, using the “fail fast” methodology (Koporcic, 2024). As the tool development was iterative, the insights from development were quickly implemented as new versions.

The most important insight from the tool development was the point of view from which to approach the problem. In the first version of the tool, the focus was on material level, and whether a single material should be warehoused or not. Further down the development, focus was shifted to the typeCode level, as the focus should be on the needs of the end customer and the offering that can be presented to them. The calculation model remained similar, and warehousing suggestions of the tool were still done on material level. However, the manual process by product managers of evaluating warehoused products was shifted to typeCode level, where the product manager could use their industry expertise to evaluate holistically which typeCodes should be in ATO offering based on categories such as valve size and pressure rating.

Another insight from tool development was the careful selection of data. Due to the amount of numeric data available, the calculations could easily exceed any available processing power for this exercise. It was thus paramount to select what kind of calculations should be done based on the required resources and the expected benefits of that calculation.

The importance of manual changes to tool suggestions was highlighted during the tool development and iterative testing phases. One of the targets of the calculation model was accurate results that could be implemented directly, but this was deemed unrealistic already in the early stages of development. There is a lot of tacit knowledge within the organization that needs to be addressed when defining ATO offering, but which is not available in data format. To address this challenge, a list of manual adjustments was created. This list includes materials or items that the tool recommends for removal from

or addition to the ATO offering but should be included or excluded based on specific considerations. This list is also used as an input file for the calculation model, hindering those items from being listed for inclusion or exclusion in the near future. As the reasons for manual alterations might change, each category of reasons for inclusion or exclusion is assigned a specific timeframe, after which the manual alteration needs to be re-evaluated. These timeframes range from six months to five years, depending on the reason for the manual change.

4.2.11 Challenges and mitigations in development of calculation model

Developing an Excel model from scratch for a real-life challenge with multiple stakeholders and a large amount of data is difficult, and there have been a lot of challenges along the process. A brief explanation of these challenges and mitigations to them is compiled in Table 14. These challenges were faced during the iterative development process of the calculation model. When a challenge was faced, it was documented and the mitigation was either discovered through informal discussions with P1, workshops, or by trial and error.

Table 14: Challenges and mitigations in the development of the calculation model

Challenge	**Mitigation**
Many ways of optimizing, difficult to take everything into consideration.	Prioritization based on interviews and workshops.
Assuming all products of level 2…n are in stock in unlimited quantities. This could lead to some components being removed from ATO offering despite having availability problems on lower levels.	This assumption is tackled by the manual review of the product managers and operations. In case they notice a situation where availability is lacking, they will not approve of removing that material.
Not considering lead time of step between level 2 and level 1. The calculation model can analyze a product to be warehoused if it has a lot of consumption, but in fact the lead time between levels 1 and 2 is so small that it is not worth stocking the level 1 item. The level 2 item can be a lot more	Similarly to the previous challenge, this aspect is difficult to implement in the calculation model. The responsibility of identifying these is with the product manager and operations, who can state these challenges and exclude or include these cases, disregarding the calculation results.

flexible for how many products it can go to.	
Availability problems: Data regarding lead times is not always reliable. Some materials are shipped from far away or have otherwise uncertain supply chains. These can be reasons to stock an item, which is not visible in the data	Similarly, if data is not to be trusted, a manual review is needed to solve this challenge.
Calculation results based on other calculations, which are then modified, leading to inaccurate results.	This challenge can be mitigated by more accurate calculation results. The results improve with each iteration as new manual reasons are added which decrease the need for new manual modifications.
Inaccurate or missing data. For example, some cost or lead time information is missing, which leads to problematic or incorrect assumptions and calculations. For example, if cost data is missing, the calculation model can assume the cost is zero, which distorts the results.	Inaccurate data should be highlighted and corrected whenever such is encountered. Correcting incorrect data is not in the scope of this thesis but should of course be done as much as needed to obtain accurate results.
As the calculation model was developed in Excel, calculation capacity quickly became a challenge if it was not considered in the solutions. For example, an input scope of approximately 3000 typeCode rows was turned into over 50 000 rows when expanding the BOM structure to include all level 1 materials for each typeCode level item. For example, using a FILTER formula for each row in this scope causes 50 000 ^ 2 calculations, easily causing problems in Excel, when there are dozens of columns that need to be calculated when e.g. filtering column values.	These challenges were mitigated by doing heavy calculations in PowerQuery and turning on manual calculations for navigating the calculated data and result Excel sheets.

Validation on whether the calculations include all or even most of the suggestions which improve ATO offering. It is difficult to know how optimal the calculation model developed in this study is. Results obtained can be evaluated but results not obtained are difficult to evaluate.	Qualitative analysis of the offering, also outside of the calculation model implementation, is important to evaluate the ATO offering from another point of view. This can highlight flaws in the calculation model, which can then be implemented in subsequent runs.

4.3 Implementing calculation model results in practice

Besides the calculation logic and calculation results, an integral part of this thesis is developing a method of implementing these results. In practice, this means designing the management of the entire process from data input to new materials being warehoused or removed from stock in practice. Implementing the calculation results was also done in practice, and the learnings from these test runs are analyzed in the following subchapters. This chapter discusses the process development, key steps in running the process, ownership and governance, implementation timeframe and cycle, and identification and mitigation of challenges that emerged during the first runs.

4.3.1 Process development

The focus of the process development phase was to elevate the results of the calculation model to a practical level: Even perfect calculation results are useless for the case company if they are not implemented in practice. Thus, the process development was one of the two focus points of the thesis, together with building the calculation model itself, from the very beginning.

The first step of developing the process was understanding current ways of working. This was done by interviewing relevant stakeholders on how the ATO offering is managed currently. As the ATO offering management was not very well developed, a completely new process was needed to be planned. It was clear from the interviews that a major challenge in implementing the process was how much time running the process would require from participants. Efficiency of the tool and minimizing manual work related to going through results would thus be high priority focus points.

The first run of the process was going to be more tedious due to it causing more changes to the scope compared to sustaining runs in the future. ATO offering is not changing a lot in a stable business such as in the situation of case company: The first run could

cause major changes in the offering, while subsequent runs would only affect some products. A discontinuation of a product line or the addition of a new product line could of course also cause major changes in ATO inventory, but these changes would be predictable, and cause workloads across functions.

A new process is also more likely to require more work compared to when it has already been run before. The workload expected of people affected is also important to consider. Optimizing, and when possible, minimizing required work from stakeholders should be aimed for to enable successful process implementation.

4.3.2 Key steps in process

The key steps of running the process can be divided into two sections: Running the calculations and implementing the results. Running of the calculations results in a calculated list of materials to be added to or removed from ATO offering. Implementing the results include qualitative reviews of calculation suggestions, where some of the suggestions are discarded, while others are implemented into the actual ATO offering. This high-level view of using the calculation model is visualized in Figure 13.

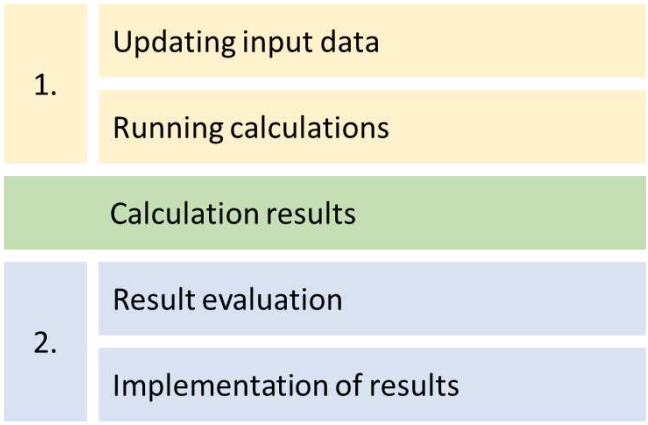

Figure 13: High-level view of using the calculation model

Running the calculations refers to the process of updating input data, running PowerQuery Queries, and refreshing Excel calculations to obtain the calculated suggestions for offering changes. The excel files are updated according to instructions in the Power BI report 'Inventory Framework – Order export.pbix' which the data is also exported from.

The result of the calculation process are lists of materials to be added to or removed from ATO offering, KPIs including the number of valves in ATO offering and offer coverage, as well as a suggestion of topwork components to be added to offering based on

the valves they are sold with. This process of updating input files and running the calculations is visualized in Figure 14.

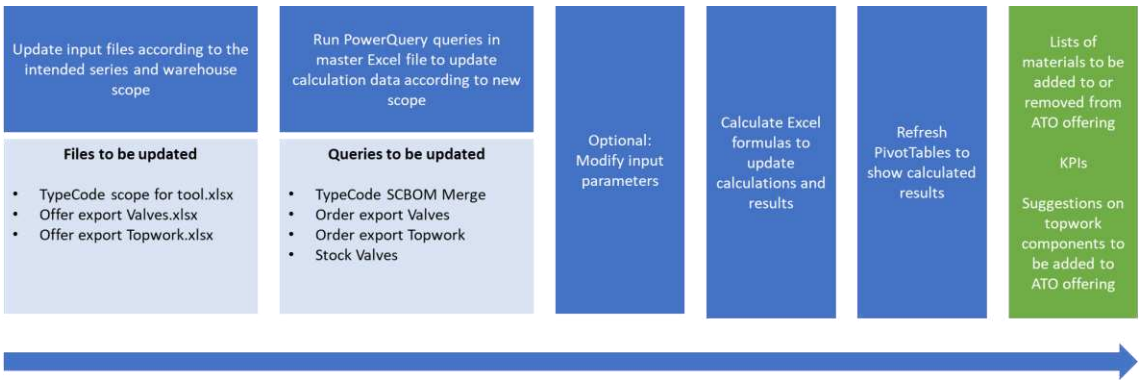

Figure 14: Steps to update input files and run calculations for a new scope

Once the calculation results are obtained, the implementation process is started. The first step of the implementation process includes a manual review of the results with the related product manager of the series in the run scope. A manual review is needed to ensure that tacit knowledge from product managers is not lost when implementing calculated results. Despite the calculations being done on material level (BOM level 1), the product manager evaluation is done on typeCode level (BOM level -1). This is because the product manager should evaluate the effects of the offering changes from the point of view of the ATO offering, despite warehousing decisions being made on a material level. Reasons to not follow calculation model suggestions can include matters such as strategic releases, availability problems and manufacturing risks that are not available in the data. Reasons noted in the implementation processes are compiled in chapter 4.1.5. These reasons are documented in a list, which is used as an input file for future runs of the model to ensure these reasons do not require multiple examinations.

The list of suggested additions and removals approved by the product manager is then transferred to Operations review, where they evaluate the feasibility of the changes. Similarly, as with product managers, operations can remove some suggestions if they are deemed not viable. In case further evaluation is needed, it is decided on together with operations.

When the list of suggested changes to ATO offering has passed through these steps, the remaining changes are implemented into the actual offering. These materials will then either be stocked, or their safety-stock status is removed. In practice, this does not mean scrapping, but instead the available inventory is used, and new inventory is not being acquired to replace the stock. The steps for implementing the valve material calculation model results are visualized in Figure 15.

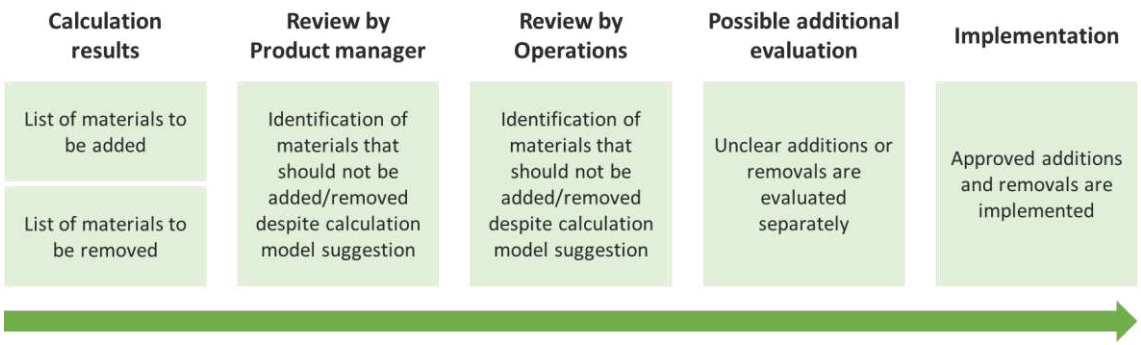

Figure 15: Calculation model result implementation process

During the first run cycles of the implementation process, meetings (either online or in person) are held to discuss and evaluate the ATO offering change suggestions with both product managers and operations. Once the process is in place and routines are clear, these meetings can be replaced by email. During the first runs of the calculation model, it was noted that these workshops where change suggestions were discussed were very valuable to gather qualitative insights on which kinds of results were feasible, which would not have been noted by reviews using only email.

When the valve material changes are implemented, an evaluation of Topwork components is conducted. This implementation follows a similar logic but as different types of topwork components have different product managers, it requires reviews with multiple product managers. Similarly, as with valve materials, the change suggestions are reviewed, then sent to operations for their review and after that a decision on implementation and possible further evaluations is made.

4.3.3 Process ownership and governance

To ensure an efficient way of updating ATO offering on a regular basis, the roles of this process need to be clearly defined. The roles and responsibilities of this process are defined with the RASCI matrix, which was introduced in the literature review. These roles, along with their main responsibilities and expected actions are compiled in Table 15.

According to the interviews, there is a clear consensus that the ownership of the process should be with the Availability and Offering Management team of the case company. In terms of the RASCI matrix, this is the role of the Responsible (R). The team's responsibility is to manage the process and initiate the process runs. Tool development and error handling is also the responsibility of the Availability and Offering Management team.

There should be one single person who oversees the process (Jacka et al., 2009). This is to ensure that responsibility is not divided among multiple professionals and all of them

assuming someone else drives the process forward. According to interviews and workshops, this accountability is with the head of the Availability and Offering Management team, P4.

The first evaluation of results is done by the product manager responsible for the product series being evaluated. Determining which changes are approved to be implemented and which should not be implemented and why is the task of the product manager. Their role in the RASCI matrix is defined as Consulted (C), as they are not directly responsible for moving the process forward but are rather used as a resource due to their expertise.

Once the results from the calculation model and product manager are ready, the list of additions and removals is transferred to Operations inventory and planning responsible persons. Operations are responsible for evaluating the results from their point of view and determining which changes can actually be implemented. In complex, unclear, or important decision-making situations, Operations can escalate a question to a specific industry expert or manager, who can make the final decision on adding or removing a product or material. Similarly to product managers, Operations inventory and planning responsible persons, have the Consulted (C) role in the RASCI matrix.

As the data exported from different data sources is key to the process, a supporting role for reporting data availability is defined. The reporting data responsible persons make sure data is available and can be used to debug problems with source data. This role is not, however, used to support PowerQuery or Excel calculations specific to this calculation model.

As the results of this calculation model affect the ATO offering, these results are of interest to many stakeholders. Quotation process functions, Sales, Management, and the Lead Time project of case company are informed occasionally, to ensure they are up to date with changes made to ATO offering.

Table 15: Overview of process ownership in RASCI format

RACI category	Person or team	Responsibility or action
Accountable (A)	P4 (Head of Availability)	Main accountable of process.
Responsible (R)	Availability and offering management team	Driving the process, initiating evaluation and implementation meetings.
Consulted (C)	Related product managers	Evaluates the feasibility of changes of own product series.
	Operations inventory and planning responsible persons	Evaluates the feasibility of offering changes from operations point of view.
Support (S)	Reporting data responsible persons	IT governance. Support regarding database functionality. Ensuring data is available.
Informed (I)	Quotation process functions Sales Management Lead time project	Results affect CPQ data, and stakeholders are informed occasionally.

4.3.4 Annual cycle

According to the interviews, one of the main challenges of implementing the calculation results is the time required from different internal stakeholders. To mitigate this, many interviewees highlighted the need for efficiency both in tool development as well as in the implementation process. This need for efficiency and the limited time available for running this process directly affect the frequency of the implementation cycles. According to P3, smaller, more frequent runs are preferred over larger, infrequent ones, as they help distribute the workload more evenly and reduce the manual effort required at any given time. On the other hand, from a management point of view, less time is used for this process if it is run just once or twice per year instead of in continuous cycles.

The calculations for defining calculated offering should be made to all valve series in the Helsinki warehouse. This is a long process and requires significant work from the organization and cannot be finished within the scope of this thesis. To accommodate these

first runs, and a continuous process after that, an annual cycle is planned. This cycle functions as a trigger for the process steps and defines when which steps should be initiated and when they should be completed.

The scope of this thesis includes the scope of the Helsinki plant, with a limited scope of valve series. However, a plan is needed for the review of all series in all plants globally, to ensure a thorough review of current ATO offering. The target of this review is to have all valve series globally reviewed within one year, by the end of 2025. After this, the process would recur annually, and each valve series in each plant would have a designated time slot for ATO offering review. The planned annual cycle is visualized in Figure 16.

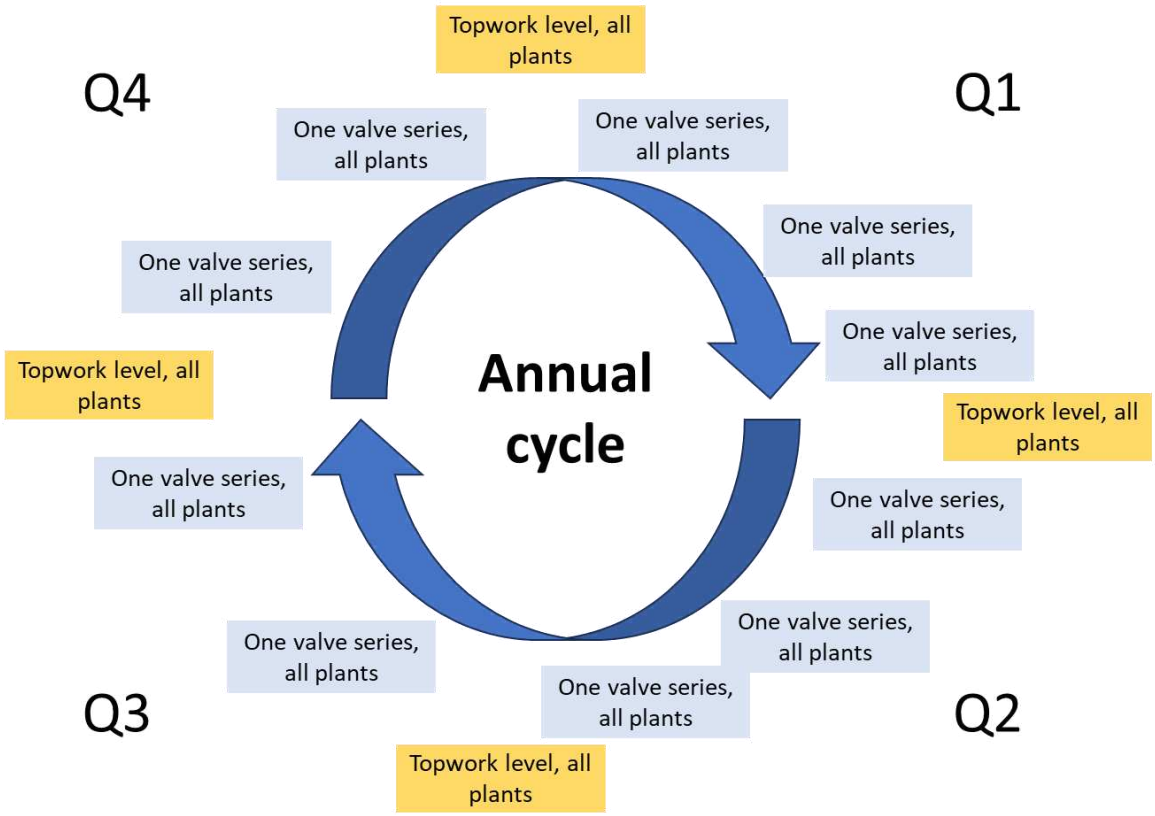

Figure 16: Annual cycle for review of product series and topwork assembly components

The first annual cycle requires significantly more work compared to the following cycles, as the ATO offering has previously not been reviewed with the model. Subsequent cycles are likely to be considerably easier and require less manual reviewing, as all series have already been reviewed during previous cycles. The only changes that need to be made are the ones affected by changes compared to earlier demand, scope or other factors that have seen changes.

The topwork assembly level should also be reviewed regularly. This would include all typeCode components sold with ATO valves globally, to ensure correct calculation results on both addition and removal of components. The calculation of the full topwork offering is not in the scope of this study but is discussed as a future project in chapter 5.7.

4.3.5 Start situation analysis for series

The evaluation of the ATO offering of all valve series is planned to be a recurring, annual, process. To evaluate the effect of changes made to offering, and to get a comprehensive view of the entire ATO offering of all valve series, a starting situation analysis was conducted. This analysis was made for all series, each plant separately, including the number of typeCodes and materials in ATO offering, quotation data (won, open, and lost) as well as safety stock. This starting situation analysis enables management to understand which series have the biggest challenges when it comes to ATO coverage, and which to not expect significant improvements from. This also functions as a verification to ensure the results obtained in the analysis of a specific series are correct. Due to confidentiality, these results are not presented in this study, but they are used internally within the case company to evaluate the ATO offering situation of different series and to compare them to each other.

The calculation logic used for this analysis is based on similar logic used within the valve material calculations for a single series. The visibility typeCode list is combined in PowerQuery with the Supply Chain BOM list so that all BOM level 1 materials for each valve are combined into one PowerQuery table. It is then determined for each material whether it is in ATO offering or not. This is based on the forecast method and the lead time of that material. All materials which are in ATO offering get value 1 in a new column ‘All materials in ATO offering’. Materials which are not in ATO offering get value 0.

As this table is very large, and contains several million rows, it cannot be exported to Excel. Instead, all valves are grouped in PowerQuery to only include one row per valve typeCode. To get the ATO-offering status for each valve, the minimum value of the column ‘All materials in ATO offering’ is calculated for each valve. If all materials are in ATO offering this minimum value is 1, otherwise it is 0. The result of this grouping is a table with approximately 82 000 rows of typeCodes and their status of ‘All materials in ATO offering’, which is exported to Excel for further analysis.

To get data regarding orders and offers of all valve series, a quotation data list is exported. This includes all quotation lines of all valves quoted during the years 2023 –

2024. The status of whether a valve offered is available in ATO offering is fetched by an Xlookup-formula from the typeCode list described in the previous paragraph.

Based on this data, a table is formed containing the following information for each valve series: Number of unique valves in ATO offering, number of unique BOM level 1 materials in ATO offering, total sales of valves (separately for won, lost, and open quotations), and total sales of valves in ATO offering (separately for won, lost, and open quotations).

This analysis gives a good overview of the starting situation for all valve series, which can be used to evaluate the potential effects of ATO offering evaluation. Due to the flexibility of the data tables used, further KPIs can easily be added to this analysis. Updating data to more recent data can also be accomplished simply by updating the input files, which are partly the same input files as for the valve material and topwork calculations.

4.3.6 Challenges and mitigations of process

As stated in the workshops, it is time consuming to evaluate calculation results qualitatively. Especially when the target is to run and evaluate many series in a relatively short amount of time, on the top of all other tasks and projects. To mitigate this, the calculation model logic and parameters were adjusted to be strict and only suggest additions or removals which have a high chance of being implemented. According to P7, the calculation results can almost be run on autopilot in case three-year consumption data is used in the calculations instead of the default 12 months consumption data. This highlights the success of the model, which identifies changes which improve the lead time of important valves affordably, while filtering out suboptimal suggestions.

It should be noted that as the valve series reviews are ongoing each month, the topwork-level review is never fully up to date, as new additions can be on their way without having been implemented yet. This challenge is mitigated with manual reviews of suggested changes, to ensure these special cases are considered before finalizing suggestions.

The annual cycle of evaluating ATO offering is problematic for comparison and evaluation of all series. As the scope of different series changes throughout the year, it is difficult for management to evaluate the entire offering at once. To mitigate this, an evaluation for the entire topwork offering is being conducted, where the topwork component sold with all ATO valves are evaluated simultaneously. This requires a lot of data processing, and multiple exports due to export file size limitations, but should be technically feasible. However, this is outside the scope of this study and is discussed further in chapter 5.7.

4.4 Calculation results of example series 1 and 2

The calculations and process were run for two valve series within case company from start to finish. The analysis includes the valve material analysis and the topwork component analysis. These series were selected as they provided a good insight into different calculation scenarios, and had a very proficient product manager, P7, who was able to evaluate the feasibility of suggested changes, so that the calculation model could be improved based on insights from evaluation workshops. The results presented in this chapter are limited and do not provide a lot of detail due to the confidentiality of data and results within the case company. Example series 1 results are compiled in Table 16, and Example series 2 results in Table 17.

The calculations and implementations of the calculation model and process developed in this tool are very much intertwined. Calculations assume that all results the tool suggests are implemented, and as the calculation results are dependent on each other, making manual changes alters the results. This poses a challenge in achieving optimal results, as it was noted that manual changes are most likely needed in all implementation steps. For simplicity reasons, the first calculated results are pushed through the entire process, but calculations are done based on an updated scope after each step. These new calculated results are only used to remove suggestions of adding or removing new materials which are not in calculated offering after manual changes.

The results of the calculation model regarding one of the in-scope series (example series 1) indicate that the benefits of implementing the valve changes to ATO scope improve offer coverage minimally. However, when analyzing the other components (besides valves), including them in offering causes major improvements in offer coverage. This highlights the idea that focus could be shifted from analyzing the valve offering toward a more holistic view of the entire offering, including all level 0 components. However, the minimal improvements of Example series 1 availability are not necessarily negative. The share of ATO scope sales of total valve sales is 74,5 %, which is a good value, and indicates that despite the ATO offering being managed manually without clear processes, is still working well. This can be caused by industry experts managing the processes and utilizing their knowledge and feedback from customers to achieve a good ATO offering. This is, however, only speculation and the reason behind the current success is not within the scope of this thesis.

The results of the Example series 1 run highlights challenges faced in the calculation, including the interconnectedness of results and calculations as well as the data quality. Offer data and data used to determine historical demand were not fully in line with each

other, making the calculation model evaluate an improved availability despite that not materializing in practice. This result highlights the need to shift calculation to even more accurate sources, where data truly reflects reality.

Table 16: Calculation results for example series 1

	Model proposal	**After manual reviews & implementation**
Number of TypeCodes in ATO offering	+13,7 %	+9,2 %
Number of materials in ATO offering (number of materials)	+28 -32 = -4 pcs	+15 -12 = +3 pcs
Safety stock	-1,2 %	+1,2 %
Valve offer coverage (won)	N/A	+0,4 %
Valve offer coverage (lost)	N/A	+3,6 % (ATO: LT < 3 weeks)
Offer coverage (including valve & top-work components)	+14,6 %	+3,0 % (ATO: LT < 3 weeks)

Table 17: Calculation results for example series 2

	Model proposal	**After manual reviews & implementation**
Number of TypeCodes in ATO offering	+4,2 %	+ 9,2 %
Number of materials in ATO offering	+ 8 - 7 = +1	+5 - 0 =+5
Safety stock	-0,2 %	+0,1 %
Valve offer coverage (won)	+0,1% if ATO is LT < 5 weeks +19,5 % if pure ATO	+0,1% if ATO is LT < 5 weeks +19,5 % if pure ATO
Valve offer coverage (lost)	+0,0 % if ATO is LT < 5 weeks +22,1 % if pure ATO	+0,0 % if ATO is LT < 5 weeks +22,1 % if pure ATO

Offer coverage (including valve & top-work components)	+ 5,2 % if ATO is LT < 5 weeks + 17,5 % if pure ATO	To be confirmed

The results of example series 2 show the significance of the definition of ATO offering. In the first version of the calculation model and in the first runs of the final version of the model ATO offering was defined as being in ATO offering based on forecast method. However, in the final results, management requested that the calculations include items with under 4 weeks lead time into ATO offering. This is especially prevalent in the results of example series 2, which show the offer coverage both for pure ATO offering (including only products which have all materials in stock) and extended ATO (including materials with a lead time of under 5 weeks). This definition does of course not affect customer availability, but it does affect the appearance of the results. There are many items with a lead time of 2-3 weeks, which are not considered to be a part of ATO offering if the definition is based on pure ATO warehoused items, while they are considered to be in ATO offering with this “softer” approach.

4.5 Discussion of findings

This chapter discusses the key findings of the study in relation to existing theory and the insights gained from interviews, workshops, discussions, calculation model development and practical implementation. The research objective of the study, based on the research questions, was to define what kind of parameters and calculation logic should be considered when defining a computational ATO offering, and what to consider when implementing such calculation results. The findings in the literature review were tested in the calculation model and implementation process development in a practical environment. The study began with a literature review to lay a foundation for the development of the calculation model and its logic and practical implementation. During the development of the model, the theoretical background was used to form the big picture of what to include in combination with the industry and company specific insights from stakeholder interviews and workshops. The most important findings related to this thesis were the ability to create a model which challenges the current ATO offering based on historical data. The literature analyzed during this study included high-level theories, as well as specific, context-bound theories on how to optimize ATO offering in specific circumstances, as discussed below. As the situation of case company was different from these theories and there was a lot of need for practical application, the calculation model had to be developed from scratch, based on simple guiding principles of theory.

The different trade-offs in inventory management proved to be at the core of the calculation model development. The trade-offs were considered in the development of the calculation logic but were also very prominent in the implementation process. In practice, all warehousing decisions were based on an evaluation of some trade-off. The fundamental inventory management trade-off of stock investment versus service level (Sbai & Berrado, 2018) was highlighted in the form of the cost / lead time ratio used in the calculation logic. In the qualitative result evaluation process step with product managers, the balance between inventory investment and benefit of service level was the main consideration.

Kourentzes et al. (2020) discuss the costs of poor availability and stockouts. These are difficult to estimate, as it is difficult to know how much of customer demand is dependent on high availability. Cost or stockouts are not directly relevant in the scope of this study, as customer orders are generally not received for items not in stock. However, the cost of availability was accounted in the study by focusing warehousing efforts on materials which improve lead time and availability of valves with demand. Cost of stockouts and poor availability could, however, be improved, and ideas to implement this are discussed in the chapter Limitations of calculation model in the form of a lost reason analysis. Similarly, Fadwa (2025) discusses the trade-off between centralized and decentralized inventories, which is suggested to be added as a functionality in the calculation model developed in this study.

In ABC and XYZ analyses, inventory items are according to their importance and demand variability (Kaabi et al., 2015, 2022; Dhoka, 2013). In this study, a direct classification of items was not made, but the ideas of including factors of importance and demand variability were discussed in the interviews and workshops. The importance of items was defined based on the demand of the product, combined with the qualitative evaluation of product managers of which items to stock. Suggestions for additions and removals were evaluated based on whether a product manager deems a valve important or not to be in stock. This qualitative evaluation considers a variety of factors including cost, how many end-products a material is part of which customers the items are sold to, and how rare the valve is. Demand variability is not directly included in the calculations, which could add some further insight into which items to stock. However, the variation of demand is often used in determining the size of safety stock (Sweeney, 2022), which is not in the scope of this study. If the calculation model would produce a large set of suggested additions or removals, a systematic way of evaluating these suggestions could be implemented with more systematic way for example with the help of an ABC XYZ matrix, as presented by Schönsleben (2007).

The main criteria for determining which materials to stock were defined as cost, demand, and lead time (Ruiz-Torres & Mahmoodi, 2010; Chase et al., 2001; Stevenson, 2018; Kolawole et al., 2019). These were compiled in a triangle introduced in this study, presented in Figure 2. These criteria proved also in practice to be the most relevant aspects of computationally evaluating which materials to stock. The easiest way to define stocked materials would have been to simply stock materials which have a sufficient demand and lead time, while their costs are small enough. However, this calculation logic would have filtered out suggestions, where the lead time improvement would be significant and the material has high demand, but it is too expensive to stock. To mitigate this challenge, the parameters were developed into ratios, which consider the relationship between the different parameters: A parameter is not good or poor by itself, rather the warehousing of the material is dependent on the ratio between the different parameters. This is a good example of theoretical foundation combined with iterative development to create a functioning system, which can be used across organizations. In the workshops where results were reviewed, these three criteria were evaluated compared to each other, and low cost, high demand, high lead time materials were often directly added to stock, while the opposite were not. According to Kolawole et al. (2019), materials which cost little while improving availability should be prioritized compared to more expensive materials. This thought was implemented in the calculation logic, where the ratio of cost per lead time improvement was considered. The lead time benefit was considered from an ATO point of view: One lead time bottleneck item can increase the lead time of an entire end-product, as discussed by Bah (2023) and Xu et al. (2018). This was mitigated in the calculation model by finding the bottleneck materials of each end-product and focusing warehousing efforts on those materials.

From an inventory management point of view, the goal is to improve availability with as small inventory investments as possible (Eroglu & Hofer, 2011). In an ATO environment, this can be achieved by focusing warehousing efforts on materials which have high component commonality (Collier, 1981). Additionally, warehousing efforts should be focused on materials, which are availability or lead time bottle necks (Bah, 2023). In an extreme situation, as mentioned earlier, the availability or lead time of an entire order can be deteriorated due to the shortage of one critical screw. As was noted in the implementation evaluation workshops, adding these affordable bottle-neck items can improve the lead times of entire valves with moderate inventory investment. Similarly, the addition of one common material can improve the availability of many end-products.

Component commonality and dependent demand were highlighted in the literature review, and these theories were utilized indirectly to form the logic of including materials in

offering which improve the lead times of higher-level items (Karaarslan et al., 2018; Jacobs & Chase, 2010, p. 354). The calculation logic of ranking the lead times of each -1-level item, then evaluating how many bottle neck materials can be added to offering and thus improving the lead times of -1-level items can be derived from the theory but is heavily influenced by the iterative development and feedback processes. The interconnectedness of dependent demand affects most calculations in the model and requires many test-runs for successful implementation.

A problem with many of these approaches is the lack of sophistication which disregards some relevant factors which are difficult to pinpoint in the data. For example, there can be significant demand for highly customized valves due to sporadic demand, which might lead to a computational suggestion of adding such special valve materials to ATO inventory. This, however, might not be optimal, as these materials can be assembled quickly from BOM level 2 items. Another example is strategic inventory: Some materials might not have any demand, which leads them to be suggested to be removed from ATO offering. However, these can be part of a strategic inventory, which means that they are being phased in, and therefore, they should be readily available for customer orders. These, and other similar reasons for diverting from calculation suggestions are compiled in Table 7 and Table 8. These reasons highlight the importance of not only abiding by computational results, but also reviewing the suggestions with relevant stakeholders, who possess this kind of tacit knowledge.

Regarding the practical implementation of the calculation model, the RASCI framework (Cabanillas, 2012, p. 59-60) proved to be very successful. This clear division of responsibilities combined with the Action Design Research (Sein et al., 2011) approach of building, intervention and evaluation proved to be successful in achieving the targets of this study. The calculation model provides a mathematical way to evaluate and challenge the current ATO offering, while having already two full cycles of test runs completed. During these test runs, challenges in practical implementation were resolved, ensuring that the final version of the calculation model provides tried and tested results that case company can be confident will deliver accurate and reliable outcomes.

5. CONCLUSION

This study aimed to define a historical demand based ATO offering by developing and implementing a calculation model, which utilizes both theoretical and practical knowledge. The findings demonstrate the complexity of the problem, caused by many affecting parameters, significant amount of data, quality of data, different points of view of the challenges faced, and the difficulty of striking a balance between opposite targets, for example inventory costs and availability.

This chapter summarizes the findings in this study by highlighting the implications of the results in this thesis for the case company, for research on a more general level, as well as the limitations and areas for future research.

5.1 Answers to research question 1

- *RQ1: How can a calculation model be developed to determine the materials and products to be in stock in an ATO environment?*
    - *RQ1a: What are the main parameters to include when defining which materials to stock?*
    - *RQ1b: How can the parameters be formed into a calculation logic, where both theoretical and practical factors are considered?*

The most important factors to consider when defining a historical demand-based calculated offering include three core parameters including demand, cost, and lead time. Defining warehoused materials and components based on these parameters requires a variety of considerations, including the variability of demand, share of project consumption, inventory-tied equity, the lead times to assemble final products from lower BOM level materials, and the supply chain of materials and risks associated with availability challenges.

When defining an algorithm for defining a calculated ATO offering, the most important aspect to consider is the desired result: What do we want to optimize? The answer to this question usually includes a set of parameters, including the core challenge of inventory management: Improving availability and lead times, while minimizing costs. *"Improving lead times for end-products with high demand in an affordable way"* was the leading thought for the calculation model developed in this study. This captures the core components of inventory management. As the calculations use modifiable parameter values to

determine the weights in the calculations, the model can adapt to managerial decisions on what to prioritize or deprioritize in relation to other factors. Finding the optimal parameter values is difficult or even impossible, as views on what should be prioritized can differ, depending on what factors are prioritized. The default parameters used in the calculations for Example series 1 and 2 provide a good balance of high-quality suggestions, while reducing the number of suboptimal suggestions.

When creating a complex model such as the one in this study, it is easy to include an incomprehensible number of parameters and data, which are difficult to internalize for anyone not part of the development team. Effort should be taken to create an understandable model, which has a clear logic and can be deciphered by other individuals with the help of documentation. Similarly, the results created by the model should be easy to understand for both the operational staff, as well as for managerial purposes. Calculated results should have different levels of detail, which show what the results are both on a higher and a more detailed level.

5.2 Answers to research question 2

- *RQ2: How can the results obtained in the calculation model be implemented in a practical process?*

The practical implementation of calculation results requires adaptation to fit the practical requirements and limitations of the implementation organization. To successfully implement computational results as efficiently and accurately as possible, a leading thought should be:

“Can these results be implemented as is, and if not, why?”

This question includes two assumptions:

(1) The computational results are accurate and effectively align with the intended outcomes.

(2) Participating stakeholders in the process understand qualitatively whether the calculation results are feasible or not.

To overcome the challenge of accuracy, the logic of the calculation model needs to reflect the requirements of the organization, as discussed in the previous chapter. The challenge of qualitative understanding of the feasibility of results can be mitigated by including the relevant stakeholders in the implementation process. Due to the practical nature of implementation, practical limitations pose challenges regarding workload, ease of use, and personal commitment to the process. Even the best theoretical model is

useless if it is not used, and benefits from optimizing the offering can be nullified if the process of evaluating and implementing results in practice requires too much labor.

As the calculation model was developed for a real-life challenge of the case company, the practical aspects of implementing the results were particularly relevant. The need for manual reviews and evaluations of calculation logic and results proved to be crucial for the success of the calculation model. Many crucial modifications to the tool would not have been done if the development had been solely based on the findings from the literature review and the interviews, without the practical workshops. Even now, when the calculation model is complete, the manual reviews of the calculation results are crucial: In a complex environment such as the one of case company, there are numerous qualitative aspects to consider when defining ATO offering: Even the best calculation model cannot include all factors that industry experts consider when determining which suggestions to implement.

5.3 Implications for research

The main challenge in this thesis, developing a way to evaluate current ATO offering with a computational model, has been heavily influenced by the specific characteristics of the case company. However, the results obtained in this thesis can also be analyzed from a broader, more academic perspective.

The element of an ATO offering in a valve manufacturing company is quite specific, but not unique. This context requires considerations which has not been a lot of scientific research about. For example, the number of possible end-products and combinations posed a challenge, which has not been widely documented in prior research. The challenge of creating a calculation model to optimize ATO offering is likely faced by other organizations. The high-level findings can be useful as a starting point when developing any optimization tool within inventory management, that is used in a recurring process.

The calculation logic for evaluating ATO offering could be utilized in similar scenarios faced by other organizations challenged with a large ATO offering. Cost, lead time, and historical demand were highlighted as the most important factors for warehousing decisions in the literature review, stakeholder interviews, and the calculation model development. Utilizing these in the form or ratios, as presented in 4.2.2, and utilizing these ratios as KPIs is an important finding. The use of the three ratios as KPIs for evaluating warehousing decisions can be used by any organization who needs to evaluate their inventory, even if not having an ATO offering. These ratios, combined with color-coding, give a comprehensive overview of the state of materials or components being reviewed.

The logic of the calculations of determining the important typeCodes is based on a holistic understanding of the requirements to evaluate the ATO offering. The idea of finding the lead time bottlenecks of the materials for important end products could be utilized in a range of industries using ATO warehousing. The logic of the calculation model, presented in chapter 4.2.6, can be generalized for most ATO environment purposes, visualized in Figure 17. This logic is not only based on a theoretical foundation but includes a variety of practical considerations from workshops and informal, open-ended discussions with industry experts.

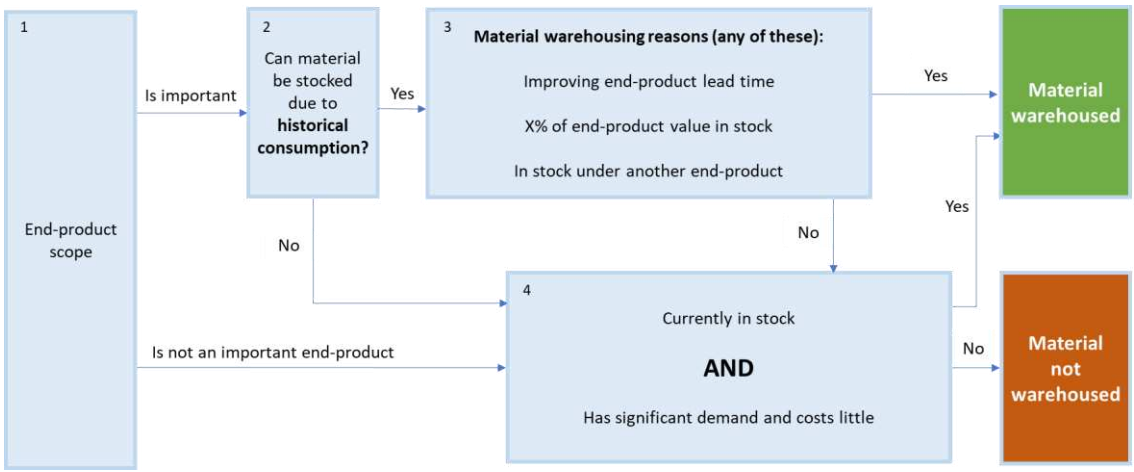

Figure 17: Generalized logic for determining which materials to stock in ATO environments

The process of evaluating calculation results developed in this study is a good framework for reviewing any calculation model changes which are based on calculation results, which require manual reviews and modifications. The simplicity enables it to be efficiently managed and implemented, and defines clear checkpoints for evaluating results, giving clarity on which changes have been made by whom and at which stage. The process is the following:

Results → Product manager review → Operations review → Implementation

One of the most valuable research findings includes the practical considerations of working with incomplete data, combining it with the need for manual reviews and addressing different points of view, while maintaining low need for manual labor and reducing complexity for ease of understanding and performance of programs executing the calculations.

5.4 Practical implications

The main result of this study is a calculation model for determining which products should be in short lead time offering, accompanied by a process to implement the calculation results. The calculation model reviews a certain valve and topwork scope and evaluates which valve materials should be added to or removed from ATO offering, based on historical demand, cost, lead time, and other criteria. The model also evaluates which topwork components should be added to ATO offering by analyzing their impact on actual quotations alongside the selected valve scope. The process of implementing these suggested changes includes a qualitative review of relevant product managers and operations inventory and planning responsible people. This manual review process ensures that no suboptimal changes are made to ATO offering, which would have a significant impact on customer experience, manufacturing, operations, and business.

One of the main achievements of this thesis is the ability to perform systematic, continuous monitoring of the ATO offering. Previously, changes made to ATO offering have been reactive, based on challenges faced by lacking availability or ad-hoc analyses regarding smaller scopes of items. The process developed in this study enables a systematic approach to offering management, and enables a holistic view of the entire valve, and in the future topwork, offering. The calculation suggestions challenge the current ATO offering by identifying materials that could improve availability if added and those that could be removed to reduce tied-up capital in inventory.

On a larger scale, the results of this study can also be applied to other organizations with similar challenges or a desire to determine which products should be stocked in an ATO environment. The challenges faced and mitigated during the iterative development and evaluation process can be used as a basis for similar analyses in a variety of organizations. The core element of these findings is the calculation logic which determines items to add to or remove from ATO inventory. Similarly, the process of implementing the results in a qualitative way can be utilized for implementing any calculation results which require qualitative screening and evaluation.

For the purposes of the case company, a brief, practical list of recommendations and a suggested timeline for how to proceed is compiled in Appendix A.

5.5 Limitations of calculation model

The calculation model developed in this thesis was developed in Excel, and the input data was very large (several input files with over 100 000 rows). This created calculation

challenges, where the performance of Excel was pushed to its limits, slowing the calculation down and thus hindering the dynamic nature of the model. In the requirements gathering phase of the thesis, a request for a dynamic tool was presented, where the parameters could be changed and real-time changes to results could be obtained. Due to the complexity of the calculations and the large amount of data, results from changed parameter values can take 30 minutes to several hours, depending on the input scope. Similar logic used in the calculation model could be used in another software and could potentially enable more dynamic parameter alteration. The slow calculations cause challenges regarding the dynamism of the calculation model: Since the values cannot be adjusted anywhere close to real time, conducting scenario analyses or comparing parameter values is challenging. This highlights another challenge: How can the parameter values be evaluated and validated to be optimal. Even though the results obtained using the default parameter values are good, it might be that they are not optimal. This might lead to some improving additions to not being detected, which could cause the calculation model suggestions to be sub-optimal.

There are some limitations in the calculation model based on the scoping decisions made. The model which was developed in this thesis focused on BOM level 1 inventory, and an assumption was made for the purpose of calculations, that all lower-level materials have infinite inventory and cannot run out of stock. This assumption works well in most cases, as the stocks are generally in good condition and do not run out often. However, there were cases noted in the test runs where a lower-level material was assumed to be in stock but was in fact not. This problem could be mitigated by extending the scope of the calculation model to lower levels and conducting analyses for levels from 2 down. This analysis would also create a historical demand-based analysis tool for warehousing decisions, similar to the one conducted for BOM level 1 in this thesis.

Component commonality could be increased in the calculation model. There are scenarios where a certain component or product can be used for multiple purposes. For example, a valve might have qualifications or functionalities which are unnecessary for certain applications but are not barriers either. This means that those components or products could be used to replace another product with longer lead time to improve availability. This would lead to higher costs, as a more complex is used for an application it is overqualified for. On the other hand, this would enable optimization of reducing inventory levels.

Lost reason analysis could be considered to be added to the calculation model. ATO offering management affects the demand for products by altering the lead times of products. As stated in the literature review chapter 2.5.1, lost reason analysis is important to

consider understanding the customer needs of lead times. Orders which are lost due to availability or long lead times should be prioritized when determining ATO offering, while products which customers do not require short lead times could be de-prioritized. Lost reason analysis is being conducted at case company, and analysis regarding that could be added to the calculations in this thesis to improve the impact of the offering changes.

The topwork component analysis conducted in this study is limited to reviewing components sold with one valve series at a time. However, as most components sold in complete topwork solutions are not related specifically to a certain valve series, the analysis of only looking at the components sold with a specific valve series does not fully reflect the entire offering. This is especially prevalent when analyzing components to be removed from ATO offering: Suggestions on removals cannot be made, as it is not possible to validate that a component has no demand if only looking at how many times it has been sold with a specific series valve. The solution to this challenge is a comprehensive analysis containing all topwork components sold with all valve series within 12 months. Components, which are sold infrequently and do not increase lead times of quotations could be removed, while components which are lead time bottlenecks should be added to ATO offering. This analysis has been conducted in parallel with this study at case company, and the implementation process has begun as of February 2025. Additionally, further analysis of topwork component materials is going to be conducted, to evaluate the topwork component ATO offering in a similar way to the valve ATO offering.

5.6 Limitations of research

This subchapter analyzes the limitations of this study from the point of view of research, especially reliability and validity.

Reliability refers to the reproducibility and consistency of the study. In this thesis, the focus of creating a customized calculation model for the purposes of a particular organization affects the repeatability of the study, and utilizing these results in another environment could require a lot of adaptation. As a major part of the data used in this study is based on organizational information gathered in interviews and workshops, the results might be skewed according to the subjective understanding of stakeholders. The results obtained in this thesis might have been different depending on the organization chosen as case company. On the other hand, this lack of reproducibility enabled a strong focus on the real-life challenges of the case company, and the development of a calculation model that mitigates the challenge faced: Defining products and materials which should be in ATO offering. An example of this was the default values of parameters used in

calculations. These were defined in workshops and informal discussions, where theoretical aspects were combined with actual calculation results and industry expertise, to form a functional set of values that yield feasible results.

Validity refers to how well the research and methodology measure what they are intended to measure. The aim of the research was to develop tools to define which materials and products should be in ATO offering at the case company. On a broader level, the findings of this study can be utilized in other organizations facing similar challenges. From the point of view of case company, validity is carried out successfully, as interim results have been evaluated by multiple stakeholders in different positions of case company. On a higher level within case company, a question can be posed whether the priorities selected in the calculation logic are the ones that yield the most optimal results. The question of how much to emphasize availability, lead time, inventory cost and other factors remain subjective, and it is difficult to pinpoint the optimal cross-section of these criteria. From the point of view of other organizations utilizing the findings in this study, the validity of the findings can be up for debate. It is difficult to estimate how well the calculation logic and implementation process fits other organizations. Many of the challenges faced and mitigated in this study are not company or even industry specific, increasing the likelihood of successful utilization of results outside the case company.

5.7 Areas for future research and development

Many of the challenges faced in the previous chapter, 5.5, can be mitigated by further developing the calculation model. For example, calculations can be sped up by improving the efficiency of the calculations or by transferring the system to a more powerful program. This would also enable more dynamic parameter testing and sensitivity analysis. Adding BOM levels beyond level 1 or adding component commonality or lost reason evaluation algorithms to the calculation model could solve the other limitations.

The long-term goal of the calculation model is to transfer it from Excel to a direct database solution, which is more suitable for handling large datasets wand complex calculations. The calculations will continue to work in Excel while the development of the database version is yet to be completed. Case company currently uses top of the line inventory management software for other purposes, which includes, for example safety stock calculation. A rough safety stock calculation is also done in this thesis, to get an understanding of the magnitude of the changes made. However, actual safety levels will still be calculated in the more sophisticated Rapid Response tool. This highlights the question, could Rapid Response, or other similar tools already used by the case company, be utilized as a part of this calculation model. The scope of this thesis does not include

the integration of other software, but it could be considered in the future when developing the functionalities of this calculation model further.

The warehousing of components in other warehouses is not considered in the valve material calculations. This could be an avenue for further optimization, where a material could be shipped from one warehouse to another in case of availability problems. The integration of all warehouse inventories in a calculation model could enable optimization of which materials are warehoused at which locations, reducing the need for duplicate stock globally.

The calculation model developed in this thesis is based on relatively simple optimization, which fits the needs of the case company. Further optimization could be done, by including more sophisticated mathematical models, or using professional software specifically designed to optimize offering. The emergence of artificial intelligence and machine learning could enable new ways and tools to further optimize ATO offering and include more criteria and parameters. Perhaps even some of the qualitative reviews could be replaced by artificial intelligence which could be trained on other similar instances. Case company already possess some top-tier tools within inventory management, which could be combined with this calculation model in the future. One of these tools is RapidResponse, which is currently used to, among other things, define safety stock levels for warehoused products.

The target of the case company is to run the calculation model for all series in all warehouses within the current year (2025). This requires persistent running of calculations and evaluation of results. The first run cycle for each series in each warehouse is going to be the most laborious, as the offering needs to be evaluated fully, without the support of previous runs. After the first full cycle, the goal is to run each series for each plant annually and thus keeping the ATO offering up to date.

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APPENDIX A: RECOMMENDATIONS FOR CASE COMPANY

This chapter presents the author's recommendations on how the case company can best leverage the results of this thesis. The recommendation of time-bound targets is compiled in the list below.

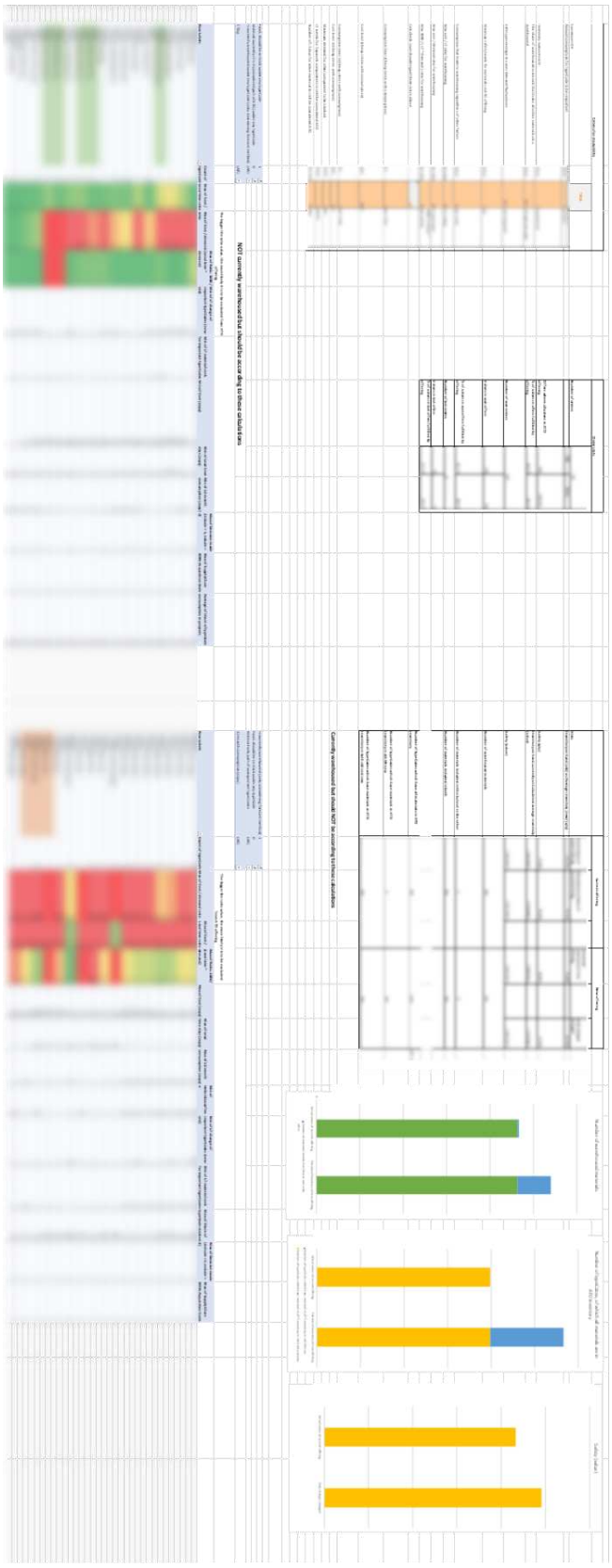
- **During the first half of 2025:** Runs and implementations for two main plants done, including topwork analysis and starting situation analysis. Development of the calculation model to enable runs in North America.
- **During the second half of 2025:** Runs and implementations in North America, including topwork analysis and starting situation analysis. Topwork analysis run again for two main plants.
- **During 2026:** A new starting situation analysis run, to compare and evaluate implemented changes during 2025. All series in all plants are run in the first annual cycle presented in chapter 4.3.4. Topwork analysis is conducted at the end of each quarter.
- **Annually from 2027 forward:** A starting situation analysis is to be run at the start of each year, to evaluate obtained results of implemented changes. There should be an established way of running and implementing offering change suggestions across all valve series and topwork components for all plants.

From 2027 forward, the process should be familiar to all stakeholders, which reduces the amount of unclarities and manual work. Evaluation meetings can potentially be replaced by emails as decision criteria is stabilized. The result is a process which evaluates and refines the ATO offering systematically and holistically.

To further improve the calculation model, the following future implementation suggestions are ranked based on the author’s subjective assessment:

1. Computing power increase, to enable runs of larger datasets and faster refreshes.
2. Calculation model development to enable runs in North America.
3. Topwork analysis to include material-level evaluation.
4. Lost reason analysis to highlight which offers have been lost due to availability and suggesting stocking those critical items and materials.
5. BOM-level analysis including BOM level 2 and below.
6. Warehousing optimization across plants.
7. Product commonality. Evaluating which products could be replaced by others.

APPENDIX B: EXCEL DASHBOARD (VALVES)



APPENDIX C: EXCEL DASHBOARD (TOP-WORK)

	Old model	New model: Added	New model: Removed	New model: Sum	Change
Number of typeCodes fully warehoused	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Number of unique materials warehoused	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Value of inventory on hand inventory	[illegible]				
Value of safety (BOM level 1)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total sales won (valves only, excl. projects)				[illegible]	
Total offers lost (valves only, excl. projects)				[illegible]	
Total offers open (valves only, excl. projects)				[illegible]	
Sales in ATO won (valves only, excl. projects)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Share of sales in ATO (valves only, excl. projects)	[illegible]		[illegible]		[illegible]
Lost orders in ATO (valves only, excl. projects)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Share of lost orders in ATO (valves only, excl. projects)	[illegible]		[illegible]		[illegible]
Open orders in ATO (valves only, excl. projects)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Share of open orders in ATO (valves only, excl. projects)	[illegible]		[illegible]		[illegible]

Count of components to add	[illegible]	
FBC of these sum	[illegible]	FBC * 5 = 157 076 €

Number of typeCodes	[illegible]
Number of typeCodes with all materials having demand	[illegible]
Number of typeCodes with demand in ATO BEFORE	[illegible]
Number of typeCodes with demand in ATO AFTER	[illegible]

	Old before changes	Old after parameters	Old after additions	New before parameters	New after parameters	New after additions
Number of orders (won)			[illegible]			
Number of orders with all valves and components in ATO (won)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
% of won orders in ATO	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Number of orders (lost)			[illegible]			
Number of orders with all components in ATO (lost)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
% of lost orders in ATO	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Number of orders (open)			[illegible]			
Number of orders with all components in ATO (open)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
% of lost orders in ATO	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Net sales (won)						[illegible]
Of which valves						[illegible]
Offers where all valves in scope (this series) in ATO (won) €			[illegible]			[illegible]
Share of offers with all valves in ATO (won) %	[illegible]			[illegible]		
Valve offer ATO coverage (won) €			[illegible]			[illegible]
Share of valves in ATO (won) %	[illegible]			[illegible]		
Of which other components						[illegible]
Other comps sum if valve is in ATO (won) €			[illegible]			[illegible]
Offers where all other comps are in ATO coverage (won) €	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Offers where all other comps are in ATO coverage (won) %	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Net sales of valve & other components in ATO offering (won)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
% of won orders covered by ATO	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Net price (lost)						[illegible]
Of which valves						[illegible]
Offers where all valves are in ATO (lost) €			[illegible]			[illegible]
Share of offers with all valves in ATO (lost) %	[illegible]			[illegible]		
Valve offer ATO coverage (lost) €			[illegible]			[illegible]
Share of valves in ATO (lost) %	[illegible]			[illegible]		
Net price of valve & other components in ATO (lost)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
% of lost orders covered by ATO	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Net price (open)						[illegible]
Of which valves						[illegible]
Offers where all valves are in ATO (Open) €			[illegible]			[illegible]
Share of offers with all valves in ATO (Open) %	[illegible]			[illegible]		
Valve offer ATO coverage (Open) €			[illegible]			[illegible]
Share of valves in ATO (Open) %	[illegible]			[illegible]		

Value (FBC) of other components suggested to be added	31 415 €
Value (FBC) of other components to be added	3 391,00 €

ID of other component to be added to ATO	Description	Count of order rows (won)	Number of offers, where this component is increasing LT of ATO valve (won)	Helsinki FBC	12 Month demand	Acquisition code	Product group ID	Product manager nam	Helsinki LeadTime
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	

APPENDIX D: ORIGINAL INTERVIEW QUESTIONS (IN FINNISH)

Nykytila

- Miten hyvin ATO-tarjoama tällä hetkellä vastaa optimaalista tarjoamaa?
- Onko sinun näkökulmastasi ATO-tarjonnassa tällä hetkellä oikeat tuotteet?
- Millä perusteella varastoitavat ATO-nimikkeet määritellään?
- Miten nämä kriteerit huomioidaan?
    - Historiallinen kulutus: Mitä asioita jää huomioimatta, jos katsotaan vain historiallista kulutusta?
    - Kiertonopeus
    - Lead Time
    - Hinta/kustannus
    - Muut kriteerit
- Jos tietyn tuotesarjan nimike varastoidaan, varastoidaanko muut saman sarjan nimikkeet automaattisesti?
- Onko vastaavia ”ketjutusjärjestelmiä” varastoitavuudessa (jos A on varastoitava, niin B:kin on)?
- Varastoinnin kustannukseksi on suunniteltu laskettavaksi vain sitoutunut pääoma. Onko tämä hyvä oletus?
- Mitä muita ”pehmeitä” kriteerejä on, joita on vaikea huomioida laskuissa?
    - Tärkeän asiakkaan tyytyväisyyden takaava nimike varastoitava
    - Toimitusvaikeudet
    - Toimittajariskit
- Miten kysyntää ennustetaan, ja miten se vaikuttaa ATO-tarjontaan?

Tavoitetila

- Mitä konkreettisia tuloksia odotat diplomityöltä?
- Minkälainen olisi tämän diplomityön täydellinen lopputuotos?
- Mitä ajatuksia tarjoaman optimoinnin jatkamisesta diplomityön jälkeen?
- Mitä muutoksia toivot varastoitavien tuotteiden tarjoaman muutosprosessiin liittyen? Mitä muutoksia et halua?
- Miten optimaalinen ATO-tarjoama tulisi määritellä laskennallisesti?
- Miten kysyntää tulisi ennustaa? Riittääkö historiaperusteinen arvio?
- Työn yhtenä tavoitteena on toteuttaa laskentamalli, joka arvioi, mitkä tuotteet ovat laskennallisesti varastoitavia ja mitkä eivät. Mitä haasteita näet tämän listan toimeenpanemisessa käytännössä?

ATO-tarjonnan määrittäminen

- Miten ATO-tarjoamaa päivitetään tällä hetkellä?
- Missä tapauksissa ja kuinka usein siihen lisätään tai poistetaan nimikkeitä?
- Miten varastoivien nimikkeiden listan muokkaamisprosessi menee tällä hetkellä?
- Ketkä osallistuvat prosessiin, kuka omistaa sen ja mikä on sen aikataulu?

Laskentamallin implementointi

- Tutkimuksen tarkoituksena on luoda työkalu nimikkeiden varastoitavuuden määrittämiseksi. Mitä ajatuksia tämä herättää?
- Mitä virheitä tämänlaisessa analyysissä voi helposti tehdä, mitä tulisi välttää?
- Mitä tulisi huomioida tämälaisen laskentamallin implementoinnissa?
- Minkälaisessa muodossa tulokset tulisi esittää?

Muut huomioitavat seikat

- Miten varaston suoriutumista arvioidaan, ja mikä on eri mittareiden painoarvo suhteessa toisiinsa?
- Mitä mahdollisia tai todennäköisiä riskejä näet listan toimeenpanemisessa?
- Miten nämä riskit vaikuttaisivat liiketoimintaan, asiakastyytyväisyyteen ja muihin sidosryhmiin?
- Vapaa sana: Onko ideoita tai ehdotuksia, joita voisi olla hyvä pohtia tätä diplomityötä tehdessä?

APPENDIX E: TRANSLATED INTERVIEW QUESTIONS (IN ENGLISH)

Current state

- How well does the current ATO offering align with the optimal offering?
- In your view, does the current ATO offering include the right products?
- On what basis are the stockable ATO items determined?
- How are these criteria considered?
    - Historical consumption: What factors are overlooked if only historical consumption is considered?
    - Turnover rate
    - Lead time
    - Price/cost
    - Other criteria
- If a certain product series item is stocked, are other items in the same series automatically stocked as well?
- Are there similar "chaining systems" in stockability (e.g., if item A is stockable, then item B must be as well)?
- The storage cost is planned to be calculated based only on committed capital. Is this a good assumption?
- What other "soft" criteria exist that are difficult to account for in calculations?
    - An item that ensures the satisfaction of an important customer
    - Delivery difficulties
    - Supplier risks
- How is demand forecasted, and how does it impact the ATO offering?

Target state

- What concrete results do you expect from the master's thesis?
- What would be the ideal final outcome of this thesis?
- What are your thoughts on continuing the optimization of the offering after the thesis?
- What changes would you like to see in the process of modifying the stockable product offering? What changes do you not want?
- How should the optimal ATO offering be defined computationally?
- How should demand be forecasted? Is a history-based estimate sufficient?
- One of the thesis goals is to create a calculation model that evaluates which products should be stocked and which should not. What challenges do you see in implementing this list in practice?

Defining the ATO offering

- How is the ATO offering currently updated?
- In what cases and how often are items added or removed?
- What is the current process for modifying the list of stockable items?
- Who participates in the process, who owns it, and what is its timeline?

Calculation model implementation

- The purpose of the research is to create a tool for determining the stockability of items. What are your thoughts on this?
- What mistakes can easily be made in this type of analysis, and what should be avoided?
- What should be considered when implementing this type of calculation model?
- In what format should the results be presented?

Other considerations

- How is warehouse performance evaluated, and what is the relative weight of different metrics?
- What potential or likely risks do you see in implementing the list?
- How would these risks impact business operations, customer satisfaction, and other stakeholders?
- Open discussion: Do you have any ideas or suggestions that could be useful to consider for this thesis?