Gaining visibility and improving Inventory Health

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Management Summary

Kramp Netherlands BV, managing an extensive portfolio of 500,000 SKUS and network of 10 distribution centers, is open to operational and financial challenges as exposed by global disruptions. The onset of the pandemic served to increase the role of supply and demand dynamics, raising the value of stocks and introducing variability into inventory dynamics. Long lead times, combined with low stock turnovers in the product assortment, add high storage costs and considerable capital tie-ups, and therefore escalate stock obsolescence. These are not just operational issues, but it directly impacts the financial performance and overall efficiency of the main Distribution Centre in the Netherlands. Thus, this study is targeted to help mitigate these challenges, striving for transparency and improvement into inventory health at the central warehouse of Kramp in the Netherlands.

At the heart of this report is a model that was systematically built for the identification, analysis, and consequent addressing of the root causes of the poor performance of the inventory. This segmentation within the model, based on critical factors as shortage value, excess value and rates of expected inventory turnover, makes it very specific for the pinpointing of inventory items and identification of specific areas where the performance is poor and reasons for this.

The report has made use of the set of the theoretical concepts of inventory management towards the systematic identification of the performance in inventory. Key metrics like the Inventory Quality Ratio (IQR) showing the ratio of the inventory value below the maximum allowed inventory, and the Inventory Control Index (ICI) showing the ratio of the SKUs within the minimum and maximum threshold, so as to get an insight of the general well-being of the inventory system. Multi-criteria decision analysis (MCDA) brings in a well-structured platform for inventory evaluation even further and therefore the identification of the worst inventory performers. From the worst inventory performers, causes that are going to have an impact on the inventory the most are identified based on the root cause analysis (RCA) of it.

The analysis uncovers several causes contributing to the inventory's unhealthy status. It includes high Minimum Order Quantities (MOQs), panic-buying behaviors witnessed during the time of the COVID-19 pandemic —wherein demand for some items remained stable over the past two years while for others it also declined, an extensive amount of items featuring no demand at all, and a cautious approach towards ordering. All these factors, combined together with many others, have individually and collectively created an unhealthy inventory where as of November 2023 the IQR registers at 75.90%, as to where 16.19M out 67.24M is excess, and the ICI at 75.09%, as to where 205,607 out of the 273,804 fall within the acceptable range. This means that around three-quarters of inventory is well aligned with the upcoming year's forecast.

The actions developed to work out first before targeting the SKU directly are segmented into 3 categories. This involves external events, SKU parameters, and strategy & decision making. After addressing these three the focus is on the targeted actions through SKUs to improve the IQR and ICI. The identification of the issues related to the address with targeted actions implies the potential in terms of bringing about significant improvements to the operational efficiency and cost effectiveness of the inventory. This is not only to improve the level of inventory itself but to form a process for the inventory that can respond well to challenges such as external events, parameters

and inventory strategies. When targeting the SKU directly actions are created and prioritized based on the overall goal for Kramp regarding already bought assets, which is to maximize revenue.

Thus, the actions are: reviewing MOQs with suppliers to reflect demand more closely, addressing a better End-of-Life (EOL) strategy, adopting a no action approach as demand persists, anticipating that the SKU will align with the desired range within a year, thereby decreasing excess inventory by 6.26M; initiating stock transfers to other warehouses of Kramp, to enhance the management of surplus stock, aiming for a reduction of 1.73M in excess value; Utilizing of alternative sales channels, including Kramp Market, and selling to last and only customer, to reduce surplus inventory, aiming for decreases of 0.31M and 0.37M, respectively. Should any inventory remain or its sale is uncertain, the final actions involves returns to suppliers or scrapping, with goals of removing excess by 1.16M and 2.35M, respectively.

These actions are designed to align with Kramp's overarching objectives, ensuring revenue maximization and followed up by cost-effective actions. Success of these measures within a year could result in an IQR of 92.90%, reducing the excess inventory from 16.19M to 4.01M, and achieving an ICI of 97.25%, indicating that 266,276 of the 273,804 SKUs would meet the acceptable range. This outcome demonstrates that adherence to the action plan can lead to an inventory status more closely aligned with the future needs of Kramp's customers.

The conclusion drawn from this report is that the utilization of IQR and ICI allows for an effective analysis of inventory healthiness. Employing MCDA for assessing article performance helps identify and address key drivers influencing the current inventory status. The proposed action plan prioritizes the examination of external events, SKU parameters, or strategic decisions before specific targeted actions for SKU improvement, which can help to improve and maintain the inventory healthiness.

It is therefore recommended to initiate this process by reviewing MOQs, setting up a better EOL strategy, followed by adherence to the devised action plan, with monthly evaluations of identified values as Slim4 (which is Kramp’s inventory management system) updates certain values monthly. Additionally, given that future KPIs, IQR and ICI, do not achieve a 100% target, it becomes worthwhile to seek alternative sales avenues to help reach this.

Contents

Glossary

Word/abbreviation	Definition
DC(s)	Distribution Center(s)
SKU(s)	Stock keeping unit(s)
Slim4	Slimstock 4 – "An integrated solution for forecasting, demand planning (demand scheduling) and inventory management." (QBS Group, 2023)
Stock value	the total dollar value of the inventory you have left to sell at the end of an accounting period. (Shopify, 2022)
Stock turn	is a financial ratio showing how many times a company turned over its inventory relative to its cost of goods sold (COGS) in a given period. (Fernando, 2023)
S&P countries	Warehouses located in the Netherlands, Germany, Poland, France, Spain, Italy and the United Kingdom.
Nordics	Warehouses located in Denmark, Sweden and Finland.
100 – STR	Warehouse Strullendorf (GER)
200 – KON	Warehouse Konin (PL)
300 – VSV[1]	Warehouse Varsseveld Breukelaarsweg (NL)
350 – VSV KST	Warehouse Varsseveld Aaltenseweg (NL)
350 – ZEV	Warehouse Zevenaar (NL)
500 – REG	Warehouse Reggio Emilia (IT)
600 – BGW	Warehouse Biggleswade (UK)
700 – POI	Warehouse Poitiers (FR)
920 – GET	Warehouse Getafe (SP)
100 DEN	Warehouse Skjern (DK)
250 SWE	Warehouse Eslöv (SW)
400 FIN	Warehouse Paimio (FL)
KPI	Key Performance Indicator
EOQ	Economic Order Quantity
MOQ	Minimum Order Quantity
IOQ	Incremental Order Quantity
GBQ	Google Big Query
SQL	Structured Query Language
ICI	Inventory Control Index
IQR	Inventory Quality Ratio
EIV	Excess Inventory Value
SIV	Shortage Inventory Value
EIT	Expected Inventory Turnover
YoC	Years of Coverage
EOL	End-of-life

[1] Main warehouse of Kramp Netherlands B.V.

1. Introduction

1.1. Kramp Netherlands B.V.

Kramp Netherlands B.V. is a leading supplier of agricultural parts and equipment in Europe, with over 70 years of experience in the industry. The company was founded by Johan Kramp, a 34-year-old entrepreneur from Varsseveld, in 1951. Since then, it has grown from a one-man operation to a multinational corporation with over 3000 employees, 24 branches and 10 DCs across Europe. Kramp locations, consisting of warehouses and shops, are shown in Figure 1 below. The company offers a comprehensive and relevant assortment of products and services for farmers, contractors, landscapers, and gardeners, covering various categories such as bearings, filters, cylinders, belts, lighting, and more. Kramp has a network of dealers and branches across the Netherlands and other countries, providing fast delivery and expert advice to its customers.

Figure 1 Locations of Kramp Netherlands B.V.

Kramp's motto is "It's that easy", reflecting its commitment to making customers' lives easier and more productive by offering quality products, reliable service, and innovative solutions.

Kramp's mission is to be the preferred partner for agricultural professionals by providing them with everything they need to run their businesses efficiently and effectively (Kramp, 2023). Kramp's vision is to be the essential partner in parts and services in the agricultural, construction and forest & grass care industries in Europe for a futureproof and responsible supply chain (Kramp, 2023). The company's operations are guided by a set of core values, including integrity, teamwork, and customer focus, which help to ensure that it always acts with the highest level of professionalism and responsibility.

Kramp is committed to driving growth and profitability for its customers, while also minimizing its impact on the environment. By leveraging its expertise and experience, the company is able to deliver innovative solutions that help its customers operate more efficiently and effectively.

1.2. Research motivation

With a network of 10 distribution centers, and a product range of over 500,000 SKUs (of which 300,000 are on stock), Kramp is a significant player in the agricultural industry. However, Kramp's inventory management practices face several challenges. For example, the company's product range is characterized by a long tail with a low stock turn. Additionally, the long lead times (average 45 days) from supplier to Kramp often lead to stock shortages.

These inventory management challenges have been further amplified by the COVID-19 pandemic. Supply chain disruptions, accelerating demand, and dropping availability of products have led to significant fluctuations in Kramp's stock positions. During the pandemic, Kramp aimed to guarantee the availability of its products to customers. To achieve this, they continued placing orders despite the limited supply. Although delayed stock began arriving from Autumn 2021, demand significantly declined in Q4 2021 as the pandemic came to an end, and it has remained relatively low ever since.

Furthermore, supply chain data scientists have analyzed that since July 2021, the stock value, represented by the continuous line in Figure 4 below, has also experienced an increase of 58% to €290,000,000 as of April 2023. This increase can be attributed to the disruptions caused by the COVID-19 pandemic, red sea blockage, other disruptions, inflation and is closely connected to the high occupancy levels in the warehouses as previously described. However, the supply chain team has managed to reduce the stock value in May 2023 by implementing measures such as stopping certain purchase orders to limit the inflow of certain SKU(s). Despite this improvement compared to the initial measurement, the stock value indicated by the continuous line still shows a 51% increase, while the number of items in stock depicted by the dashed line has only grown by 6%.

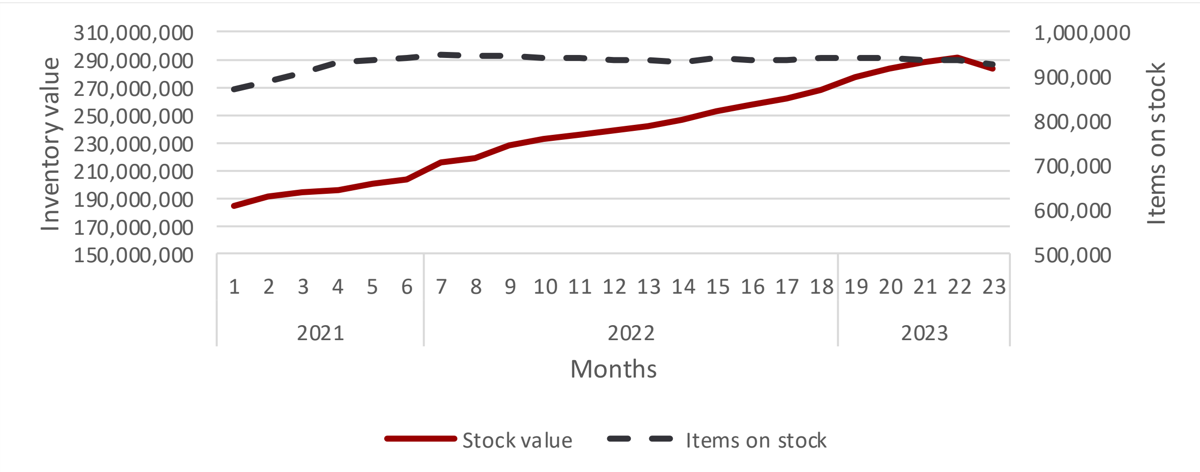

Figure 2 Items on stock and stock value starting from July 2021

This data in Figure 2 reveals that during Q4 of 2021, there was a substantial increase in the number of items in stock, which later stabilized throughout the year 2022. Despite this stabilization and a slight decrease in the number of items on stock, the stock value continued to rise.

High stock value is undesirable because it is risking capital tie-up and reduced profitability due to potential market misalignment and increased obsolescence. This indicates a need for strategic inventory management to align costs with market demand and operational efficiency.

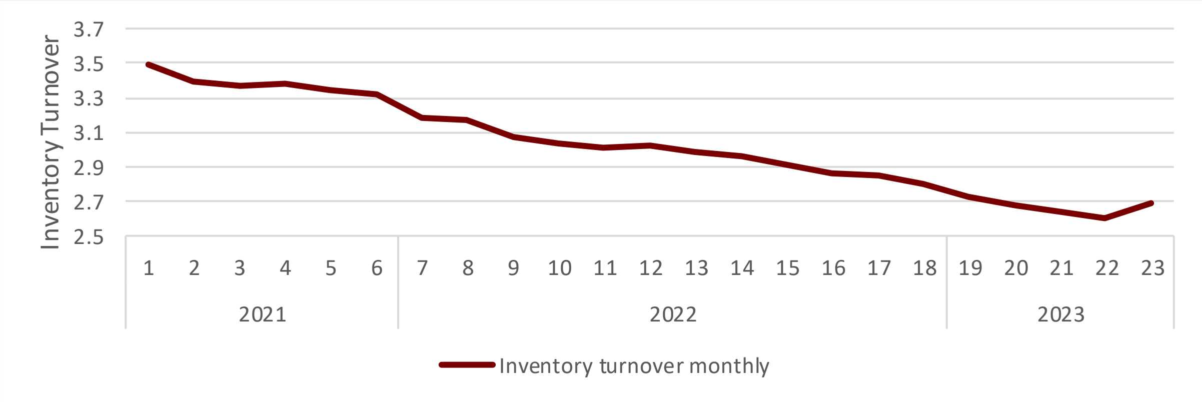

Figure 3 Stock turn yearly and monthly

Additionally, stockturn has been decreasing because of this increasing stock value. This can be seen in Figure 3 above. A greater ratio usually indicates good sales or having insufficient inventory while a lower ratio generally indicates poor sales or having too much inventory. In this case, having too much inventory plays a leading role.

1.3. Problem statement

Kramp Netherlands B.V. currently faces a significant lack of insight into their inventory health. Inventory health is the company's inventory holdings relative to expected future customer demand (Gartner, 2017). According to Kramp insight into inventory health encompasses factors such as having insight into inventory performance, main drivers of inventory levels, and the characteristics of supply and demand. This lack of visibility into these essential inventory aspects poses significant challenges for Kramp, including the inability to make informed decisions, optimize inventory levels, and promptly respond to market fluctuations. Without adequate insights into their inventory, Kramp encounters difficulties in achieving efficient inventory management.

The main area of concern for Kramp Netherlands B.V. revolves around the lack of transparency regarding their inventory healthiness. At present, Kramp only possesses knowledge of what the total inventory is. This lack of comprehensive understanding regarding inventory performance poses challenges for Kramp to effectively optimize inventory levels, allocate resources efficiently, and identify areas for improvement. Without transparency surrounding the inventory performance, the company's ability to adequate manage inventory is hindered, leading to potential imbalances, and suboptimal utilization of warehouse space.

Furthermore, Kramp faces the challenge of not being aware of the specific drivers that significantly impact their inventory. Kramp currently utilizes Slim4 as its software for forecasting, demand planning, and inventory management. Although a lot of data is present about the articles, their specific influence on inventory remains unknown as there has no research been done to it. This lack of insight hampers their ability to optimize inventory levels, prioritize efforts, and make data-driven decisions in procurement, demand planning, stock management, and supply chain management. By identifying and focusing on the main drivers of inventory and gaining transparency into performance, Kramp can enhance their inventory management strategies, improve supply chain performance, and maintain optimal inventory levels.

Overall, Kramp faces significant challenges due to the lack of transparency regarding the current inventory performance and the main drivers. Without this visibility, the company struggles to make informed decisions, improve inventory levels, and adapt to changing market conditions effectively. Addressing the inventory health is essential for improving inventory management practices, reducing costs, and maintaining a competitive edge in the agricultural industry. See Appendix A for the cluster problem.

1.4. Research goal

The research objective is to establish transparency into the inventory health at the main warehouse of Kramp, consisting of main drivers of inventory levels. The aim is to gather comprehensive insights and understanding of these key aspects of inventory health and capture these in a KPI-dashboard. In addition, improvements for the inventory will be identified during and after the development of this dashboard.

By accomplishing this research objective, the study aims to enhance transparency into inventory health, improve inventory performance, and enable data-driven decision-making within Kramp Netherlands B.V., ultimately leading to improved supply chain and inventory performance.

1.5. Research questions

The following research questions have been formulated to address the lack insight into the inventory health of Kramp Netherlands B.V.'s main distribution center in Europe. These questions aim to explore the current situation, examine relevant literature, assess the application of inventory management principles to Kramp's operations, identify causes and actions to take. Through a comprehensive investigation and analysis, this research aims to provide valuable insights and recommendations to empower Kramp in making informed decisions, reducing costs, and ensuring efficient inventory operation.

Current Situation:

1. What is the current state of inventory insight and management at the main distribution center of Kramp?

Literature:

2. What theories, factors, and metrics are commonly employed in the literature to measure and evaluate inventory health?

Demonstration:

3. How can Kramp effectively integrate inventory data and apply the theory to gain insight into inventory health?

Application:

4. What are the causes that have the most effect on Kramp’s inventory health?

Actions:

5. What potential actions can be taken to mitigate or even eliminate these causes to improve inventory health?

1.6. Scope

- Gain insights into inventory management practices within Kramp Netherlands B.V.'s supply chain, specifically focusing on the stockkeeping units (SKUs).
- A KPI-dashboard will be developed to gain more insight into the inventory health. This KPI-dashboard will contain the inventory build-up, the main drivers of the inventory. These insights are translated to actions to improve inventory performance.
- The primary focus of this study will be the main warehouse located in Varsseveld. However, the KPI-dashboard should be easily expandable to include other warehouses of Kramp.
- A new model which determines wat should happen regarding ordering will not be developed as Kramp uses Slim4 as its forecasting, demand planning and inventory management program. Besides, it has contracts with this software provider. Advice to what should be changed or added, could be given.
- Identify and analyze the main drivers influencing inventory levels for the in-stock SKUs.

1.7. Approach

This research employs a comprehensive approach that combines desk research, field research, internal data analysis, benchmarking, and interview with key stakeholders. Desk research involves reviewing existing inventory records and reports, while field research includes physical visits to validate findings. Internal data analysis utilizes historical data on inventory levels, demand patterns, and supplier performance. Statistical methods identify and quantify demand patterns, seasonality, and trends. Benchmarking against industry standards and consulting with experts provide valuable insights. Finally, this approach gives an expected outcome to each question.

1. **Current situation**

Research Question 1: What is the current state of inventory insight and management at the main distribution center of Kramp?

- Desk Research: Conduct an extensive review of internal reports, inventory management systems, and relevant documentation to gather existing data on inventory levels, stock turnover rates, and used parameters.
- Interviews: Conduct interviews with stock managers, to gather qualitative data on inventory challenges, known parameters, strategies, bottlenecks, and issues faced.
- Expected Outcome: A comprehensive understanding of the current state of inventory and inventory management, combining quantitative and qualitative data, to identify key areas of improvement and validate findings through interviews.

2. Literature

Research Question 2: What theories, factors, and metrics are commonly employed in the literature to measure and evaluate inventory health?

- Literature Review: Conduct an in-depth review of academic and industry literature to identify the key factors and metrics commonly used to assess inventory health. Explore existing inventory management theories, models, and frameworks that address transparency and optimization of inventory levels.
- Desk Research: Collect relevant articles, books, and research papers that discuss inventory health and metrics in the context of similar industries or supply chains. Identify and study theories to understand their potential applicability to Kramp's inventory management.
- Expected Outcome: A compilation of the key factors and metrics used in the literature to assess inventory health, providing a foundation for evaluating and improving Kramp's inventory management practices. A comprehensive understanding of inventory management theories that can provide insights and guidance for improving transparency and optimizing inventory levels within Kramp.

3. Application

Research Question 3: How can Kramp effectively integrate inventory data and apply the theory to gain insight into inventory health?

- Data Integration: Develop a strategy to standardize and integrate inventory data, ensuring compatibility and consistency.
- Data Analysis: Analyze the collected data and compare it with the identified inventory management theories to identify gaps and improvement opportunities.
- Expected outcome: The establishment of a robust dashboard for monitoring and evaluating inventory performance within Kramp's supply chain. This framework will utilize key performance indicators (KPIs) and industry benchmarks to assess the effectiveness of inventory management practices and identify areas for improvement.

4. Causes & Actions

Research Question 4: What are the causes that have the most effect on Kramp's inventory health?
Research Question 5: What potential actions can be taken to mitigate or even eliminate these causes to improve inventory health?

- Data Analysis: Analyze the found data to identify causes, actions and savings.
- Quantitative Assessment: Develop financial insights to estimate potential cost savings by implementing improved inventory transparency and optimization strategies.
- Expected Outcome: A quantitative assessment of the potential causes and actions that can be achieved by enhancing inventory health, providing valuable insights for decision-making and resource allocation.

2. Current situation at Kramp

This chapter focuses on investigating the key aspects related to inventory insight practices and management strategies employed at the main distribution center. It aims to provide a comprehensive analysis of the existing systems and processes in place, shedding light on the level of visibility and transparency into inventory data and the effectiveness of inventory management. By examining these critical areas, valuable insights can be gained to assess the strengths, weaknesses, and opportunities for improvement.

Through a combination of data analysis and interviews with key stakeholders, this chapter seeks to provide a detailed assessment of the current state of inventory insight and management. The findings from this investigation will serve as a foundation for identifying potential areas of enhancement and formulating recommendations to optimize inventory operations.

2.1. Visibility of inventory

The current visibility into the inventory can be described on inventory control software and dashboard level.

2.1.1. Slim4

Kramp currently utilizes Slim4 as its forecasting, demand planning and inventory management system. The software extracts information from the ERP system and calculates the required parameters for the forecast and inventory. This is mainly used by the stock controllers to make orders at the supplier.

The effectiveness of Slim4 lies in its ability to leverage a diverse range of data to determine optimal forecasting and inventory parameters. These parameters, on item-level, are derived through a combination of automated calculation performed by the software itself and user-defined inputs.

Furthermore, Slim4 incorporates a feature that generates exceptions for the user when inventory levels surpass predefined thresholds. These exceptions are designed to enable swift action by the stock controller in case a particular item is not meeting its expected performance. Slim4 has established a set of exceptions specifically for inventory management. Each exception with its description can be found in Appendix B.

2.1.2. Available dashboards regarding inventory management

Kramp utilizes Google Bit Query (GBQ), Structured Query Language (SQL) and Tableau to generate reports that are updated on different timeframes. The goal of these reports is to get an insight into the development of processes, inventory, financials and more. Kramp currently relies on the following data sources regarding inventory:

Stock value comparison (vs year before)

This dashboard keeps track of the stock value for each warehouse and compares it to the value the year before. It shows the difference between those 2 years, in absolute values and percentages.

Stock management utilizes this comparison to assess the performance of their stock in relation to the previous year. Currently no action is taken, if this year's pattern displays greater divergence than the previous year. This dashboard can filter it on a specific warehouse in combination with class 2 (product category). While this can give a quick glance into its trend compared to the year before, this metric fails to give insight into which product groups or article contribute the most to this value.

Stock value

This dashboard keeps track of the stock value in combination with the unique items on stock. Supply chain management relies on this dashboard to evaluate the performance of their stock while considering the quantity of items in stock. Users can apply filters not only based on warehouse and class 2 but also on additional parameters such as Supplier, ABC-code, double ABC-code, class3 (product group), class4 (article group), product managers, and if it is non-stocked.

By leveraging these filters, users can take more targeted actions towards specific product or article groups. Currently, this only serves as a driving force for making a decision according to the supply chain planning manager, regardless of the type of decision. It's important to note that while these filters can reduce the quantity of items, such as those in the range of 190,000-200,000 items within warehouse 300-, down to few ones, tens or hundreds, the displayed information only represents aggregated stock values. Unfortunately, the dashboard does not provide insights into whether the stock level / stock value is appropriate for the specific product or article group.

In summary, this more advanced dashboard equips supply chain management with the tools to assess stock performance and item quantity, facilitating more focused decisions on specific product or article groups. However, it falls short in providing information about the adequacy of the stock level or the underlying causes for the observed stock quantities and stock values.

Stock turn

This dashboard serves as a tool for swiftly gaining insights into inventory performance. Additionally, it prompts action if performance falls below expectations, though it doesn't specify the nature of that action.

While stock turnover is a commonly employed Key Performance Indicator (KPI) to evaluate inventory performance, its limitations must be acknowledged. Stock turnover primarily reveals whether sales have decreased, or inventory levels have increased (when the stock turnover ratio goes down), or if sales have increased and inventory levels have decreased (when the stock turnover ratio goes up). However, stock turnover alone does not provide a comprehensive understanding of the underlying factors driving these changes or the broader dynamics of inventory management.

Clean-up overstock

Introducing the latest dashboard, designed to empower stock management and product management teams at Kramp to take measures regarding overstock. This comprehensive tool offers various actions to address the situation, including stock transfers, listing on Kramp's marketplace, selling to the most recent customer, returning to the supplier, or initiating the scrapping process.

While this dashboard provides valuable insights into the number of overstocked SKU items and their corresponding value, it has two notable limitations. Firstly, it lacks visibility into potential stock shortages for specific SKUs. Finally, the overstocking rules are simple. For example, dead stock is defined by having it not sold in the past 24 months. This doesn't show whether Kramp has too much of a certain SKU or group of items, while it is still selling frequently. The other overstocking types and actions related to this dashboard can be found in Appendix C.

Moreover, similar to previous dashboards, the values displayed are aggregated into groups. This means that when applying filters such as warehouse, ABC-code, overstock type, warehouse area, location type, and stock status, the aggregated values can be narrowed down to a few items, tens, or hundreds, but not down to the level of individual SKUs. Consequently, the dashboard's focus remains primarily on taking actionable steps to address existing or potential overstock situations on an aggregated level.

Overview

The aforementioned metrics offer a concise overview of inventory performance, offering a snapshot of its overall effectiveness. However, they fall short in providing insights into the underlying factors that impact these values or offering a comprehensive understanding of the inventory itself. This lack of visibility poses challenges in identifying optimal parameters and appropriate range of stock levels, requiring additional time and effort to address these effectively.

As it stands, the supply chain at Kramp utilizes these dashboards to drive decision-making based on insights into stock value. However, a limitation of these dashboards is their inability to provide any specific insights into the type of decision that needs to be made. A decision could be to scrap a certain product, start a promotion, stop purchase orders or change supplier. However, without having a deeper visibility into the contributing factors that influence the stock value, there is a risk of making suboptimal decisions.

Although other KPIs may be available, such as days of coverage, lost-sales ratio or stock-out rate, they are not currently being utilized according to the supply chain planning manager. This suggests a missed opportunity to leverage additional metrics that could provide valuable insights into the overall performance of the inventory and aid in making more informed decisions.

By neglecting to consider these untapped sources of information, the supply chain planning manager may be limiting their ability to optimize inventory management and make strategic choices based on a comprehensive understanding of the underlying factors impacting inventory.

2.2. Inventory Management

In addition to the metrics mentioned earlier, Kramp's inventory management involves close collaboration among three key departments: Stock Management, Product Management, and Supply Chain Management. Each department carries specific responsibilities related to the inventory.

As of writing this study, Stock Management is primarily responsible for direct engagement with Slim4, which includes monitoring parameters and placing orders with suppliers. Product Management, on the other hand, focuses on the creation and scrapping of products. As for Supply Chain Management, it is a relatively new department that has assumed additional responsibilities in inventory management, such as scrapping of products.

Despite the interdependence of these departments, there is currently no comprehensive report or system in place to facilitate collaborative work on the management of inventory. As an example, product management is responsible for scrapping products when they do not sell anymore. According to them, they get a signal from stock management that a certain product is not selling anymore. They receive this signal mainly when this product already has not been sold for 24 months, which means it is dead stock. The change from mature to declining phase (from the product life cycle) is currently very hard to detect for product management and therefore they can't take proactive action to, for example, do a promotion on that product.

To elaborate on that, the product management project manager acknowledges the challenge of gaining a holistic view of inventory status at a higher level within Kramp. Consequently, they heavily rely on Stock Management to help identify items that are no longer selling. However, Stock Management finds it time-consuming to identify declining stock on an individual item level. Consequently, items stay on stock while they don't sell anymore.

2.3. Conclusion

In this paragraph, the research question "*What is the current state of inventory insight and management at the main distribution center of Kramp?*" is answered.

To make informed decisions for inventory at supply chain, it is crucial to have access and insight into certain parameters that influence the inventory. At stock control, the Slim4 system is effectively utilized for forecasting, demand planning, and inventory management, providing visibility into various parameters and items that impact inventory. Despite the abundance of data available within the Slim4 environment, the utilization of this data at the supply chain is currently lacking regarding inventory performance. Although a few stock value, stock turn and overstock tracking dashboards exist, which can filter down to product group and article group, a comprehensive inventory health dashboard is not present. This limitation hampers inventory management at other departments than stock control.

Currently, at Kramp, decisions lack dedicated support through a centralized dashboard. However, by gaining insights into the healthiness of their articles, the decision-making process could be substantially improved. A well-designed dashboard would empower inventory managers to evaluate the current inventory status, pinpoint potential risks or opportunities, and make informed decisions regarding appropriate stock levels, resource allocation, and potential actions.

Kramp's inventory management relies on the collaboration of Stock Management, Product Management, and Supply Chain Management. However, the lack of a comprehensive dashboard hampers efficient teamwork. Streamlining processes and implementing a unified inventory visibility could enhance inventory management efficiency and decision-making.

3. Literature review

The literature review chapter serves as a comprehensive examination of the existing body of knowledge and research related to inventory management, transparency, and health. This chapter aims to explore and synthesize relevant academic and industry literature, providing a foundation for understanding the key concepts and theories.

The literature review is an essential component of this research as it enables a deeper understanding of the challenges, trends, and advancements in inventory management.

3.1. Inventory performance measurements

Inventory performance measurements are vital tools used by businesses to assess and evaluate the efficiency and effectiveness of their inventory management processes. The implementation of robust inventory performance measurements enables businesses to make data-driven decisions and achieve improved inventory control and profitability.

3.1.1. Inventory Quality Ratio (IQR)

The Inventory Quality Ratio (IQR) is a method used to analyze and optimize inventory within a business (Pukkila, 2019). It calculates the ratio of active inventory to total inventory, categorizing inventory into "active" and "excess" segments. IQR enables inventory managers to conduct regular evaluations of inventory practices, including lead times, safety stocks, and order quantities (Martin, 2016; Pukkila & Lord, 2015). It is particularly useful for identifying and addressing slow-moving inventory by either stimulating its movement or eliminating it, thereby improving inventory performance and metrics (Empowering CPO, 2023; Pukkila & Lord, 2015).

The IQR metric assesses inventory value against future demand, making it applicable across various inventory types by normalizing differences between high-value/low-volume and low-value/high-volume items (Howardell, 2010). This approach allows for focused improvements in specific inventory areas (Pukkila & Lord, 2015). As a KPI, IQR answers the critical question of how well inventory aligns with projected demand and lead times. A 50% IQR value indicates that half of the inventory investment is well-aligned with needs, while the remainder could be excess or slow-moving stock (Pukkila & Lord, 2015; Smartlog, 2017). This provides crucial insights into inventory specifics concerning future demand, while simultaneously offering a consolidated and comprehensive metric that assesses the overall health of a company's inventories across all organizational levels (Howardell, 2010).

Although there are no established benchmarks for IQR, it remains an essential tool for evaluating inventory management effectiveness (Smartlog, 2017). It provides a concise assessment of how effectively inventory meets demand and identifies areas requiring optimization or corrective actions to enhance overall inventory performance (Pukkila & Lord, 2015; Howardell, 2010).

IQR Data

To calculate the IQR, the following information is required to be available at SKU level (Pukkila & Lord, 2015):

- *Safety stock:* To determine the Minimum Days of Coverage, which will be discussed later, the safety stock is used. This should be extracted from existing inventory system present or calculated. The method for calculating this value is explained in the subsequent section.

- *Lot size*: To determine the Maximum Days of Coverage the lot size with safety stock is used. The lot size, which is the amount of inventory that needs to be ordered, is expressed in either the Economic Order Size (EOQ) or Minimum Order Quantity (MOQ). The EOQ should be extracted from the inventory system or calculated, while the MOQ can only be extracted. The method for calculating the EOQ is explained in the subsequent section.
- *Total on-hand inventory units:* Total on-hand inventory in unit volume, expressed in the unit of measure that corresponds with the standard cost unit of measure. This value can be aggregated over various time-windows, spanning from a single day to several months. In addition it can be aggregated over multiple SKUs, varying from single to company level.
- *Standard cost per unit:* The inventory cost of a unit per standard unit of measure. This is optional if the total inventory value is available because the unit cost can be calculated from the total inventory value for the SKU at the given location. When reporting the IQR across locations in multiple countries, the inventory valuation has to be done in common currency.
- *Forecast horizon in days:* The time period that covers the forecast demand volume. For example, if the forecast is 300 units per quarter, then the forecast horizon is 90 days. This is used in the calculation of the IQR in the succeeding section.
- *Demand forecast in units:* The forecast total SKU/location demand volume over the chosen forecast horizon. This is expressed in the unit of measure that corresponds with the standard cost unit. This is used in calculating the daily run rate, which will be discussed later.

Minimum and maximum inventory threshold.

The minimum inventory levels can be determined in multiple ways. There are four possible scenarios to consider in setting these levels (Pukkila & Lord, 2015):

- Contractual inventory obligations: These are the agreed upon inventory levels. These are the easiest to apply.
- Defined safety stock levels as expressed in unit volumes in the materials planning systems.
- No expectation to hold any inventory of the items. A zero-inventory goal.
- Products that require some level of inventory buffer. However, they do not have anything currently set in the planning and/or materials management systems. With safety stock calculated as multiplying the safety factor (Z) with the standard deviation of the demand ($Stdev(D)$), which is finally multiplied with the square root of review time (r) and lead time (L) combined. See Equation (1).

$$Safety\ stock = Z * Stdev(D) * \sqrt{(r + L)} \qquad (1)$$

While the inventory level may occasionally fall below the safety stock (as it serves as a buffer for deviations in lead time), it is still a valuable threshold for assessing inventory health. If measurements over time consistently show that the stock is not above the safety stock level, it could be an indication of an issue. One potential issue could be that the supplier is unable to deliver this item anymore. When evaluated over quarters or years, the stock should generally be maintained above this minimum threshold.

In inventory management, service level is the expected probability of not hitting a stock-out during the next replenishment cycle or the probability of not losing sales (Constantin, 2016). Higher service levels increase the safety stock service level multiplier (Z in Figure 4 below and Formula 1 above) exponentially (Slimstock, 2023), which increases inventory levels.

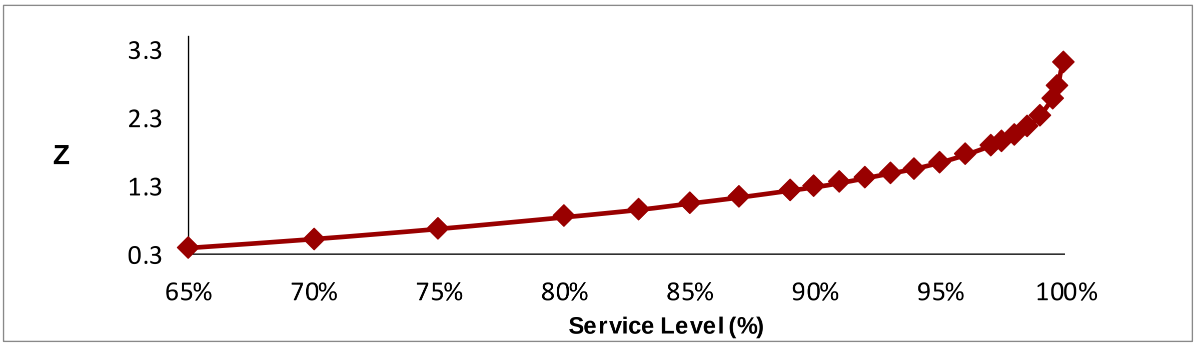

Figure 4 Service level factor (Z), for safety stock calculation, based on the service level (Gartner, 2021).

Once the minimum inventory levels have been determined, the maximum ends of the ranges have to be assigned. The maximum depends on the inventory policy that is applied.

(s,Q) & (R,s,Q) policy

This inventory policy follows a periodic review system where the inventory position is examined at regular intervals, typically occurring every R time units (for (s, Q) policy a R of 1 day is used). If, during this review, it is found that the inventory position has fallen below a predetermined level s, then an order is placed. This order is for a quantity that is usually a fixed size Q, which ensures that the inventory position is replenished to a level between s and $s + Q$ for SKU i (Fred Janssen, 1997). See Equation (2).

$$InventoryMax_i = s_i + Q_i \tag{2}$$

An important observation is the preference for selecting the maximum inventory position over choosing the maximum inventory, which includes the safety stock with the ordered quantity. This decision is influenced by the variability in sales, where sometimes sales may be slightly below expectations, leaving a residual inventory if looked at safety stock with lot size. Opting for the maximum inventory position as maximum inventory provides a buffer. This approach adds a margin of safety to avoid categorizing the remaining inventory as excessively high, recognizing potential variations in demand. Anything beyond that is definitely deemed as excessive.

The lot size is established through the Economic Order Quantity (Q^*) or a specified variable lot size, like the Minimum Order Quantity. The EOQ is calculated by taking into account factors such as annual demand (D), order costs (C), and holding costs (H). The primary objective of the EOQ is to determine the optimal order quantity that minimizes total inventory costs, encompassing both ordering and holding costs. See Equation (3).

$$InventoryMax_i = s_i + Q_i = s_i + \sqrt{\frac{2 * D_i * C_i}{H_i}} \tag{3}$$

The lot size, based on the EOQ, remains in use unless the Minimum Order Quantity (MOQ) exceeds the EOQ. In such cases, the MOQ is chosen as the order quantity.

Minimum and maximum days of coverage.

Once the max and min values have been computed, they need to be converted to days of coverage. The maximum and minimum days of coverage are determined by dividing the calculated inventory minimum and maximum of the SKU i, by the demand forecast for the selected time span t and then multiplying it by the forecast horizon of time span t. See Equation (4) and Equation (5).

$$Min\ DoC_{i,t} = \frac{Safety\ stock_{i,t} * Unit\ Price_{i,t}}{Forecast\ Value\ Over\ Horizon_{i,t}} * Forecast\ horizon\ in\ days \qquad (4)$$

$$Max\ DoC_{i,t} = \frac{InventoryMax_{i,t} * Unit\ Price_{i,t}}{Forecast\ Value\ Over\ Horizon_{i,t}} * Forecast\ horizon\ in\ days \qquad (5)$$

When looking at longer time periods, such as quarters and years, different thresholds should be used. Because if looking at these timeframes, inventory averages more out, as to where highs and lows diminish. Therefore tighter thresholds could be used, because these current thresholds would mean a higher IQR.

IQR Calculation.

When all information is available and the maximum and minimum days of coverage are determined, the calculation of the IQR can start. The Total Inventory Value (TIV) of a SKU i is calculated by summing the average on-hand inventory units ($OHIU$) over a defined time period t and then multiplying this total by the average standard cost per unit (UP) during that same period, see Equation (6). The choice of the time period t – whether daily, weekly, monthly, or yearly – is determined by data availability. In cases where no data is available initially, it is advisable to begin with daily measurements and later extend to longer periods as more data becomes accessible.

$$TIV_{i,t} = AVG(OHIU_{i,t}) * AVG(UP_{i,t}) \qquad (6)$$

Next, the Days of Coverage of SKU i can be calculated by taking the TIV and dividing it by the forecasted value of SKU i over period t. See Equation (7).

$$DoC_{i,t} = \frac{TIV_{i,t}}{Forecast\ Value\ over\ Horizon_{i,t}} * Forecast\ horizon\ in\ days \qquad (7)$$

Following that, a calculation involves determining the amount of Active Inventory Units (AIU), which refers to the portion of inventory that falls at or below the maximum coverage level, see Equation (8). Therefore, the lowest value between the actual Days of Coverage or the Maximum Days of Coverage is chosen and multiplied.

$$AIU_{i,t} = \frac{MIN\left[DoC_{i,t}, MaxDoC_{i,t}\right]}{Forecast\ over\ Horizon_{i,t}} * Forecast\ horizon\ in\ days \qquad (8)$$

Following this, the active inventory value (AIV) is calculated, see Equation (9). This value becomes the dividend in the IQR division. The same rules apply as for the AIU but this time, the forecast value is taken instead of the forecast in units.

$$AIV_{i,t} = \frac{MIN[DoC_{i,t}, MaxDoC_{i,t}]}{Forecast\ Value\ over\ Horizon_{i,t}} * Forecast\ horizon\ in\ days \tag{9}$$

With the AIU and AIV known, the Excess Inventory Units (EIU) and Value (EIV) can be determined. The EIU: Unit volume of inventory that exceeds the active portion. So, by extracting the AIU of the Total Inventory Units (TIU), the excess can be calculated. See Equation (10).

$$EIU_{i,t} = TIU_{i,t} - AIU_{i,t} \tag{10}$$

The Excess Inventory Value (EIV) is determined the same way, but then the inventory value instead of units is used. See Equation (13).

$$EIV_{i,t} = TIV_{i,t} - AIV_{i,t} \tag{11}$$

Finally, the Inventory Quality Ratio (IQR) can be determined, see Equation (12). The IQR: The ratio of active inventory value to the Total Inventory Value (TIV). The TIV is the same value as determined in Equation (6). This reporting can be done at any product hierarchy (i) and time frame (t), ranging from a single SKU to corporate level and daily to yearly.

$$IQR_{i,t} = 100\% * \frac{\sum_{i,t} AIV_{i,t}}{\sum_{i,t} TIV_{i,t}} \tag{12}$$

3.1.2. Inventory Control Index (ICI)

Inventory health evaluation is an assessment of a company's inventory holdings relative to expected future customer demand according to service-level expectations (Gartner, 2017). In addition to the Inventory Quality Ratio, the Inventory Control Index can be calculated. The same data is used, except Formula 6, Minimum Days of Coverage, now comes in to use.

ICI Calculation.

Initially, the detailed calculation procedures for the Inventory Quality Ratio (IQR) are omitted, as these mirror the methods already utilized.

Healthy stock pass/fail: This is an indicator that flags an SKU i as being healthy or not healthy based on the inventory level relative to the minimum and maximum target levels over time period t. If the inventory is between the two (i.e., in the "healthy zone"), the flag is set to 1. When the inventory level is outside the zone, either high (excess) or low (shortage), the flag is set to 0. See Formula (13) below.

$$\begin{gathered} If\ DoC_{i,t}\ in\ Range[Min\ DoC_{i,t}, Max\ DoC_{i,t}], then\ S_{i,t} = 1 \\ Else, then\ S_{i,t} = 0 \end{gathered} \tag{13}$$

Healthy stock metric across a group of SKUs: This calculation establishes a metric for the healthy stock concept. It computes a percentage of products in the healthy stock zone in a population of inventory items (N). The values will range between 0% (none in the healthy zone) and 100% (all SKUs in the healthy zone). The reporting this time starts on group level and can be done until corporate level, denoted as (G). This can also be aggregated to daily, weekly, monthly or yearly values, denoted as (t). See Formula (14) below.

$$ICI_{G,t} = 100\% * \frac{\sum_{i \in G} S_{i,t}}{N_{G,t}} \quad (14)$$

With the initial identification done, a deeper systematic approach is needed to identify the main drivers to unhealthy inventory, which finally should help form appropriate actions. This systematic approach utilizes the Multi Criteria Decision Analysis (MCDA) to help initially find the worst performing inventory.

3.1.3. MCDA analysis

MCDA, or Multi-Criteria Decision Analysis, is a decision-making approach designed to systematically evaluate and compare alternatives by considering multiple criteria. Its goal is to provide a structured framework for decision-makers to make informed choices, taking into account diverse factors and preferences in complex decision scenarios (Mendoza & Martins, 2006). The criteria in this research will be the KPIs on what inventory should be scored on.

The evaluation of SKUs using KPIs includes a scoring system that benchmarks each SKU's performance between the dataset's best and worst outcomes. Scores range from 0 to 1, with 1 representing the highest performance level, see Equation (15). This scoring is achieved by comparing the performance of each SKU across various KPIs with the dataset's extremes, favoring metrics like zero excess value as ideal. This approach helps in understanding the relative performance of SKUs and supports enhancements in inventory management. Although extreme values can affect scores, the overall ranking of SKUs is not impacted.

$$Interpolated\ Score_i^x = \frac{(Actual_x^i - Worst_x)}{(Best_x - Worst_x)}\ for\ x = KPI, \forall i \quad (15)$$

This score per KPI needs to be multiplied with a weight to create the performance score, depending on the priority of Kramp on that KPI. The method to gather weights is discussed in subsequent section.

Determining weights with Analytical Hierarchy Process (AHP)

The weights for the MCDA are determined by using the Analytical Hierarchy Process (AHP) method developed by Saaty in the 80s (Godwin, 2019). During the pair-wise comparison, a matrix is created based on the number of KPIs. Stakeholders assign scores, typically using values like (1,3,5,7,9), based on their perception of the importance of KPI x in relation to KPI y. Higher scores signify greater significance for KPI x compared to KPI y. So, if KPI i receives a score of 3, then the compared KPI y would receive the reciprocal score of 1/3, see Equation (16). In cases where the same KPIs are compared, a score of 1 is assigned, as they cannot be considered more or less important relative to themselves, see Equation (17).

$$a_{yx} = \frac{1}{a_{xy}}, \qquad for\ x \neq y \quad (16)$$

$$a_{xy} = a_{yx} = 1, \qquad for\ x = y \quad (17)$$

The filled matrices from the input of multiple stakeholders are averaged to create a consensus matrix. From this matrix a normalized matrix is calculated by dividing each element a_{xy} in column y by the column sum S_y, see Equation (18).

$$n_{xy} = \frac{a_{xy}}{S_y} \quad (18)$$

Finally these normalized values n_{xy} are summed for each row i, creating value S_x. That value is divided by the N amount of KPIs assessed, see Equation (19). The resulting values represent the final weights for each KPI, serving as the weights for MCDA analysis.

$$W_x = \frac{S_x}{N} \quad (19)$$

To check the consistency of the input, a consistency ratio (CR) is calculated. CR servers as a critical checkpoint in the AHP process to ensure that the decision-making is based on consistent and logical evaluations, enhancing the reliability and credibility of the results. In the theory, if the CR falls within the acceptable range of less than or equal to 0.1, then the assessments are deemed sufficiently consistent. If not below or equal to 0.1, then the pair-wise comparison should be revisited and adjusted to obtain the desired ratio of less than or equal to 0.1. Another option could be to exclude certain inputs if deemed to inconsistent with the other inputs.

To calculate the CR, the Consistency Index (CI) is divided by the Random Index (RI), see Equation (20).

$$CR = \frac{CI}{RI} \quad (20)$$

To obtain the CI and RI and calculate the CR, the following steps are followed.

1. Start by multiplying each element in column y of the pairwise comparison matrix by the corresponding weights found in Equation (19). So each element in column 1, which is KPI 1, is multiplied by the weight obtained for KPI 1. This step adjusts each comparison in the matrix based on the relative weights of the criteria.
2. Sum the adjusted values for each row of the matrix to get a set of row sums. These row sums represent the aggregated comparisons for each criterion, weighted by their importance.
3. For each criterion, divide its row sum obtained in the previous step by its weight to calculate the weighted sum. These weighted sums reflect the agreement of the priority vector with the pairwise comparisons.
4. Calculate the principal eigenvalue, denoted as λ_{Max}, by averaging all the weighted sums. The principal eigenvalue is an indicator of the pairwise comparisons' consistency.
5. Compute the Consistency Index (CI) using Equation (21) below. The CI measures the consistency of the pairwise comparisons, with lower values indicating a higher level of consistency. In this case N is the number of KPIs.

$$CI = \frac{(\lambda_{Max} - N)}{(N - 1)} \quad (21)$$

6. Next the Random Index (RI) is obtained by the size of the matrix, which is also the amount of KPIs (Saaty, 1980). The RI is a value that reflects the average consistency index of a large number of randomly generated reciprocal matrices. The RI's can be found in Table 1.

Table 1 Random index (RI) per N KPIs (Saaty, 1980).

N	RI	N	RI
1	0.00	**9**	1.45
2	0.00	**10**	1.49
3	0.58	**11**	1.51
4	0.90	**12**	1.54
5	1.12	**13**	1.56
6	1.24	**14**	1.57
7	1.32	**15**	1.59
8	1.41		

Calculating performance

The final step involves calculating the performance score of each SKU by integrating the weights derived through the AHP with their corresponding interpolated scores for each KPI. This is achieved by multiplying the AHP-derived weights with the interpolated score for KPI x of SKU i, as outlined in Equation (22). This calculated performance score is pivotal in ranking the SKUs, enabling the identification of the overall worst-performing SKUs. By determining the SKUs with the lowest performance scores, it becomes easier to pinpoint the primary drivers contributing to unhealthy inventory levels.

$$Performance_i = \sum_x W_x * Interpolated_x^i \quad \forall i \tag{22}$$

3.2. Conclusion

In this chapter the question "*What theories, factors, and metrics are commonly employed in the literature to measure and evaluate inventory health?*" is answered.

With the introduction of the Inventory Quality Ratio (IQR), see equation (12), Kramp can overcome its limitation of not having any insight into inventory performance and gain a more proactive approach to inventory management. The IQR measures the ratio of inventory value that is deemed healthy.

By employing the Inventory Control Index (ICI), see equation (14), Kramp gains valuable insights into the health of its SKUs. This approach allows Kramp not only to identify SKUs that are in excess but also to detect potential shortages. The ICI measures that ratio of SKUs within the healthy range.

Although these metrics provide valuable insights into the performance of the inventory, they alone are not sufficient to meet Kramp's comprehensive needs for inventory insights. In addition to these metrics, Kramp requires a more detailed understanding of main drivers of unhealthy inventory, and formulating appropriate actions. As a result, there is systematic approach that could help by utilizing Multi Criteria Decision Analysis (MCDA), with Analytical Hierarchy Process (AHP) for determining the weights.

4. Demonstration

This chapter delves into the methodologies for analyzing Kramp's inventory health, detailing parameter selection and providing an example to illustrate the approach. It focuses on two key performance indicators (KPIs): the Inventory Quality Ratio (IQR), which assesses the value of acceptable inventory against the total, and the Inventory Control Index (ICI), which checks if an SKU is within the set thresholds. These KPIs, tailored specifically for Kramp and elaborated upon in this chapter, target a 95% achievement rate. Initially, without complete historical data from Slim4, monitoring is set on a daily and monthly basis, with plans to extend to longer periods as data grows. The chapter also introduces a scoring method based on Multicriteria Decision Analysis (MCDA) to identify key factors affecting inventory health and pinpoint underperforming articles, thereby being an initial step into improving the IQR and ICI.

4.1. Information

The subsequent section delves into the information that presets the criteria for evaluating specific items to ascertain their health status. When all information is discussed, a step-by-step calculation is performed, where a pre-selected article is shown and discussed.

4.1.1. Status “non-Stocked” vs “Stocked” articles

Kramp allows for articles to be configured with specific settings regarding whether they should be held in stock or not. It's important to clarify that not all non-stocked items in current inventory should be automatically considered as excess. This is because backorders and the required order level can sometimes lead to non-stocked items temporarily coming into stock in the warehouse. As a result, for non-stocked items, the stock position should precisely align with the order level, see Equation (23). Any surplus of non-stocked articles beyond this point is then classified as Excess Inventory Value (EIV).

$$EIV_{i,t}^{non-stocked} = MAX\{IP_{i,t} - s_{i,t}, 0\} * UP_{i,t} \tag{23}$$

Stocked articles within Slim4 follow the same path as the (R,s,Q) inventory policy. Under this policy, the maximum inventory level is determined as the order level plus the quantity to order, see Equation (3). Any stock exceeding this maximum is classified as excess.

4.1.2. Exclude product, article groups and demand class.

This analysis omits several product and article groups due to their unique characteristics. The "00 Generic" product group, which equates man hours with inventory units for service-based invoicing, is excluded since these service hours, while not physically held, are counted as available stock in Slim4. Products labeled "Killed" are also omitted, as they are inactive but still listed in the ERP system and Slim4. The category “988 Excluded From Item Turnover,” encompassing only a few products with specific uses, is not considered relevant to this research.

Additionally, specific article groups are excluded, including items for internal use, non-physical entities, customer-specific products, medical supplies, assembly tools, documents, and promotional materials. These items pose challenges for quantity assessment due to insufficient registration, their non-physical nature, or their inapplicability to inventory health evaluation.

SKUs in the 'New' demand class, active for less than four months at Kramp and lacking sufficient performance data, are also excluded. After four months, these SKUs are reclassified by Slim4 into other demand classes, where they become eligible for inventory health assessment. Excluding the mentioned SKUs results in about 68k SKUs being omitted from the initial 341k, leaving approximately 273k SKUs for analysis. . A description of other demand classes can be found in Appendix D.

4.1.3. Assessment periods & thresholds

This study utilizes day and month assessments for inventory evaluation, limited by the absence of historical forecast data for distributions to other warehouses, which impedes accurate excess inventory calculations. As more data becomes available, the scope of assessments may expand to include quarterly or yearly analyses. Current days of coverage thresholds are established based on an annual forecast, chosen to simplify the initial analysis of inventory health at Kramp. Shorter periods will offer more accurate thresholds for SKUs with unstable demand, but consequently more inventory needs to be removed, if for example, a lower demand period is active.

For extended periods, tighter thresholds will be set to reflect inventory averaging effects. This involves analyzing average inventory for specific SKUs or groups, testing different deviations, and validating these through expert consultations to align with operational requirements.

4.1.4. Article performance scoring

A performance scoring system is introduced to pinpoint the SKUs exhibiting the weakest performance. Identifying these underperforming articles facilitates the discovery of root causes significantly affecting Kramp's inventory efficiency. To assist in isolating these SKUs, new KPIs have been established, in addition to the Excess Inventory Value (EIV) metric from the IQR.

Expected Inventory Turnover (EIT)

Low inventory turnover indicates either excessive inventory or insufficient sales. This analysis deviates from the traditional inventory turnover calculation by considering the forecast for the upcoming year rather than actual sales from the previous year, aligning the turnover metric with the forecast-based EIV. The Expected Inventory Turnover (EIT) is calculated by dividing the average forecasted units for SKU i in time period t. It is critical to note that the forecast period for the average forecasted units is projected 12 months ahead of the inventory assessment period, which is measured on a daily or monthly basis. See Equation (24) for the calculation.

$$EIT_{i,t} = \frac{Average\ Forecasted\ Units_{i,t=12\ Months}}{Average\ Inventory_{i,t}} \quad (24)$$

A critically low inventory turnover signifies a significant misalignment of inventory with the forecast for the upcoming year. While some might argue that an excessively high inventory turnover is not ideal either, it could be viewed more as an opportunity rather than a threat to inventory health.

Shortage Inventory Value

In addition to the theory, where active inventory value and excess inventory value are discussed extensively in the theoretical chapter, this study also addresses a shortage inventory value (SIV). This study defines unhealthy inventory value as value that is in excess and in shortage.

The shortage inventory value is determined by checking average forecast during the lead time (FL) is larger than the average inventory position (IP) for SKU i in assessed time-period t, See Equation (25). When the item is ordered according to the lead time setup, a stock-out is very likely to occur.

$$SIV_{i,t} = MAX\{FL_{i,t} - IP_{i,t}, 0\} * UP_{i,t} \tag{25}$$

By adding these additional KPIs to the article performance scoring, SKUs that perform worse can be determined even better.

MCDA analysis

In this study, the goal of the MCDA-analysis is to gather the worst performing SKUs on a set of three KPIs.

1. Excess Inventory Value (EIV) – The amount of average excess value measured during the assessment period t of SKU i.
2. Shortage Inventory Value (SIV) – The amount of average shortage value measured during the assessment period t of SKU i.
3. Expected Inventory Turnover (EIT) – The calculated inventory turnover based on the average forecast during the assessment period t of SKU i.

To initiate the MCDA, the first step involves collecting the best and worst value of all SKUs for each measured KPI over the assessed time-period. The determination of these values as 'best' or 'worst' hinges on whether the KPI's objective is minimization or maximization. For instance, in the case of Excess Inventory Value (EIV) and Shortage Inventory Value (SIV), the aim is to minimize these KPIs (so have zero value), whereas for Excess Inventory Turnover (EIT), maximization is desired. Next, each KPI value of that specific SKU i is assessed with this best and worst value of all SKUs within that KPI to get the interpolated score. See Equation (26).

$$Interpolated\ Score_x^i = \frac{(Actual_x^i - Worst_x)}{(Best_x - Worst_x)}\ for\ x = EIV, SIV, EIT\ \ \forall i \tag{26}$$

When this interpolated value is 1 it indicates that the actual value is the best value in comparison to the other values; otherwise, 0 indicates it's the worst value.

Now to create a performance score these interpolated values need to be multiplied with weights. These weights are determined by the Analytical Hierarchy Process (AHP) developed by Saaty, as described in the literature chapter. When a Consistency Ratio (CR) of less or equal to 0.1 is reached the weights are determined consistent and reliable.

All calculations for Kramp, following the steps of the AHP, are described in detail in Appendix E. For this study five stakeholders were asked to fill in a pair-wise comparison. By following all steps as described in the literature, two sets of weights were obtained. There are two obtained as one stakeholders gave substantially different input due to its work regarding excess inventory. As this stakeholder's work mostly revolves around this topic, its input deviates compared to the other stakeholders. Therefore, in run 1 this stakeholder is excluded from the analysis, and in run 2 this stakeholder is included.

Table 2 Weights with their Consistency Ratio (CR).

Run	W1 (EIV)	W2 (SIV)	W3 (EIT)	CR
1	0.15	0.18	0.67	0.05
2	0.25	0.16	0.59	0.61

Excluding a specific stakeholder results in consistent weights with a CR below 0.1, while including them yields an unreliable CR over 0.1. Both sets of weights will be assessed in sensitivity analyses to examine their impact on SKU scoring. By utilizing Equation (22), a performance score of 1 indicates optimal SKU performance with no excess or shortage and the highest turnover. A score of 0 is impossible due to the mutual exclusivity of excess and shortage values, with lower scores indicating poorer performance.

4.2. Demonstration of calculations

This paragraph demonstrates the application of specific calculations for a predetermined article, illustrating how the governing principles operate within this study.

4.2.1. Article selection for demonstration

This chapter is structured to provide a comprehensive understanding of how these calculations work, using a set of articles with different characteristics as examples to illustrate the process and validate its effectiveness. The following article '300-ABCD123' will be used to illustrate it. While the article code, '300-ABCD123,' is fictitious, the parameters it represents are based on a real and active article within Kramp. All the following calculations are done on day level, as it is for demonstration purposes.

Table 3 Reference articles for chapter 4 in November 2023.

#	Article	Stock on Hand in units	Non-stocked	Demand class
1	300-ABCD123	801	False	Slow

This article has been chosen due to having many units on stock but having a demand class slow (i.e., typically selling only a few articles per year).

4.2.2. Demonstration of the calculations for the IQR, ICI, and Article Performance Scoring.

The demonstration calculation is conducted in units for clarity and ease of follow-up. However, for the Multi-Criteria Decision Analysis (MCDA) analysis, values are converted into financial terms to account for differences between the financial and unit-based performance of articles. This distinction is crucial because a single unit with a high excess value can be more detrimental financially than multiple units with a lower excess value.

To determine the health of inventory items, first calculate the Minimum Days of Coverage (Min DoC) using Formula 6. This metric establishes the minimum inventory coverage period deemed satisfactory for keeping stock levels healthy.

The safety stock figure is obtained directly from Slim4, which applies a dynamic method for calculating safety stock for Kramp products. This calculation is updated monthly, meaning the safety stock—and consequently the minimum threshold for an article's health—may vary at the start of each month. Additionally, the 12-month forecast, which includes country-specific forecasts, Distribution Requirements Planning (DRP) data for other Kramp warehouses, and confirmed customer orders, is also sourced from Slim4.

The Min DoC is then calculated by dividing the safety stock by the total forecast for the upcoming year and multiplying by the number of days in a year. This calculation is essential for determining the ICI, which assesses whether an article's coverage falls within acceptable ranges.

Table 4 Minimum days of coverage calculation.

Minimum inventory	Forecast 12 Months	Min DoC (Safety stock in days)
$\boldsymbol{Safety\ stock = 7}$	67	$\frac{7}{67} * 365 \approx \mathbf{38.13}\ \boldsymbol{days}$

Next, the actual Days of Coverage (DoC) can be calculated. Recall the formula for DoC from Equation (7).

Table 5 Days of Coverage calculation.

Formula	Days of Coverage
$\frac{\boldsymbol{Stock\ on\ Hand}}{\boldsymbol{Forecasted\ units}} * \boldsymbol{Forecasted\ days}$	$\frac{801}{67} * 365 \approx \mathbf{4363.66}\ \boldsymbol{days}$

Let's proceed with the calculation for the maximum days of coverage, as detailed in section 4.1.1. For articles categorized as "stocked", the upper limit for maximum days of coverage is determined by the standard order level, along with the ordered quantity (comprising either the EOQ or MOQ). In contrast, for articles labeled as "non-stocked", the maximum days of coverage depends on the order level in combination with any outstanding backorders (i.e., never have more stock than actually ordered).

In the Slim4 system, when choosing between Economic Order Quantity (EOQ) and Minimum Order Quantity (MOQ), MOQ overrides EOQ if it's larger due to supplier contracts. This is shown in two ways in this study: first, by calculating EOQ and adjusting it to Incremental Order Quantity (IOQ) without considering MOQ, and second, by factoring in the supplier's MOQ. Refer to Appendix F for a detailed example of this.

In Slim4 software, the order level is calculated by adding the base forecast (predicted units for lead time and review period), event forecast (predicted units for future events within the lead and review period), confirmed extra (transfers to other warehouses and customer orders confirmed during the lead and review period), and safety stock. The Economic Order Quantity (EOQ) and Minimum Order Quantity (MOQ) values are directly retrieved from Slim4. EOQ is determined using a specific formula, while the supplier MOQ is a predefined quantity outlined in the supplier contract. These calculations are based on a 215-day cover period, which encompasses both the review period and lead time.

Table 6 Build-up parameters of order level.

Base forecast	Event forecast	Confirmed extra	Safety stock	Order Level
17	0	20	7	$= \mathbf{44}\ \boldsymbol{units}$

Table 7 Maximum inventory

Order Level	Q	$Inventory_{MAX}$
44	EOQ rounded to IOQ = 17	$44 + 17 = \mathbf{61\ units}$
	Supplier MOQ = 1000	$44 + 1000 = \mathbf{1044\ units}$

With the order level gathered the maximum days of coverage can be calculated. By using the order level (s) and the order quantity (Q), which is either the EOQ or MOQ. So the first row contains the maximum inventory when supplier MOQs are ignored and the second row contain the maximum inventory when the supplier MOQs are taken into account.

Table 8 Maximum days of coverage calculation.

$Inventory_{MAX}$	Formula	Max days of coverage (Max DoC)
61	$\left(\frac{Inventory_{MAX}}{Forecast}\right) * Forecasted\ days$	$\left(\frac{61}{67}\right) * 365 \approx \mathbf{332.31\ days}$
1044		$\left(\frac{1044}{67}\right) * 365 \approx \mathbf{5687.46\ days}$

The analysis of the maximum days of coverage reveals that the supplier MOQ significantly extends the maximum days of coverage to more than 15 years, while the EOQ suggests a maximum inventory of less than a year. As the MOQ arises from the existence of a contract with the supplier, obliging Kramp to order that specific quantity, including it in the maximum allowable gives a distorted picture on deciding whether a SKU is in the right amount present. Therefore, supplier MOQ is excluded from the maximum allowable inventory rule when applied in the next chapter, but will still be shown in the toy problem to show its effects.

If the DoC is larger than the maximum DoC, then the maximum DoC is multiplied with the forecast translated to days, otherwise the DoC is multiplied with the forecast translated to days. Recall the forecast to days from the DoC calculation.

Table 9 Amount of inventory that is within the maximum limit calculation.

DoC	Max DoC	Formula	Active Inventory Units (AIU)
4363.66	332.31	$\left(\frac{MIN[DoC, Max\ DoC]}{Forecasted\ days}\right) * Forecasted\ Units$	$\frac{MIN\{4363.66, 332.31\}}{365} * 67 \approx \mathbf{61\ units}$
	5687.46		$\frac{MIN\{4363.66, 5687.46\}}{365} * 67 \approx \mathbf{801\ units}$

As the DoC is larger than the maximum DoC for the maximum rule ignoring the supplier MOQ, means that there's excess inventory units present. Excess inventory units (EIU) represents the remaining portion of the stock that is not considered active.

Table 10 Amount of inventory that is not within the maximum limit calculation.

Stock on hand	AIU	Formula	Excess Inventory Units (EIU)

801	61	$EIU = TIU - AIU$	$= 801 - 61 = \mathbf{740\ units}$
	801		$= 801 - 801 = \mathbf{0\ units}$

Now that all parameters are calculated, the IQR can be determined. Although the excess units is not directly used in calculating the IQR, it does provide insight into the amount of excess.

Table 11 The IQR calculation.

Max rule	AIU	TIU	Formula	IQR
Supplier MOQ left out	61	801	$IQR = 100\% * \frac{AIU}{TIU}$	$100\% * \frac{61}{801} = \mathbf{7.62\%}$
Supplier MOQ accounted for	801	801		$100\% * \frac{801}{801} = \mathbf{100\%}$

This shows again taking supplier MOQ into account give a distorted picture of whether a SKU is deemed healthy, signifying once more why the supplier MOQ will be left out of the maximum inventory rule for this study.

Formulas (13) and (14) calculate the ICI, revealing SKUs outside the acceptable DoC range with a 0% ICI, suggesting a 'Fail'. This indicates the ICI's better suitability for group-level rather than individual SKU assessments, as it shows whether SKUs meet the coverage criteria. With IQR and ICI determined, additional KPIs like SIV and EIT are calculated. EIT is derived by dividing the next year's forecasted units by the day's average inventory, offering an inventory efficiency snapshot. In this example, no SIV is calculated due to EIV.

Table 12 Inventory Turnover.

Average inventory	Formula	EIT
$\frac{\mathbf{801 + 800}}{\mathbf{2}} = \mathbf{800.5}$	$\frac{Forecasted\ units}{Inventory_{Avg}}$	$\frac{67}{800.5} = \mathbf{0.084}$

A very low inventory turnover indicates excessive inventory or weak sales for this SKU.

The interpolated value of the SKU is then calculated by first identifying the best and worst values for each KPI on the assessed day, focusing on value rather than units to avoid misleading interpretations.

Table 13 Best and worst values per KPI x.

KPI (x)	Best	Worst	Actual
EIV	€0	€86,962.35	€10,404.4
SIV	€0	€3,795.75	€0
EIT	29097	0	0.084

So by applying Formula (20) the interpolated value can be calculated for this SKU.

Table 14 Interpolated values per KPI.

KPI (x)	Formula	Interpolated value
EIV	$\frac{Actual_x^i - Worst_x}{Best_x - x}$	$\frac{€10{,}404.4 - €86{,}962.35}{€0 - €86{,}962.35} = \mathbf{0.880357419}$
SIV		$\frac{€0 - €3{,}795.75}{€0 - €3{,}795.75} = \mathbf{1}$
EIT		$\frac{0.08 - 0}{29097 - 0} = \mathbf{0.0000027}$

The performance score of the SKU is calculated by applying the weights specified in Table 2, where each row represents a different set of weights, indicating the varying importance of each KPI.

Table 15 Performance score calculation.

KPI (x)	EIV	SIV	EIT	Performance Score
W_x	0.15	0.18	0.67	$0.15 * 0.880357419 + 0.18 * 1 + 0.67 * 0.0000027 = \mathbf{0.312}$
	0.25	0.16	0.59	$0.25 * 0.880357419 + 0.16 * 1 + 0.59 * 0.0000027 = \mathbf{0.380}$

Table 15 shows that prioritizing Expected Inventory Turnover (EIT) results in a lower performance score for this SKU due to its significantly lower turnover rate compared to others. This score allows for ranking against other SKUs, with lower scores indicating poorer performance. For more precise assessment, additional digits in the score are considered. While further weight adjustments are possible, this demonstration limits itself to two runs for demonstration purposes.

4.3. Conclusion

In this chapter the question "*How can Kramp effectively integrate inventory data and apply the theory to gain insight into inventory health?*" is answered.

It concludes that while the Key Performance Indicators (KPIs) such as the Inventory Quality Ratio (IQR) and Inventory Control Index (ICI) lay a foundational framework for evaluating inventory health, they necessitate adjustments for full efficacy within Kramp's context, considering stock status, product groups, and demand classifications. Given the scarcity of historical accurate forecast data, this study's analyses are confined to daily and monthly intervals, not extending to quarterly or yearly evaluations.

Additionally, a performance scoring method using Multicriteria Decision Analysis (MCDA) has been introduced to identify the lowest-performing Stock Keeping Units (SKUs). Through the Analytic Hierarchy Process (AHP), a specific set of weights for KPIs—Excess Inventory Value (EIV) from the IQR, Shortage Inventory Value (SIV), and Expected Inventory Turnover (EIT)—has been established, marking the first step towards identifying key factors behind poor inventory performance. Evaluating the determined weights (0.15, 0.18, and 0.67 for each KPI, respectively) with the interpolated scores of each SKU, allows for a deeper understanding of the main drivers of unhealthy inventory, facilitating the development of more precise actions to improve inventory health.

5. Application

In this chapter the IQR, ICI, MCDA analysis, including a sensitivity analysis, and a root-cause analysis are applied to the whole inventory of the warehouse in the Netherlands to find the main drivers of inventory.

5.1. Applying IQR, ICI and Article Performance Scoring

In this paragraph, the IQR, ICI and Article Performance Scoring are applied to the whole inventory of the warehouse in the Netherlands.

5.1.1. IQR on warehouse level with multiple assessed time-periods.

The demonstration of the calculation can be extended to the corporate-, warehouses- and product class-level for by aggregating all okay values and dividing the sum by the total stock value of the total company, warehouse or product class. The day measurement was done on the 26th of November 2023. The month measurement was done between 26th October 2023 till 26th of November 2023.

Table 16 IQR on Kramp's main warehouse level.

Time-period	Active Inventory Value	Excess Inventory Value	Stock Value	IQR
Day	51.05M	16.19M	67.24M	75.90%
Last Month	53.20M	16.09M	69.29M	76.78%
$\Delta\,\boldsymbol{Difference}$	-2.15M	+0.10M	-2.05M	-0.88%

Upon scrutinizing aggregated values over the last month, a noticeable observation emerges: the IQR at the latest snapshot is lower compared to the average of the last month. This decline in the active inventory value can be attributed to Kramp being in a low season for the past few months, resulting in a decrease in the amount of active inventory due to reduced forecast for the upcoming coverage period. Simultaneously, the excess value is slightly increasing, contributing to the overall decrease in IQR. This is a slight increase because inventory is still selling, resulting in that all not ‘active’ did not become ‘excess’.

5.1.2. ICI on warehouse-level with multiple assessed time-periods.

While Inventory Control Index (ICI) is not possible on item-level, it is possible to determine it on higher levels. This is because if it would be assessed on item-level it would be a zero or a one depending on if it has zone “active” or not. By using Equation (16), the ICI can be calculated on warehouse-level for the different assessed time-periods, the same as in the IQR application.

Table 17 ICI on Kramp's main warehouse level.

Time-period	Shortage inventory SKUs	Active inventory SKUs	Excess inventory SKUs	Total Inventory SKUs	ICI
Day	14,645	205,607	53,552	273,804	75.09%
Last Month	11,976	207,928	54,232	274,136	75.85%
$\Delta\,\boldsymbol{Difference}$	+2669	-2321	-680	-332	-0.76%

Similar to the IQR, the ICI shows an decrease in the number of active inventory units. It can be seen that more SKUs more towards the shortage, which is expected, as on day level there are more SKUs that can be ordered too late meaning that the code implies that a shortage will occur, but that later the stock controllers addresses this and move the order forwards. So, that on monthly level this SKUs was not expected to be in shortage.

5.1.3. Identifying worst performers

The improvement of the IQR and the ICI necessitates a comprehensive analysis of the root causes contributing to inventory underperformance. Utilizing a weighted scoring method, by the MCDA, is pivotal in identifying the most underperforming SKUs. This identification serves as a precursor to a detailed examination of the factors affecting their performance, finding the biggest root-causes.

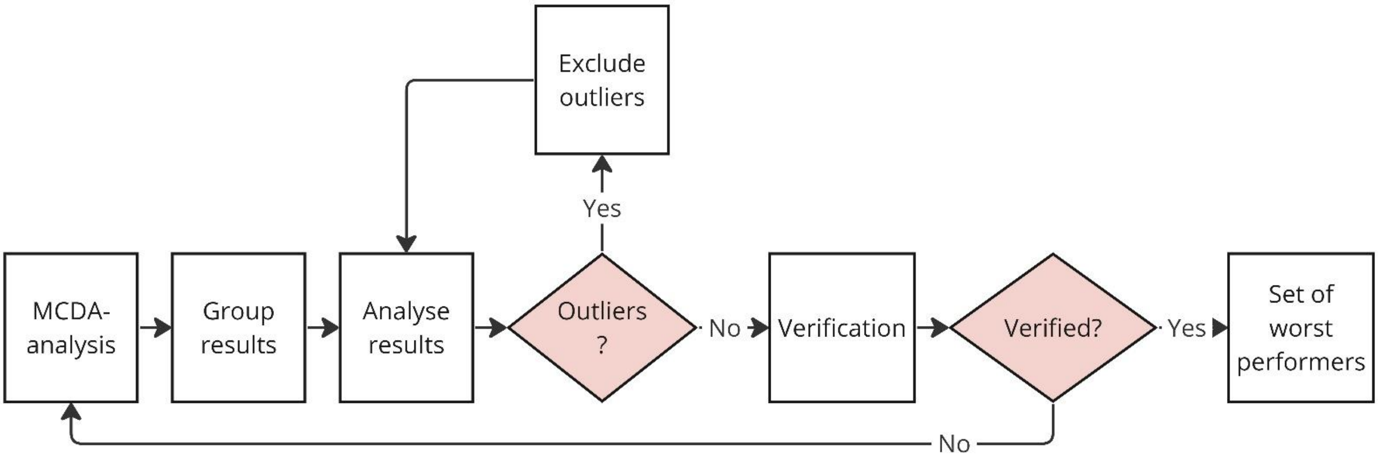

Figure 5 Path to find worst performers through MCDA.

- Step 1: Apply MCDA

By employing previously discussed MCDA analysis worst performers can be calculated. Establish criteria for selection, such as a specific percentile, score threshold, or the bottom-performing entities.

- Step 2: Group Results

Group the entities according to a relevant category (such as product groups, services, departments, persons, etc.). Aggregate and analyze the MCDA results at this grouped level to understand broader impacts.

- Step 3: Analyze results

Analyze the groups to see what kind of values there are present and how they are affecting the groups.

- Step 4: Refine and Exclude Outliers

If outliers significantly skew results, consider refining the groups or excluding these outliers with proper documentation and justification for a more balanced analysis. Reanalyze the refined groups or entire set to confirm the worst performers. Adjust the approach based on the initial findings and any additional insights gained.

- Step 5: Consultation and Verification

Engage with domain experts, stakeholders, or experienced personnel to verify the findings and gain additional insights. Incorporate their feedback and knowledge into the analysis.

- Step 6: Set of worst performers

Finally a set of worst performers is gathered as groups. These will later be used in determining what most likely are the largest root-causes of unhealthy inventory.

The MCDA analysis is employed to identify the worst-performing SKUs in Kramp's inventory, following the outlined steps above, which yield specific insights. These insights are derived from the top 1000 worst performers and are evaluated based on average values over a one-month period. To enhance clarity, the days of coverage are converted into years of coverage. While the weights from Table 1 is utilized as the baseline, additional weights are formulated for assessing robustness, as elaborated in Table 18 below. The creation of these alternative weightings involves reallocating points from one KPI to another, starting from Run 1. The reallocating will be minor, so at most 0.2 points, because if the decision is highly sensitive to minor weight changes, it may require reevaluation of the weight adjustments. Subsequently, each run is compared to the Run 1 to assess the impact of these changes. Run 2 is present to show to effects if the other stakeholder, who gave substantially different input, is included in the determination of the weights.

Table 18 Weights used for sensitivity analysis of the MCDA.

Run	EIV	SIV	EIT	Changes from Run 1
1	0.15	0.18	0.67	-
2	0.25	0.16	0.59	-
3	0.15	0.38	0.47	-0.2 EIT → +0.2 SIV
4	0.35	0.18	0.47	-0.2 EIT → +0.2 EIV
5	0.25	0.28	0.47	-0.2 EIT → +0.1 EIV & +0.1 SIV
6	0.05	0.08	0.87	-0.1 EIV & -0.1 SIV → +0.2 EIT

For a comprehensive, step-by-step description of the process leading to Table 19 & 20, refer to Appendix G.

Table 19 Totals and averages based on top 1000 worst performing SKUs in the last month.

Run	SUM SIV	SUM EIV	AVG EIT	AVG YoC
1	€ 205.4K	€ 7,027.8K	1.33	56.03
2	€ 165.7K	€ 7,194.1K	1.43	58.11
3	€ 246.5K	€ 6,817.0K	2.74	55.35
4	€ 158.3K	€ 7,210.4K	1.93	56.76
5	€ 206.0K	€ 7,030.1K	2.27	57.15
6	€ 229.0K	€ 6,929.9K	1.30	56.54

Table 20 Check if top 10 worst product groups in run 1 is present in top 10 of the other runs.

Ranking Run 1	Run 1 vs 2	Run 1 vs 3	Run 1 vs 4	Run 1 vs 5	Run 1 vs 6
50	1	1	1	1	1
68	1	1	1	1	1
44	1	1	1	1	1
30	0	1	0	1	0
64	1	1	1	1	1
46	1	1	1	1	1
42	0	1	0	0	1
22	0	1	0	1	1
24	1	0	1	1	1
SUM	**7**	**9**	**7**	**9**	**9**

When looking at the overall ranking between the original run and the sensitivity run, some insights are gained when the different set of weights are used.

- Referring to Table 19, it can be observed that when a particular KPI is given higher priority, it leads to an expected increase in its value or a decrease in the average EIT, depending on the prioritization. For example, in run 3 where SIV is prioritized, this preference is reflected in the totals, with SIV showing a significant increase compared to other runs where it holds either a middle or lower priority. Additionally, in this run, the years of coverage are the lowest, primarily due to SKUs with shortages taking precedence in the top 1000 list, rather than SKUs with EIV or low EIT, which typically have higher years of coverage.
- While prioritizing EIT the most in run 1, the average value found is not much lower than the average value found in run 2, where the weight for EIT is lower. This is due to that shortage is deemed second most important in the first run, allowing for more SKUs to climb up the list with average higher expected inventory turnovers.
- Looking at table 20, the persistent presence of at least 7 groups suggests the existence of a core group of poorly performing SKUs. This core remains identifiable regardless of adjustments made to the weights for EIV, SIV, and EIT. This consistency implies that these SKUs are likely underperforming based on the established criteria.
- The ranking appears to be somewhat sensitive to the perceived importance of SIV. Once this KPI is considered relatively significant, product group 30 consistently appears in the top 10 rankings. If not, then this group leaves the top 10 worst performing groups.

Conclusively, the weights in the first run can be considered appropriate for identifying the worst-performing SKUs, as evidenced by the significant consistency of the majority of these SKUs across various sensitivity runs with differing weight distributions, aligning well with expectations and core worst performers, reinforcing the robustness of the initial weighting scheme.

5.1.4. Primary-causes unhealthy stock

Now that the worst performers have been determined, a structured methodology is employed to identify the most impactful root causes of the unhealthy stock. This approach will systematically analyze the top underperforming SKUs, enabling the pinpointing of key factors driving their underperformance, thereby facilitating targeted improvements in IQR and ICI.

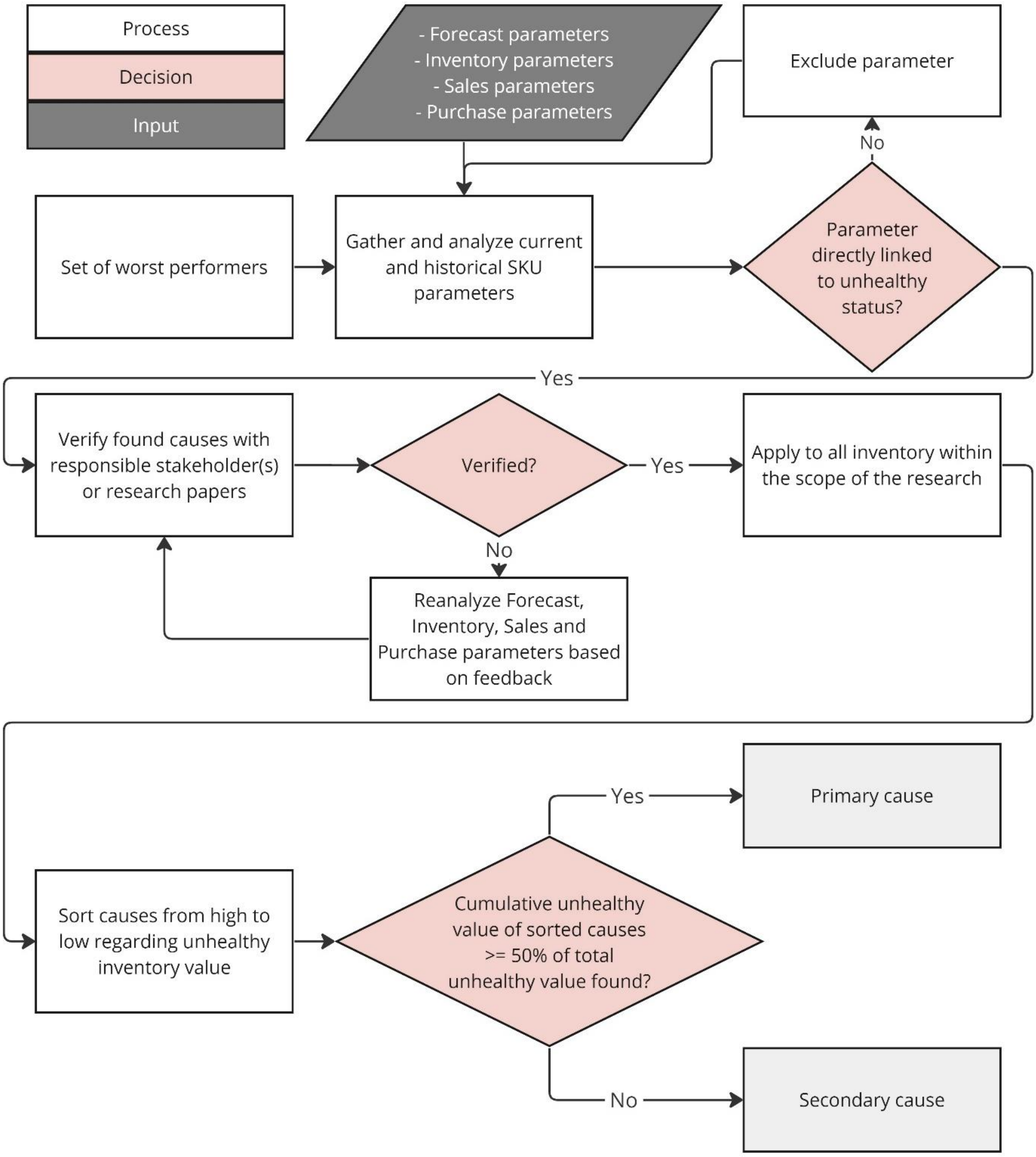

Figure 6 Gather the biggest root-causes based on the set of worst performers.

The Root Cause Analysis (RCA) process, as depicted in Figure 6, outlines a systematic method for identifying and verifying the most impactful causes of unhealthy inventory. It begins with identifying the worst-performing SKUs through a Multi-Criteria Decision Analysis (MCDA), as previously discussed. After identification, a comprehensive data collection phase is undertaken, focusing on forecast, inventory, sales, and purchase parameters to understand these SKUs' current and historical behavior. An extensive list of possible parameters can be found in Appendix H. The goal is to link these parameters directly to the inventory's unhealthy status.

Verification of findings involves collaboration with responsible stakeholders, leveraging their expertise and insights to confirm the identified causes' validity. This step enhances the reliability of the findings. If causes are not verified, a feedback loop is initiated, incorporating stakeholder feedback and reanalyzing the SKU parameters or source additional parameters. This iterative approach ensures the analysis adapts to new insights.

Upon establishing and verifying a direct linkage, the findings are applied to the broader inventory within the scope of the study. The analysis phase concludes by sorting causes based on the impact on unhealthy value in descending order, prioritizing issues for action. Causes are categorized into primary causes (accounting for 50% or more of total unhealthy value) and secondary causes. This categorization focuses resources on the most impactful issues and provides a quantifiable criterion for action, facilitating decision-making and stakeholder alignment.

This thorough and iterative RCA approach is designed to not only identify but also validate and address significant root causes, thereby enabling impactful improvements in inventory health. When applied to Kramp's inventory, this process revealed the following primary causes as seen in Table 21.

Table 21 Primary causes unhealthy stock.

#	Primary Causes		Unhealthy inventory SKUs (% total)	Unhealthy inventory value
1	Panic buying during covid	Decline in demand past two year	7673 (11.6%)	€1,700K
		Stable demand past two years	12704 (19.2%)	€ 4,444.0K
2	High MOQs		3245 (4.9%)	€1,040K
4	No demand		6072 (9.2%)	€858K
5	Cautious and no ordering of inventory		2099 (3.2%)	€416K

A distinction was made regarding panic buying during COVID-19, as some SKUs experienced a decline in demand after COVID-19, while many did not. This distinction aims to illustrate the types of SKUs that were also affected by a decrease in demand. A detailed example of each cause above and secondary causes can be found in Appendix I.

Panic buying during covid

Approximately two years ago, with the advent of COVID-19, Kramp experienced a surge in demand as customers engaged in panic buying. To address the heightened demand and concerns about potential product shortages, senior leadership made the decision to purchase large quantities. This strategy was aimed at securing stock to ensure product availability to its customers. As there was no Sales & Operations Planning process in place, there was no alignment cross-functionally to check whether this is an reasonable amount for the future, this amount accumulated into the main warehouse of Kramp.

In order to identify these SKUs, an analysis was conducted on the order level, stock on hand, and on order for the past 3.5 years. Specifically, during the COVID period, an examination of demand was carried out to ascertain any notable increases. In response, Kramp promptly placed orders for a substantial quantity to meet and potentially surpass this heightened demand. The SKUs identified exhibit discernible patterns, illustrated in Figure 7 below.

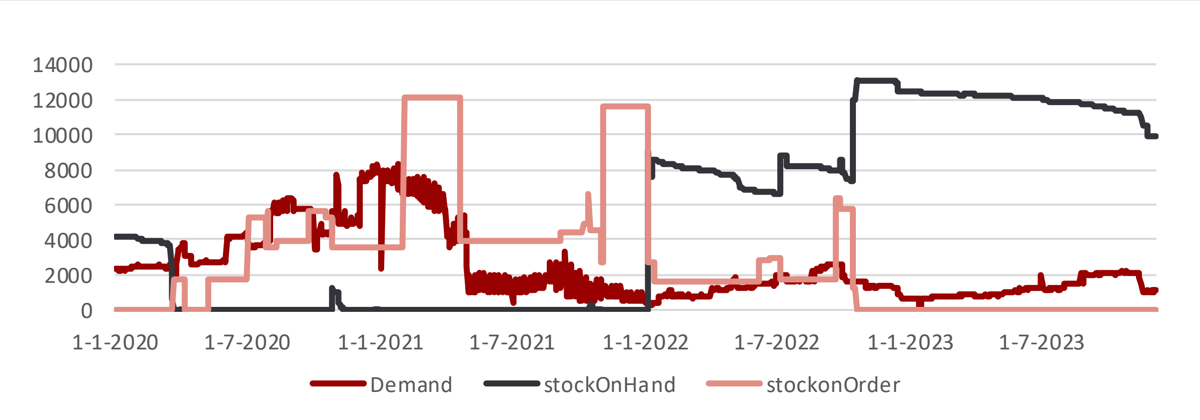

Figure 7 Demand, stock on hand and on order of 1 SKU in the last 3.5 years.

Figure 7 depicts the demand, stock on hand, and stock on order for a single SKU over the last 3.5 years. Notably, when COVID unfolded in March 2020, the stock on hand experienced a decline due to customer panic buying. Forecast escalated throughout the year, prompting the stock manager to procure increased quantities without extensive deliberation. The initial batch successfully fulfilled the demand, but the second batch did not arrive until the beginning of 2022, by which time the demand had reduced to a fraction of what it was. Consequently, stock on hand surged rapidly and has remained high ever since.

Figure 7 clearly illustrates that this issue identified had emerged quite some time ago. During the period leading up to this study, measures have already been implemented to prevent such occurrences in the future. Previously, the decision to purchase a specific quantity of inventory was made by a single individual. However, the current process at Kramp requires that multiple personnel assess and agree on the appropriateness of the inventory quantity to be acquired. Therefore, no immediate action for this cause has to be taken.

While for this example SKU the demand remained relatively stable in the past two years, indicated by the dark red line from the last measured day until December 2021. For many SKUs, in addition to being bought extensively during COVID, also a decline in demand happened. Therefore, the primary cause panic buying during covid will be separated into two sub causes, stable demand and decline in demand.

Decline in demand after COVID-19

To pinpoint the products impacted by declining demand, a comprehensive analysis was undertaken, focusing on their demand and inventory patterns over the past 3.5 years. This assessment primarily involved evaluating whether the average order volume for each SKU was anomalously high during the COVID-19 period, spanning from March 1, 2020, to January 1, 2022. The analysis then compared the average demand in the past year with that from two years prior, categorizing the changes into several ranges: from a 10-20% decrease, a 20-30% decrease, up to reductions exceeding 50%.

Furthermore, the study considered whether average stock levels that were deemed sufficient during the COVID-19 period remained adequate in the past year, alongside projections of continued product viability in the upcoming year.

The primary discovery from this investigation is that the most significant demand decline occurred at the 30% threshold. Consequently, subsequent analyses will focus specifically on SKUs that experienced a demand reduction exceeding 30%. A more in-depth examination revealed that these groups predominantly consist of SKUs categorized as 'Destination'. Kramp has besides product groups also product categories as a different segmentation, to distinguish SKUs based on competitors and traffic to their website.

- Destination: These are SKUs that drive traffic to Kramp's webshop. Kramp is the primary provider of these products and these define Kramp's image.
- Routine/Core: These are SKUs that are competitive with other wholesalers. Kramp wants its fair share of sales and growth in these categories.
- Seasonal/Occasional: Drive traffic to the webshop of Kramp and convinces customers to also buy products from the Routine category.
- Convenience: Smaller and simpler ranges, these categories play an important role in the area of profit generation and tend to be less competitive.

Table 22 Excess value per product category where there's more than 30% decline in demand.

Product Category	Amount of SKUs	Excess Value	AVG excess value per SKU
Destination	3724	€ 1,020K	€322.23
Routine	3777	€637.3K	€168.73
Seasonal	0	€0	€0
Convenience	178	€59.6K	€334.83

A striking characteristic of these SKUs is their relatively high average price point as seen in Table 22. This observation leads to a plausible assumption: the declining demand for these SKUs could be attributed, at least in part, to their pricing levels. High prices may act as a deterrent for potential buyers, especially in a post-COVID economic context where purchasing patterns may have shifted.

Stable demand

Following the conclusion of COVID-19, these SKUs were introduced into the warehouse, and subsequent demand in the past two years remained stable. As it was determined that SKUs that were in decline was set if there was more than a 30% drop in demand, means that in this study SKUs that remain within 30% deviation from the average two years ago versus last year are considered stable. The same checks apply here as in the decline demand, the inventory level would be considered okay during the COVID period and the SKU is still expected to sell in the coming year.

Table 23 Values found for SKUs where demand remained stable.

Number of SKUs	SUM EIV	AVG EIT
12704	€ 4,444.0K	2.76

The analysis reveals a noteworthy contrast in Kramp's inventory dynamics. Despite the presence of SKUs with substantial excess values, the average inventory turnover rate across Kramp's product groups consistently exceeds 1, with an overall average of 2.76 as seen in Table 23. This indicates that, on average, the existing inventory for the majority of SKUs is expected to be fully depleted within a period of less than one year. This rapid turnover rate underscores an efficient inventory management system, despite the identified issues with excess inventory in specific SKUs.

In an in-depth analysis of SKU types, it was revealed that approximately 75% of the inventory classified as unhealthy is concentrated within three of the eight present demand classes. These classes are Demand Class 0 (Frequent), Demand Class 1 (Normal), and Demand Class 5 (Slow). This distribution aligns with expectations considering the average EIT (Table 23) exceeds well above 1, suggesting that a significant proportion of SKUs experience rapid turnover, as in Demand Classes 0 and 1. The notable presence of Demand Class 5 in this segment is primarily attributable to its substantial representation in Kramp's overall inventory, leading to a higher likelihood of these unhealthy inventory being present there.

High MOQs

In Chapter 4, the analysis reveals that a number of SKUs are impacted by disproportionately high Minimum Order Quantities (MOQs), which are rooted in contractual obligations with suppliers. These MOQs significantly exceed the actual market demand for these items. To evaluate the effects of these MOQs, a comparative approach was adopted. For SKUs with regular demand, the MOQ was compared with the Economic Order Quantity (EOQ), while for those with irregular or slow demand, the comparison was made against the forecast for the upcoming year. This methodology allows for a more accurate assessment of MOQ's implications, especially for SKUs where demand patterns are not stable.

The study categorizes the ratio of MOQ to EOQ or the forecasted demand into three levels: three, five, and ten times higher. This classification aids in quantifying the extent of misalignment between MOQs and actual demand. A critical aspect of the analysis is the distinction between excess inventory due to high MOQs and that resulting from past over-purchasing.

The analysis indicates that SKUs with irregular or slow-moving demand are significantly affected by high MOQs leading to an average inventory coverage of 25-35 years when MOQs are ten times higher than annual demand. Conversely, faster-moving SKUs, while also impacted by high MOQs, demonstrate a more moderate effect with an average coverage around or below 5 years for MOQs that are then times higher than annual demand. This suggests that faster-moving SKUs are relatively more resilient to the challenges posed by high MOQs compared to slow moving SKUs.

The findings highlight the need to tailor MOQ agreements to SKU demand rates. High MOQs, particularly for slow or irregular demand SKUs, lead to excessive inventory coverage, indicating a supply-demand mismatch. Adjusting MOQs to align with demand can improve inventory efficiency and reduce surplus. Analyzing scenarios without these high MOQs could further demonstrate their impact on inventory turnover and coverage days.

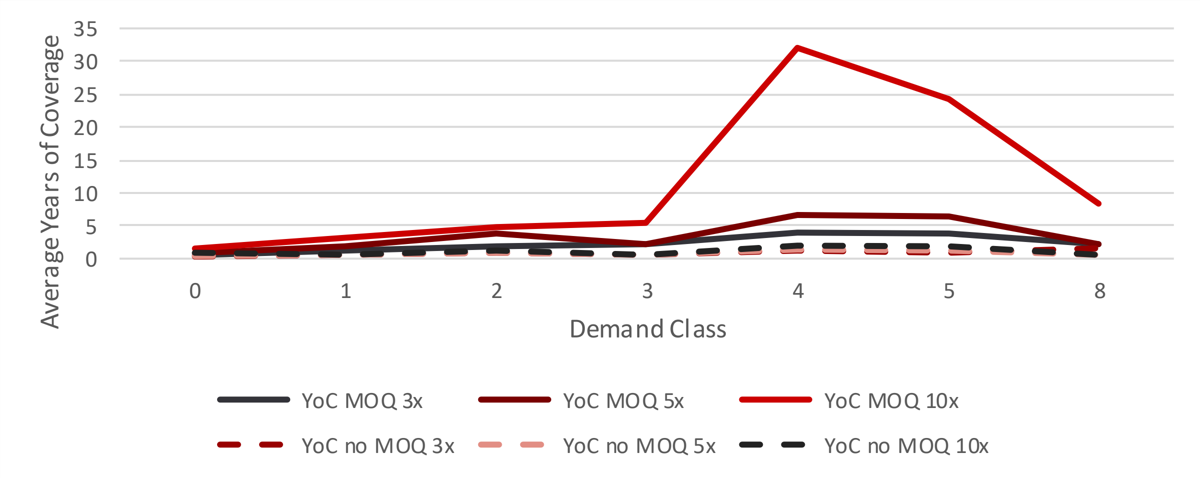

Figure 8 Average years of coverage if MOQ and no MOQ was in place for SKUs with excess value due to high MOQs.

The data in Figure 8 shows that with high MOQs, average Years of Coverage vary widely, from about 1.5 to a peak of 32 years. Without these MOQs, this range would narrow significantly, falling between 0.3 and 1.75 years, as the dashed lines suggest. There's a general trend of reduced average days of coverage across most demand classes, with figures settling at or below a year, except for classes 4 and 5. For class 5, longer coverage periods may be economically viable to minimize frequent order costs. Class 4, with its irregular demand, might also benefit from longer ordering periods due to demand unpredictability. Furthermore, analyzing the expected inventory turnover using EOQs instead of high MOQs could provide additional insights.

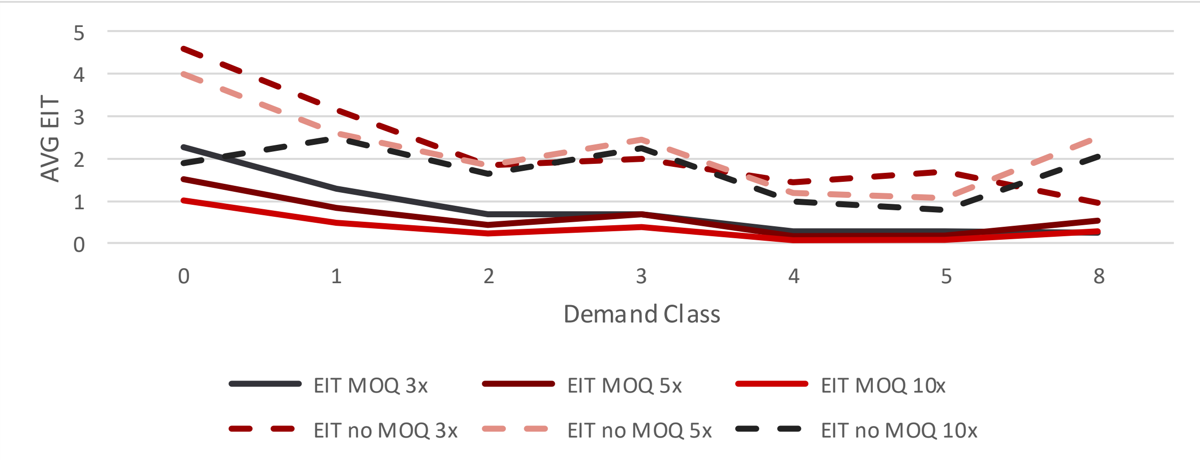

Figure 9 Average EIT if MOQ and no MOQ was in place for SKUs with high MOQs.

An improvement in expected inventory turnover is observed across all demand classes in Figure 9, indicating that aligning orders with forecasts rather than high MOQs could enhance efficiency. Particularly for demand classes 4 and 5, using EOQ instead of MOQ might result in an average expected turnover below 1. This is due to the cost-effectiveness of ordering in larger quantities for these classes, leading to stock coverage exceeding a year. Figure 15 illustrates this, showing higher years of coverage for classes 4 and 5 compared to others.

Reviewing and adjusting MOQ parameters could be highly beneficial, potentially leading to a better inventory performance. This change is especially crucial for SKUs in demand classes with irregular or slow-moving patterns, where current high MOQs significantly decreases their performance.

No demand

Over time, certain products at Kramp have experienced a gradual decline in demand, eventually leading to a complete cessation of sales. This lack of demand results in stock accumulation in the warehouse, remaining indefinitely without strategic intervention. The persistence of these articles in inventory is primarily attributed to their historical sales records. SKUs with no sales in the recent two years are still retained in the warehouse due to their earlier sales history, coupled with a lack of proactive management measures to phase out these non-performing items. Constraints in the budget allocated for scrapping and previously ample warehouse space have further contributed to the reluctance to remove these items from stock.

Recognizing this issue, Kramp initiated an overstock project, aligning with the onset of new supply chain operations. This project aimed to address the excess stock of non-selling SKUs. Despite providing valuable insights and recommended actions, the project struggled to gain traction, partly due to some managers' belief that these items might eventually sell, leading to their continued storage in significant quantities.

A more proactive end of life approach in the past towards these non-demand SKUs could have mitigated this situation. To illustrate the impact of non-selling articles, a categorization was made based on sales activity: items sold in the last 12 months, unsold in the last 12 months, and those unsold in the last 24 months. All these categories, currently listed as having no expected future demand according to Slim4, remain active on the webshop.

The analysis reveals a significant trend in excess inventory values, primarily attributed to a lack of demand over the past 12 months. A key observation is the cessation of sales for certain items that had demand but have since been replaced by successor products. These original items remain in stock, as they can't be transferred to the successor, contributing to excess inventory due to the absence of ongoing demand. Additionally, some SKUs are experiencing such a rapid decline in demand that no future demand is anticipated. These SKUs fall under a demand class characterized by zero demand. As a result, they exhibit infinite days of coverage and an inventory turnover rate of zero, highlighting the complete lack of sales forecast and the critical need for inventory adjustment.

By initiating a better end of life planning strategy and decisive actions in line with Kramp's strategic goals, there is a significant opportunity to enhance inventory health.

Cautious and no ordering of inventory

The shortage inventory value introduction aims to assess SKU performance besides excess inventory. This value is primarily present due to Kramp's cautious ordering strategy, where SKUs with anticipated shortage values are primarily ordered by a limited number of customers, often just one, or for 1 time projects. Before placing orders, stock controllers consult with product specialists, ensuring that the SKU is genuinely necessary. This collaborative process is crucial in avoiding unnecessary orders.

Furthermore, a deliberate decision stemming from a change in assortment involves intentionally refraining from ordering certain SKUs, despite potential shortage signals. This strategic choice, made in consultation with product management, overrides automated signals and reflects a conscious decision not to stock these particular items. As a result, the primary cause indicated by potential shortage parameters may not necessarily manifest for these SKUs.

It's important to note that addressing this concern is not needed, given the close monitoring and collaboration between stock controllers and product specialists who actively manage these SKUs. The identification of worst performers remains unchanged, with final weights ensuring a secondary focus on SKUs with shortage values. This intentional focus allows for a thorough review when these SKUs appear, enabling a double-check to confirm whether the cautious or deliberately not ordering approach is genuinely in play or if a SKU is genuinely at risk of shortage.

5.2. Cause segmentation

When looking at the causes, it can be found that it can be segregated under different categories.

External event / disruption

Among these, the effect of external events or supply disruption is rather important. Such external events as, for example, during the COVID-19 pandemic, panic buying, introduce vulnerabilities. This goes to underline the need for preemptive strategies in the view of minimizing a repeat of such effects of the disruptions in the foreseeable future.

SKU parameter

Additionally, high MOQs by suppliers through contractual arrangements have been brought up as a pertinent issue related to the topic of SKU parameters. This means that the constraint not only leads to the immediate challenge but also to possible future ones, as the efforts in dealing with the MOQ issue may pass. Actions should thus be formulated with a view to change these parameters of the SKUs so as to guarantee inventory healthiness.

Strategy / decision making

In addition, some causes may be precedented by the inventory strategy or decision an organization takes. For example not adjusting Slim4 on the articles denoted as shortage while in practice it’s not in shortage or not having a good end of life procedure to address SKUs who are about the become demand-free. Therefore, inadequacy in the current strategy will present challenges in functioning efficiency and effectiveness of the supply chain. In this context, therefore, there is a need to rethink and redefine the practices of inventory management in order to make them comprehensive enough to support the supply chain against the various risks it faces.

Looking at the segmentation above, these should be addressed first when creating actions regarding improving the inventory health. Because, if left unaddressed, these are able to return in the foreseeable future.

5.3. Conclusion

In this chapter the question *"What are the causes that have the most effect on Kramp's unhealthy inventory?"* are answered.

In conclusion, the examination of Kramp's inventory data utilizing metrics such as the Inventory Quality Ratio (IQR) and the Inventory Control Index (ICI) has uncovered issues indicative of suboptimal inventory health. The Inventory Quality Ratio, standing at 75.90%, and the Inventory Control Index, at 75.09%, both exceed the average values observed in previous months, signaling potential concerns. The identification of the poorest-performing stock-keeping units, coupled with a focus on the key performance indicator of expected inventory turnover, provided insights into the presence of unhealthy inventory.

The examination of unhealthy inventory has identified four main contributors: Panic buying during COVID-19, high Minimum Order Quantities (MOQs), inventory having no demand, and cautious or no ordering approach. For the first cause already some processes have been set in place for it to not happen again. The final cause is already proactively managed by stock controllers and product managers and therefore no immediate action is needed for these kind of SKUs. To progress, effective actions for other unhealthy stock must be determined to address this and improve the IQR and ICI, enhancing overall inventory health.

6. Actions

In this chapter, an approach is developed to formulate actions that are in harmony with the company's overarching goals, specifically aimed at enhancing the Inventory Quality Ratio (IQR) and Inventory Control Index (ICI).

In managing unhealthy inventory, it is critical to initially determine whether its cause is event-driven, parameter- or strategy -based. This distinction is key in addressing the root cause effectively to prevent the recurrence of similar inventory issues. Therefore the first actions are targeted towards these categories before addressing the unhealthy value directly. This approach ensures that responses to unhealthy inventory are not mere temporary fixes but are strategically designed to enhance long-term inventory health. After addressing these foundational causes, targeted actions can be implemented directly against the unhealthy SKUs.

Most of the targeted SKU actions get to be driven towards development and prioritization for revenue maximization. With the focus on revenue maximization, the aim remains to keep inventory in such a way that it still can be sold in some way before doing other actions that do not do this.

In dealing with excess SKUs, the initial strategy involves retaining them within the company, recognizing them as assets that might still be in demand by customers. On the other hand, addressing shortages by acquiring SKUs promptly ensures that customer needs are met. As a final measure, removing SKUs from inventory is considered, particularly when it aligns with cost-saving objectives. Therefore, the selection and sequence of these actions are closely aligned with Kramp's overarching company strategy, ensuring that each decision supports both customer satisfaction and financial prudence.

A decision tree, depicted in Figure 10, has been constructed to guide the sequence and nature of actions. These are aligned with Kramp’s inventory goals, addressing first external event, strategy or parameter-based issues, followed by SKU targeted actions based on revenue maximization. This decision tree serves as a practical tool for Kramp in determining the most appropriate actions.

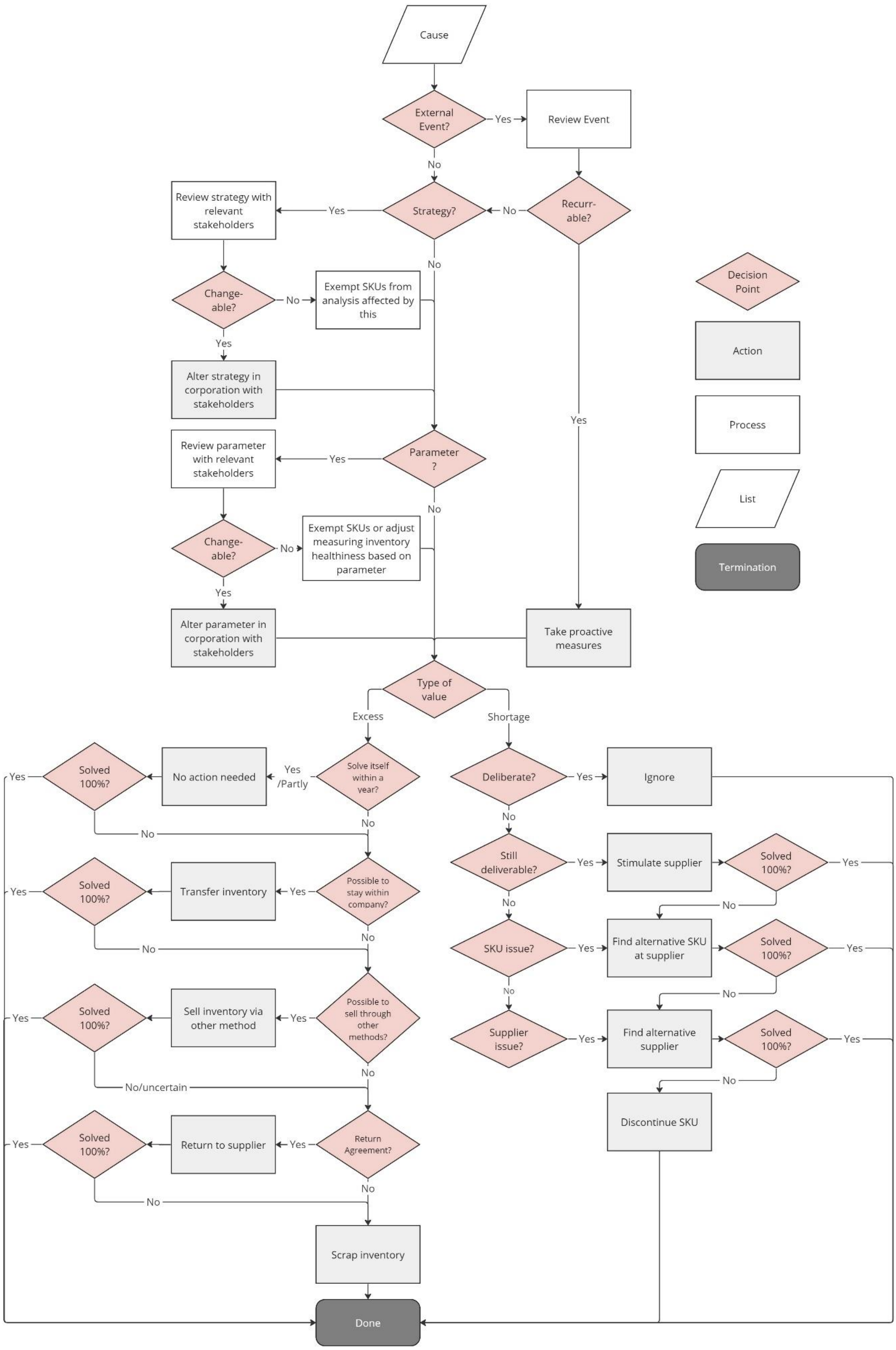

Figure 10 Decision tree for finding the appropriate action against causes and unhealth inventory for Kramp.

An enlarged version can be found in Appendix J.

The decision tree begins by identifying the found root cause. If the issue stems from a specific event, the first step is to assess the likelihood of its recurrence. In scenarios where there is a possibility of the event repeating, proactive measures are essential. These measures aim to either mitigate the effects or, ideally, prevent the recurrence of the effects of an event altogether. So in case of the COVID cause, if no measures were already taken, a measure would need to be set up with stock management, supply chain management and product management to make sure big amounts of inventory is not blindly bought upon a supply chain disruption.

If the issue stems from a strategy or parameter, a thorough evaluation determines its potential for modification. Successful modification may resolve the issue; otherwise, the determination of healthiness may need some adjustment or the SKUs should be exempt from the analysis overall. For example, the MOQ needs to be reevaluated with the procurement to see whether its first viable to change it with the supplier, and if not to see if it can easily be sourced elsewhere. If not deemed viable, the maximum inventory for those specific SKUs may need to be adjusted to the safety stock with MOQ instead of EOQ.

After thoroughly addressing both parameters, strategies and event-based causes, the focus then shifts to directly targeting the SKUs affected by these issues.

For excess inventory, the first step assesses whether the surplus will self-correct within a year. If self-correction is anticipated, no further action is taken. If not, the feasibility of retaining the excess inventory is evaluated. Should retention prove feasible, inventory transfer is considered, followed by exploring alternative sales methods. In cases where all sales strategies fail or any uncertainty is associated with it, returning becomes an option if there is some kind of return agreement with the supplier. If still any excess inventory remain, scrapping the inventory can become the final option.

In shortage scenarios, the decision tree initially focuses on supplier engagement to address the shortfall. If supplier efforts are ineffective, or if the shortage isn't supplier-related, sourcing an alternative SKU from the current supplier is the next step. If this is unviable or unsuccessful, searching for an alternative supplier is pursued. Should the shortage persist despite these efforts, discontinuing the SKU is considered as a resolution to the problem.

6.1. Actions against unhealthy inventory

Table 24 presents a comprehensive outline of the strategies implemented to address the challenge of unhealthy inventory. The primary goal of these measures is not only to enhance Kramp's IQR and ICI but also to tackle underlying parameters, strategies or events, if present. These actions prioritize the retention of existing stock within Kramp, emphasizing selling as a more favorable option compared to returning or disposing of stock, as illustrated in Figure 10. All detailed insights into the product groups of Kramp and the found effects can be found in Appendix K.

Table 24 Primary actions against unhealthy stock

Action	Targeted SKUs (% total)	Targeted excess value
Reevaluate MOQ	3245 (6.1%)	-
Improve end of life strategy	14011 (26.16%)	-
No action needed (100% IQR according to Slim4 purchase forecast)	9040 (16.9%)	€1,032.7K
No action needed partly (Better IQR according to Slim4 purchase forecast)	5797 (10.8%)	€1,887.3K
No action needed partly (Worse IQR according to Slim4 purchase forecast)	2370 (4.4%)	€573.6K
No action needed (partly) (No Slim4 purchase forecast)	18820 (35.1%)	€2,763.2K
Stock transfers	3677 (6.9%)	€1,733.7K
Kramp Market	1028 (1.9%)	€ 313.1K
Sell to last customer	7279 (13.6%)	€372.7K
Return to supplier	924 (1.7%)	€1,157K
Scrap articles	29059 (54.2%)	€2,350K

From Table 24 it may be noted that the cumulative percentage of targeted SKUs exceeds 100%. This phenomenon arises because certain SKUs are involved in multiple actions. The reason for this overlap is twofold: either the SKUs were not completely resolved by a previous action, or there is uncertainty about the effectiveness of these actions.

In addition it may be noted that no event action is formed, while there's a cause regarding panic buying during COVID, which is an event. That is because within Kramp after the ending of COVID multiple checks have been put in place, so that not one person can decide whether this absurd amount should be ordered or not. So, therefore there's already an action in place to address this, which shall not be addressed here.

6.1.1. Reevaluate MOQ with supplier, find other supplier or replacement product.

The analysis identifies high MOQs as a significant contributor to Excess Inventory Value (EIV). Consequently, reevaluating MOQs with suppliers, exploring alternative suppliers, or considering different replacement SKUs becomes a worthwhile action. However, the feasibility of these options must be assessed, as they do not directly reduce existing overstock in the warehouse.

This strategy, when applicable to certain SKUs, should involve collaboration with the Procurement department to determine its practicality. If reevaluation of MOQs is not viable, subsequent actions in the inventory management plan are to be pursued. Thus, SKUs with high MOQs will be systematically addressed through these subsequent measures.

6.1.2. Adress better End-of-life strategy.

A significant number of SKUs have not seen demand for two years, largely because of an absent effective end-of-life (EOL) strategy. An EOL strategy needs to be formulated to address SKUs before demand disappears, as opposed to the current approach of reacting after demand has been absent for years. This strategy requires collaborative development by the supply chain and product management teams, responsible for these processes.

By establishing a proactive EOL strategy, the organization can better manage SKUs anticipated to lose demand, minimizing the buildup of SKUs without demand. Those SKUs currently lacking demand will be managed through follow-up measures.

6.1.3. No action needed

Many of the articles with excess values in Kramp's inventory are expected to naturally resolve their surplus within the next year. Therefore, immediate action to reduce these values in the warehouse is often unnecessary, as long as adherence to Slim4 advice is maintained.

Slim4 continuously monitors future stock levels, including incoming orders and demand, on a weekly basis for numerous SKUs. This monitoring enables an assessment of whether an SKU is underperforming and if it is likely to return to optimal performance in the upcoming year.

Assessing average future stock levels, along with projected maximum and minimum levels, helps in determining the likelihood of an SKU returning to its optimal range and understanding the associated values. The process includes several checks to identify if no action is needed:

- The SKU is purchase forecasted by Slim4, signifying that Slim4 predicts incoming expected orders and future demand. This allows for the assessment and determination of future maximum inventory and inventory levels
- The SKU is expected to return to its optimal inventory range within a year, resulting in a future IQR of 100%. Therefore, no further actions are required.
- The current IQR of the SKU is lower than 100%, signifying that it is currently in suboptimal performance.

Table 25 No action needed where IQR becomes 100%, and values linked back to primary causes.

Remainder no action	No Demand	Stable Demand	Decline Demand	High MOQs	AVG Current IQR	AVG Future IQR
€ 471.2K	€ 0.0K	€ 468.5K	€ 93.0K	€ 0.0K	67%	100%

Table 25 indicates that a substantial part of Kramp's unhealthy inventory value is either unlinked to a primary cause or associated with stable demand, which is expected to self-correct as assumed in the primary cause itself. In contrast, a smaller portion of SKUs with declining demand may naturally improve, but this is less likely due to the downward trend in performance. Notably, SKUs with no demand and high MOQs are unlikely to resolve themselves, suggesting the need for proactive actions.

While the mentioned SKUs in those groups are expected to reach their acceptable ranges, other SKUs may move closer to the acceptable ranges, while following slim4' order advice. Therefore, the second assessment focuses on SKUs that do not reach the 100% IQR but achieve a better IQR than the current status.

Table 26 No action needed where IQR becomes better but not 100%, and values linked back to primary causes.

Remainder no action	No Demand	Stable Demand	Decline Demand	High MOQs	AVG Current IQR	AVG Future IQR
€ 670.9K	€ 0.0K	€ 930.8K	€ 278.7K	€ 6.9K	43%	59%

Table 26 indicates most of the inventory value is linked to SKUs with stable demand, which are effectively reducing their excess values. This pattern mirrors the distribution towards complete healthiness, but uniquely includes SKUs with high MOQs. The ongoing demand for these SKUs contributes to diminishing excess values, enhancing the overall IQR. However, these SKUs, still showing excess values as it doesn't reach 100% IQR, will require proactive actions and will be present in subsequent actions.

Additionally, there are SKUs that fail to attain a better IQR due to an overall decrease in demand, leading to a reduction in the maximum allowed inventory. Consequently, excess value persists, albeit at a lower level than the present as there's still okay demand, but the rate of decline in active inventory is more rapid.

Table 27 No action needed where IQR does not become better, but excess value does decrease.

Remainder no action	No Demand	Stable Demand	Decline Demand	High MOQs	AVG Current IQR	AVG Future IQR
€ 239.8K	€ 0.0K	€ 83.1K	€ 247.1K	€ 3.6K	55%	37%

Table 27 shows that SKUs with declining demand are experiencing a decrease in overall excess value. However, the rate of demand decline is outpacing this reduction, leading to a lower Inventory Quality Ratio (IQR) despite the diminished excess value. SKUs listed in this action list will have remainder excess value and require proactive actions.

Finally, Table 28 also highlights SKUs that are not purchase forecasted by Slim4, with the reasons for this being unknown. By examining SKUs not included in previous 'no action' lists and assessing whether their excess value is projected to self-resolve within a year based on forecasts, these SKUs are identified. A critical assumption in this analysis is that these SKUs will not be reordered during this period.

Table 28 No action needed where SKU is not purchase forecasted by Slim4.

Remainder no action	No Demand	Stable Demand	Decline Demand	High MOQs	AVG Current IQR	AVG Future IQR
€ 1,094.0K	€ 0.0K	€ 310.7K	€ 959.6K	€ 398.9K	48%	64%

Now that all SKUs requiring either no action or partial action have been identified, a total excess value currently at approximately 6.3 million has been acknowledged. However, this implies that there is still approximately 10 million of excess value remaining, necessitating the implementation of additional actions.

6.1.4. Stock transfers

Certain SKUs, despite underperforming in the Netherlands, may find success in other warehouses. Therefore, implementing stock transfers could prove advantageous. To determine the optimal quantity for stock transfer, the following scenario is used:

- Look 12 months ahead at the respective warehouse and send potential inventory to the respective warehouse.

This timespan shows how much could be sent to the other warehouses based on the year's forecast, so that in all cases no more than a year of stock is present in those other warehouses. While it may not be the most optimal value for the receiving warehouse, it is preferred to keep the stock within the company that is already at Kramp and sell it. The process involves several checks to see what is possible inventory that could be transferred:

- If the SKU is present in no action needed, but excess value remains, then it can be used for stock transfers, else not.
- Verify if the SKU is sold in another warehouse and has a stocked status there; otherwise, it may not be stored there.
- There's still remaining excess value after DRP is subtracted. DRP is the stock that is already designated for the other warehouse.
- Check if the years forecast minus the inventory position of that warehouse is positive, indicating that additional stock is possible.
- Evaluate the value of inventory that could be sent against the transportation costs for that SKU to the respective warehouse. If the value is below the transportation costs, the SKU will not be transferred to that warehouse.
- In cases where multiple warehouses are viable options and the possible sent value is the same, the one with the lowest transportation costs is chosen.

Table 29 Transfer value linked back to primary cause found.

Remainder EIV	No Demand	Stable Demand	Decline Demand	High MOQs	AVG Current IQR	AVG Future IQR
€ 807.3K	€ 14.4K	€ 533.8K	€ 196.8K	€ 181.4K	22%	31%

Table 29 reveals that this is the first action that also addresses inventory with no demand as there's demand in other countries for it. However, this action leads to only a marginal increase in the overall IQR The reason for this modest improvement is that while SKUs eligible for transfer represent a significant value, not their entire value is accounted for. This is influenced by factors such as the forecast for upcoming years in that other warehouse and associated transport costs limiting SKUs with low excess values from being transferred entirely.

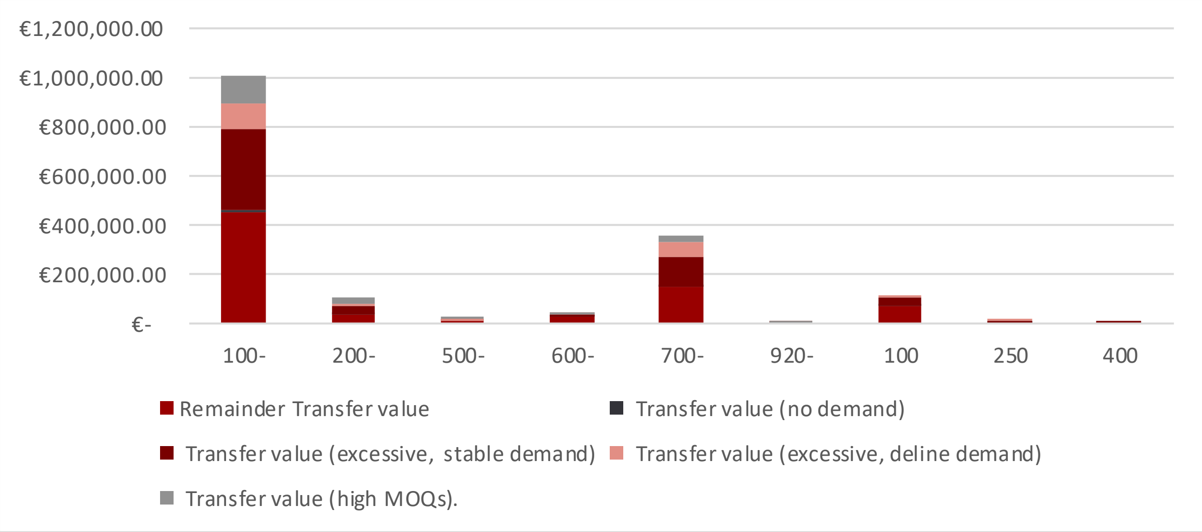

Figure 11 Amount of excess value that can be sent to their respective warehouse. From left to right Germany, Poland, Italy, UK, France, Spain, Denmark, Sweden and finally Finland.

Figure 11 indicates that a significant portion of the inventory value can be transferred to Warehouse 100- in Germany. This is an expected outcome, considering that Germany is Kramp's second-largest market and its proximity to the main warehouse in the Netherlands. The feasibility of this transfer is therefore supported by the substantial forecasted demand in Germany and the relatively low transport costs compared to other countries.

6.1.5. Sell through other methods

In addition to the conventional selling channels, additional methods could be used to sell the inventory. To find these other methods, relevant stakeholders were asked regarding the possibilities. vWithin Kramp there are currently two practices that go outside of the conventional selling method, these are:

- Kramp Market
- Sell to last (and only) customer

Choosing 'Kramp Market' and 'Sell to Last Customer' stems from their integration into Kramp's sales processes, making them immediately actionable. In contrast, other surplus inventory strategies need more development to be viable. These methods introduce uncertainty, relying on customer purchases through alternative channels, which adds variability to their effectiveness. This contrasts with previous strategies where outcomes were more predictable and under Kramp's control, meaning these SKUs may reappear in future actions.

Kramp Market

Kramp has its own marketplace where it can sell goods at discounts. Currently this sales channel is only used in Denmark, where it has shown its potential. By assessing the requirements that are taken there and following the decision tree (Figure 18) the following set of logic is set up to see whether a SKU is eligible for Kramp Market:

- If any previous actions result in remaining EIV, then that SKU should be considered for this action.

- It belongs to product groups 22, 24, 26, 32, 34, 36, 37, 38, 42, or 44. This is because articles in these categories are price-flexible, whereas in other product groups pricing is not flexible at all.
- The article should not be active on the webshop or there's a purchase stop. By having it inactive on the Kramp webshop, customers would need to visit the Kramp marketplace, where the item is exclusively available at a discounted price. If on purchase stop means that Kramp will not buy it again and therefore it can be offered to customers at a discounted price.

Table 30 Excess value that can be used for Kramp Market.

Remainder EIV	No Demand	Stable Demand	Decline Demand	High MOQs	AVG Current IQR	AVG Future IQR
€ 313.1K	€ 0	€ 0	€ 0	€ 0	1%	99%

Table 30 shows that inventory value isn't tied to the main causes identified earlier, as these causes relate to SKUs still active or not on purchase holds. While most inventory might fit Kramp Market, their success there is uncertain. Therefore, considering backup strategies detailed later in the report is wise. These alternatives offer ways to handle these SKUs, preparing for different outcomes in Kramp Market.

Sell to last (and only) customer

When certain articles are purchased by only a single customer in the last year, it suggests that the product may hold specific importance to that customer. Consequently, an approach is adopted to potentially sell these excess units directly to the last purchaser. This strategy capitalizes on the existing interest and relevance of the product to that specific customer, potentially facilitating a more precautionary sale.

- If any previous actions result in remaining EIV or there is uncertainty about their success, then that SKU should be considered for this action.
- The number of unique customers who bought the article in the last 12 months is 1.

To assess the potential for selling excess stock to the last customer, the analysis was stratified into multiple coverage periods: less than 1 year, 2 years, until even more than 5 years' worth of inventory. This segmentation was employed to test the likelihood of a customer accepting the excess inventory. Generally, the lower the years of coverage for that excess, the higher the likelihood that a customer would be inclined to acquire this excess inventory.

Table 31 EIV assessed for potential sale to the last customer, with its likelihood of success determined by the years of coverage.

YoC	EIV	AVG Future IQR
< 1 year	€ 372.7K	43%
1-2 years	€ 116.6K	52%
2-3 years	€ 70.6K	58%
3-4 years	€ 45.5K	61%
4-5 years	€ 35.0K	63%
> 5 years	€ 538.8K	100%

Table 31 reveals a wide range in inventory coverage for many SKUs, from less than a year to over five years. Adopting a conservative approach, this study assumes that customers are most likely to purchase EIV equivalent to no more than one year's inventory. The analysis will proceed with this value as a basis.

Table 32 Excess value that can be used for Kramp Market.

Remainder EIV	No Demand	Stable Demand	Decline Demand	High MOQs	AVG Current IQR	AVG Future IQR
€ 222.2K	€ 0.0K	€ 62.0K	€ 67.7K	€ 20.8K	6%	43%

Table 32 displays a notable rise in the average IQR, showing an increase of about 37%. Despite this improvement, a substantial EIV persists, as the analysis assumes one year's worth of inventory. Additionally, there remains an element of uncertainty regarding whether customers will choose to acquire this inventory. Consequently, even though some SKUs are addressed under this assumption, they may also be considered in subsequent actions due to this uncertainty.

6.1.6. Return to supplier

Some SKUs within Kramp's inventory may qualify for return to the supplier, particularly given the numerous return agreements Kramp holds with its suppliers. This is the first action where cost saving is chosen over possible revenue maximization. To determine the eligibility of a SKU for return, a specific logic is applied:

- If any previous actions result in remaining EIV or there is uncertainty about their success, then that SKU should be considered for this action.
- The supplier is not another Kramp warehouse. Within Kramp, there are instances where one warehouse supplies another. Therefore, sending an SKU back to its originating Kramp warehouse does not equate to returning it to the original external supplier.
- The article must have been delivered to Kramp within the last 12 months. SKUs that have been in inventory for longer than 12 months are not eligible for return to the supplier.
- The EIV of an SKU must exceed €200 for a return to be considered eligible for Kramp, given the associated processing costs. SKUs with an EIV below this threshold are not viable for return due to these costs.
- A return agreement with the supplier should be in place.

Table 33 Excess value that can be used for Kramp Market.

Remainder EIV	No Demand	Stable Demand	Decline Demand	High MOQs	AVG Current IQR	AVG Future IQR
€ 594.5K	€ 18.0K	€ 356.8K	€ 145.1K	€ 42.7K	31%	73%

Table 33 demonstrates that a considerable improvement in the IQR is achievable. However, it also reveals that not all excess inventory value is addressed, as the IQR improvement does not reach 100%. Consequently, a last-resort strategy is established to manage the remaining portion of excess inventory, aiming to further enhance the IQR to its full potential.

6.1.7. Scrap articles

Scrapping excess inventory is a last-resort option due to Kramp's limited budget and the total loss of product value it entails. Before deciding on scrapping, all alternative solutions should be exhausted. To find the best threshold for scrapping, eight thresholds were analyzed to see their impact on the EIV and IQR, aiming to determine the lowest threshold that maximizes the positive impact on the IQR.

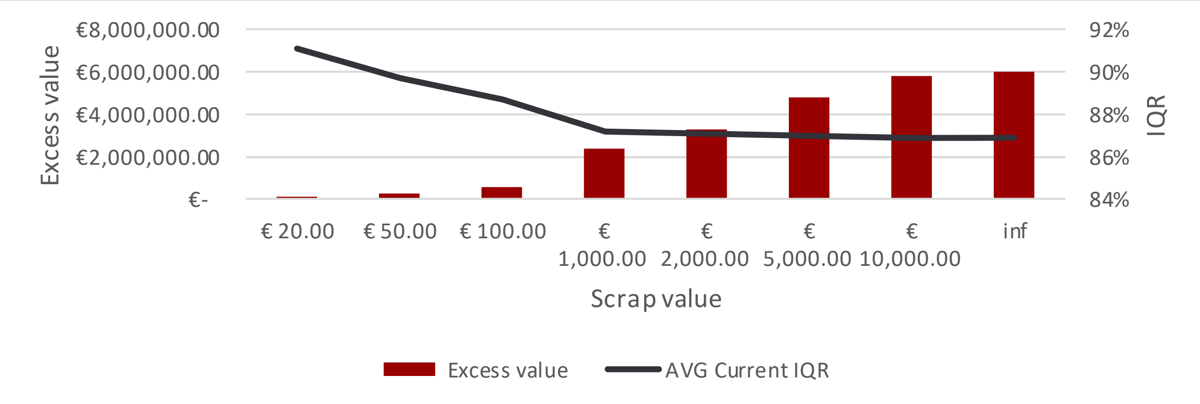

Figure 12 Resolved excess value per set scrap value.

Figure 12 illustrates that setting the scrap value at €1000 per SKU markedly improves the IQR, resulting in scrapping excess inventory worth €2.35 million and leaving €4 million in surplus. To manage the remaining excess, considering alternative sales channels or partnerships, subject to negotiation terms, is advised. Donations could be another avenue, requiring similar negotiation efforts. The selection process entails evaluating the potential partner's interest, engagement terms, and the appropriateness of each option. Should these alternatives prove impractical, scrapping remains the default solution.

6.2. Future versus current

Out of the identified 16.19M excess value, 12.18M has been addressed with these actions, leaving a remaining excess value of 4.01M in a year if no further action is taken. To project the IQR and ICI in a year, several considerations are necessary.

The future inventory level, estimated at 169,000 SKUs, is projected using Slim4's purchase forecast. For SKUs outside Slim4's forecast, future levels are assessed with current stock, this year's forecast, actions taken, and EOQ considerations. EOQ triggers when stock drops below the order level, aiding in annual inventory projections minus action values. Note that product creation or deletion isn't factored in, possibly skewing total stock projections, although existing SKU accuracy is maintained assuming actions succeed.

Table 34 IQR current versus in 1 year.

Time	Inventory Value	Active Inventory Value	Excess Inventory Value	IQR
2023-12	67.24M	51.05M	16.19M	75.90%
2024-12	56.47M	52.46M	4.01M	92.90%

Table 34 shows a large increase in IQR, if all actions went successfully. The overall goal of 95% is not yet reached due to existing excess inventory value as it is not all addressed in the actions. Therefore, additional actions should be sourced.

Now, also the future ICI can be discussed as certain SKUs move towards the okay range as some remain in excess and shortage. The shortage remains, as discussed in this study, they were left untouched from the actions due to close monitoring form stock controllers and product specialists.

Table 35 ICI current versus in 1 year.

Time	Shortage	Active	Excess	SKUs	ICI
2023-12	14,645	205,607	53,552	273,804	75.09%
2024-12	3820	266,276	3708	273,804	97.25%

Table 35 highlights a reduction in shortage units compared to current levels, not covered in this study because adherence to the Slim4 purchase forecast might order these SKUs, potentially avoiding shortages not considered in the primary analysis. This could result in actual shortages being higher within a year. Despite improvements in the IQR and ICI in both scenarios, achieving the 95% goal is hindered by unaddressed shortages and persistent residual excess.

Furthermore, a review of the top 1000 underperforming SKUs reveals that 645 remain problematic, underscoring their status as significant underachievers due to the inability of current strategies to fully mitigate their excess or shortage issues. The excess value of these SKUs stands at approximately €7.2M, with an anticipated residual of €2.7M in a year without additional actions.

6.3. Conclusion

In this chapter, the question "*What potential actions can be taken to mitigate or even eliminate these causes?*" is answered.

To enhance inventory management, six actions have been devised, with five directly targeting stock-related issues and one addressing upfront parameters. These actions include reevaluating MOQs with suppliers, exploring alternative suppliers or replacement SKUs, addressing better end-of-life strategy, determining if no action is needed, stock transfers, Kramp market, and considering options like selling to the last customer, returning to the supplier, or scrapping the article. The first action, involving MOQ reevaluation, necessitates careful collaboration with Procurement to assess its viability for the identified SKUs. The remaining actions directly tackle unhealthy inventory.

Out of the total identified excess value of approximately 16.19 million, these actions directly address 12.18 million. For the remaining 4.01 million, additional actions regarding finding different sales channels should be investigated. The viability of these actions can be determined through discussions with the relevant organizations.

Upon projecting the inventory value, a year from now, assuming the success of all mentioned actions, while 4.01 million remains and shortage unaddressed, an overall warehouse Inventory Quality Ratio (IQR) of 92.90% and Inventory Carrying Index (ICI) of 97.25% can be achieved.

7. Conclusion & Recommendations

This final chapter presents concise, point-by-point conclusions and recommendations derived from this study.

7.1. Conclusion

The study successfully met its objective of establishing transparency into the inventory health at Kramp's main warehouse, particularly in terms of main drivers of inventory levels and the effective capture of these insights and how to address them.

- **Successful KPI Implementation:** The research successfully used the KPIs Inventory Quality Ratio (IQR) and Inventory Control Index (ICI), capable of identifying unhealthy inventory, demonstrating a tangible inventory health analysis. The current status of Kramp is an IQR of 75.90% and an ICI of 75.09%, which means that three quarters of inventory is well aligned with future needs, while one quarter of inventory is not.
- **Effective Main Drivers Identification:** Through the application of Multi-Criteria Decision Analysis (MCDA) and a structured root cause analysis approach, the research effectively identifies the main drivers of current inventory performance, providing a clear and structured approach to understand and find underlying issues of unhealthy inventory. These main drivers are panic buying during COVID, high MOQs, no demand present, and cautious and no ordering of inventory.
- **Development of Structural Action Approach:** The research has developed a structured approach that can be applied by companies to improve their IQR and ICI, which can be found in Figure (10), showcasing a practical method to enhance inventory management and address the underlying issues. These actions are categorized to external events, company strategies, parameter based issues, and targeted unhealthy value actions. These actions are, in order; revaluate MOQ, no action needed, stock transfers, Kramp market, sell to last customer, return to supplier and finally scrap the article. By successfully adhering to the action approach in Figure (10) an IQR of 92.90% and ICI of 97.25% can be achieved in the last month of 2024.

7.2. Recommendations

This section presents a series of strategic recommendations designed to address the identified issues with unhealthy inventory at Kramp Netherlands BV.

- **Address MOQ Issues with Procurement:** Collaborate with procurement teams to reevaluate MOQ agreements. Negotiate adjustments to align better with actual demand and inventory turnover, aiming to mitigate overstocking risks.
- **Adress new end of life planning process:** Collaboration between supply chain management and product management is needed to setup an improved end of life planning process, to reduce SKUs accumulation that have no more demand in the future, aiming to mitigate overstocking risks.
- **Follow the Established Action Plan in Figure (10):** Adhere to the action plan developed for addressing inventory issues and improving Inventory Quality Ratio (IQR) and Inventory Control Index (ICI). Ensure the plan is implemented effectively to optimize inventory health.

- **Regular Review and Adaptation of Strategies:** Introduce a monthly review process involving stock, supply chain, and product management to evaluate and adjust strategies based on market changes or performance metrics. This frequency aligns with some of Slim4's monthly parameter updates.
- **Increase Sales Channel Diversification:** Explore and establish more alternative sales channels, including online marketplaces, B2B platforms, or donations, to facilitate the movement of inventory, especially slow-moving items.
- **Reduce forecast horizon for SKUs with unstable demand:** Currently, the forecast horizon for all SKUs is one year, given this is Kramp's first inventory assessment. After achieving over 90% IQR, the forecast period for SKUs with unstable demand can be shortened to more accurately reflect fluctuations in demand across different periods.
- **Refine and Expand KPIs**: Develop additional KPIs within the MCDA framework, focusing on areas such as supplier performance, lead time variability, and profitability. These KPIs will provide a more comprehensive view of SKU performance within the company.

7.3. Reflection

This section reflects upon personal and methodological learning from the process of research, and emphasizes growth in understanding, methodological insights, and challenging moments.

- **Assumptions:** Initial assumptions in this study is that parameters would have had a higher effect on inventory levels, but events and certain strategies appeared to have higher effects at the moment.
- **Personal Insights:** This study also provided me with a better understanding of inventory. What kind of inventories, how does a company manage it, what are right levels of inventory, and so on. In addition new skills regarding developing a method to evaluate inventory even further has been developed, which can be used at later stages of my life.
- **Methodological insights:** The methodologies gave a good initial insight into the inventory performance. The strength of my approach that it is easy to implement for any company facing having no insight into inventory performance. The weakness of my approach is that it might also be too general, as more segmentation and differentiation could provide even better inventory management.
- **Challenges:** While Kramp could provide an abundance of data, either through Slim4 or other data collection methods, sometimes a name of a column was different than the name of the method where it was collected from. This gave sometimes confusion, which was later found out after talks with people within the company who had more knowledge about this.

7.4. Limitations

The limitations section critically examines the constraints and challenges encountered in the study.

- **Limited aggregation:** This study only addresses inventory health on a daily and monthly basis. Therefore results may be subjected on how the inventory was on that particular moment or very brief aggregated moment.
- **Time constraint:** Due to time constraints not more causes have been found that are presumably present.

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