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David Pereira Martins Ribeiro

Implementation of a holistic strategy to improve the categorization and management of non-value-adding inventory

Universidade do Minho
Escola de Engenharia

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Trabalho efetuado sob a orientação do (a)
Professora Maria Sameiro Faria Brandão Soares Carvalho
Professor João Nuno Costa Gonçalves

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STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration.

I further declare that I have fully acknowledged the Code of Ethical Conduct of the University of Minho.

RESUMO

A presente dissertação aborda a melhoria do modelo de **planeamento de inventário** para uma empresa internacional cujo *core business* está focado na Indústria do Sono – **Emma, The Sleep Company**. É realizado no âmbito do Mestrado em Engenharia e Gestão Industrial, estando particularmente relacionado com a área da Logística.

Foram identificados aspetos críticos no estudo, tais como o considerável **excesso de stock**, a complexidade da gama de produtos, os picos incertos de procura devido a estratégias agressivas de promoção, a dificuldade de monitorizar e gerir produtos obsoletos ou expirados, ou a dependência de entidades externas para processos de manufatura ou armazenamento. O foco do estudo pode ser dividido em alguns objetivos principais:

1) Compreensão do **contexto atual** e identificação das ineficiências mais relevantes.
2) **Categorização** e **automatização** da identificação de inventário sem valor acrescentado.
3) Definição de uma **estratégia holística** que promova a redução de inventário, com enfoque em inventário de valor não acrescentado.
4) Definição de um plano de ação de um **projeto-piloto** que promova a implementação da estratégia.
5) Avaliação de resultados e discussão acerca dos **riscos e oportunidades**.

Inicialmente, o estudo começou por examinar os processos existentes e abordar as suas ineficiências, tendo evoluído para uma estratégia abrangente de minimização de inventário sem valor acrescentado, marcando uma mudança crucial na sua orientação. A identificação de excesso, obsolescência e expiração de inventário foi desenvolvida através de modelos automatizados, que promoveram uma redução significativa **de 50% dos custos de inventário** para situações sinalizadas, totalizando **poupanças** de **766K €** num projeto piloto de dez semanas. A estratégia exigiu a criação e mapeamento de **sete processos**, que permitiram o envolvimento de mais de **20 *stakeholders***.
O estudo destacou como elementos essenciais para a progressão nesta área a evolução da **qualidade de dados** e a melhoria das metodologias de **comunicação e colaboração** entre equipas.

PALAVRAS-CHAVE

Logística; Gestão de inventários de valor não acrescentado; Gestão da informação; Comunicação e colaboração.

ABSTRACT

The present dissertation approaches the improvement of the **Inventory Management System** for an international company whose core business is focused on the Sleep Industry – **Emma, The Sleep Company**. It is conducted in the framework of the Master's Degree of Industrial Engineering and Management, being particularly related to the field of Logistics.

Critical aspects that have a significant impact in the costs of the company can be tackled, such as the considerable excess of stock, the complexity of the product range, the uncertain peaks of demand due to aggressive promotion strategies, the difficulty of monitoring and managing obsolete or expired products, or the dependency on external entities for manufacturing or storing.

The motus of the current study can be broadly divided in some major objectives:

1) Understanding of the **current context** and identification of the most relevant **inefficiencies**;
2) **Categorization** and **automation** of the identification of non-value-adding inventory;
3) Definition of a **holistic strategy** that fosters inventory reduction by targeting non-value-adding inventory;
4) Definition of a **pilot-project** action plan that designs the implementation of the strategy;
5) Evaluation of results and discussion about **risks and opportunities**.

Initially, the study began by examining existing processes and addressing inefficiencies, but gradually evolved into a comprehensive strategy to minimize non-value-adding inventory, marking a crucial shift in its objectives. The identification of excess, obsolete and expiring inventory was developed through automated algorithms, which promoted a significant **50% reduction of inventory costs** for targeted critical situations, totalizing **766K € savings** after the implementation of a ten-week pilot project. The strategy required the creation and mapping of **seven processes**, that required the involvement of more than **20 stakeholders**.

The study highlighted as key-assets for quality progression among this field the evolution of **data quality** and the improvement of the methodologies of **communication and collaboration** within teams.

KEYWORDS

Logistics; Non-value-adding inventory management; Information management; Communication and collaboration.

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ACRONYMS

AHP - Analytic Hierarchy Process

CAGR – Compound Annual Growth Rate

DGAE - Direção-Geral das Atividades Económicas

DL - Desired Level

DP - Demand Planning

D2C – Direct-to-Consumer

GE – General Electric

GRC – Governance, Risk and Compliance

IAIA - International Association for Impact Assessment

IP - Inventory Planning

ISO – International Organization for Standardization

JIT – Just in Time

KPI – Key Performance Indicators

MCDA – Multi-Criteria Decision Analysis

NVA – Non-Value-Adding

OOO – Out-of-Stock

OP - Observing Parameter

RPN – Risk Priority Number

RQ – Research Question

S&OP - Sales & Operations Planning

SCM - Supply Chain Management

SCQM – Supply Chain Quality Management

SKU - Stock Keeping Unit

S&OP – Sales and Operations Planning

SO99+ – Sales & Operations Planning Service Optimizer

TOC - Theory of Constraints

1. Introduction

The present dissertation approaches the improvement of the Inventory Management System of an international company whose core business is focused on the Sleep Industry. The purpose of the study is dedicated to understanding what are the main factors that drive the inefficiencies of the system, and it is expected that Non-Value-Adding (NVA) Inventory plays an important role on them. There is the aim to understand and assess the potential positive impact of targeting NVA Inventory reduction. The following sections will explain the structure of the dissertation, deep diving into the problem statement and the research questions.

1.1. Background

Markets are increasingly competitive; the final customer is more demanding, and the time required to respond to their expectations and needs must be as short as possible. To be able to keep up with this evolution, organizations need to invest in the modernization of products, processes, technologies and adopt strategies that allow the reduction of costs (Mentzer & Williams, 2001).

Supply Chain Quality Management (SCQM) is defined as "The formal coordination and integration of business processes involving all partner organizations in the supply channel to measure, analyse and continually improve products, services, and processes to create value and achieve the satisfaction of intermediate and final customers in the marketplace" (Robinson & Malhotra, 2005).

For this reason, SCQM has been recognized as one of the most important ways to respond rapidly, correctly, and profitably to market demands (Wang & Zhang, 2006). As a summary, Xie et al. (2011) argues that supply chain quality is a key component in achieving competitive advantage and organizations need to redefine the way they develop relationships and synergies with their customers by adopting innovative ideas to respond to market updates (Leparachão, 2014).

According to Moura (2006), Logistics is a set of methods that coordinates the movement of products and what is associated with them. A good management of logistics, that improves cooperation between suppliers and clients is vital, so that products can be delivered at the right place and time, with the proper quantities and conditions. Inventory policies have then a considerable impact in the way a company manages their stock levels (Chopra & Meindl, 2015).

Maintaining the appropriate level of inventory to ensure that demand is matched without incurring in unnecessary inventory ownership costs is a factor of high importance in the management of logistics operations (Rabbit & Laporte, 2014).

Uncertainty is revealed as one of the major problems in Supply Chain Management (SCM), and it is also inevitable (Gonçalves et al., 2020). Its existence may be related to demand volatility, sales seasonality, or lack of historical data (Thomassey, 2010). According to Ashok (2013), the objective of inventory management is to avoid its excessive presence or shortage so that production and sales occur uninterrupted, promoting cost minimization and better customer service. In terms of cash flow, Lummus & Vokurka (1999) state that stock accumulation has an impact on a company's financial management, preventing the availability of products at lower prices.

As summary, the introduction of this study can highlight the relevance of Logistics, as a key-asset in what regards to SCQM. When discussing topics such as Logistics or Supply Chain it is imperative that one explores the fields related to inventory and stocks optimisation. The efficiency of processes to manage inventory is highly necessary, according to the financial and operational impact it has.

The work presented in this dissertation addresses the broad and demanding challenge of **defining countermeasures and action plans** that can mitigate the negative effect of the inefficiencies that the **current set of processes regarding Inventory Management** at Emma, The Sleep Company faces. It is inserted in the field of the Inventory Planning (IP) Team but requires the connection and understanding of multidisciplinary roles or procedures from various departments within the Operations Area. The main responsibilities of the IP Team consist of seeking the most accurate definition of inventory targets, respecting the dichotomic mindset of minimizing holding costs of inventory, while achieving high service levels. It establishes the need to simultaneously meet customer demand and satisfaction, while reducing the resources applied by the company to the lowest. The evaluation of the quality of inventory is a responsibility as well, meaning that the identification and categorization of inventory according to the age, rotation or prediction of selling shows up as a remarkable role of the department too.

The need to develop this study comes from an internal desire of **reducing the impact of the inefficient holding of inventory, especially due to the strong financial impact that it adds and due to the lack of capacity of storage** that the warehouses have faced in previous high-demand seasons, according to historical information. There are several root causes that can be contributing to the low operational efficiency of the overall process, and multiple solutions that can help improve flexibility and cash-flow optimisation.

The study will consist of an end-to-end analysis of the possible causes and solutions, delving into literature review to understand traditional patterns and strategies to enhance this topic. Further on, a generalist analysis of the current situation will be developed, where the main concerns will allow the study to be driven to the improvement activities.

1.2. Context

The following sections will introduce a contextualization of the company. First, a market research will be developed, to understand the current situation of the Sleep Industry, diving into different countries to better describe the analysis. Second, the current Inventory Management Policy of the company will be explained, since important concepts related to the scope of the study must be presented.

1.2.1. Market Research

The core business of the company where the internship is developed is inserted in the Sleep Industry. The Sleep Industry encompasses various sectors and businesses involved in the production, distribution, and sale of sleep-related products and services. It includes not only sleep brands but also mattress manufacturers, bedding companies, sleep technology providers, sleep clinics, sleep consultants, and even wellness brands that offer sleep-related products or services as part of their services.

The Sleep Industry is the trade of any product or service connected with sleep improvement. It encompasses products and services aimed at improving sleep quality, including items like mattresses, pillows, sleep devices, medications, and wellness programs. Entrepreneurs have been recognizing the demand for innovations to combat sleep deprivation, and as awareness of the significance of sleep grows, this industry is gaining popularity (Hutt, 2023).

Numerous research studies and government initiatives are dedicated to enhancing public awareness regarding the significance of sleep across various countries. The growing recognition of the importance of sleep has led to a surge in demand for preventive care products, including smart bedding and other related devices. These technological advancements in sleep-related solutions cater to the needs of individuals seeking to optimise their sleep experiences and promote overall well-being (Arizton Advisory and Intelligence, 2021).

The sleep economy is projected to grow at an annual rate of 6,3 %, which shows a "vivid image of a booming industry, poised for unprecedented growth" (Gitnux, 2023). In addition, the same authors state that the estimated growth of the global sleep aids market shows a widespread prevalence of sleep disorders and highlights a trend to attract and inspire entrepreneurs to build and shape the future of the Sleep Industry.

Leader (2019) states that sleep has become a commodity, which customers aim to acquire and possess, considering it a road to personal salvation. But since discussing the Sleep Industry might deviate the analysis to the evaluation of historical sleep awareness, or to the correlation between occupation or industry and quality of sleep (Luckhaupt et al., 2010; Jackson et al., 2013; Dorrian et al., 2011), the focus of the market research will be oriented to the mattress industry, which can properly represent the consumer attention placed upon the quality of sleep (Gitnux, 2023), since it is one of the most popular products regarding historical and predictive sales (Hutt, 2023).

The United States Sleep Products Market is expected to grow by US$ 2.07 billion during 2020-2026, progressing at a Compound Annual Growth Rate (CAGR) of 4.1% during the forecasted period (Gen Consulting Company, 2020). The mattress market in Germany saw a steady growth in the period of 2017-2021, and the market is expected to grow at a robust CAGR in the forecasted period (Ken Research, 2022). The German mattress market is currently experiencing growth, primarily driven by factors such as increasing disposable income, urbanization, and the expansion of the healthcare and hospitality sectors. Furthermore, government initiatives have played a role in fostering this growth. The market exhibits a moderate level of fragmentation, with numerous players vying for market share. Over the past decade, the German mattress market has witnessed significant expansion, with the emergence of online retailers offering greater convenience compared to traditional channels. Notable online start-ups are fiercely competing with brick-and-mortar merchants, while also expanding their product ranges to cater to diverse customer needs. However, despite the success of online retailing, it is worth noting that a substantial portion of German consumers (around 80%) still prefer to physically test mattresses before making a purchase decision (Mordor Intelligence, 2023).

The mattress sector in Portugal confirms the trend as a highly significant sector within the broader sleep market. In the Appendix 1 – Introduction and Literature Review, Figure 36 explains the categorization of the mattress sector under the Furniture Industry (Direção-Geral das Atividades Económicas (DGAE), 2016).

The mattress market is a sector from the Furniture Industry, but does not represent a significant share of the companies of the industry or the Gross Added Value (GAV), as can be seen in Figure 1. Further on, one can see that the Furniture Industry has an average turnover of 1% of the Gross Domestic Product (GDP) considering data from 2010 to 2016, as can be seen in Figure 2. From the figures, one can conclude that currently the sector does not represent a significant share of the overall economy. Although, a deeper investigation promoted the belief that the mattress sector is experiencing a significant growth.

Firstly, there has been an increased awareness of the importance of sleep health among consumers, leading to a greater emphasis on investing in quality sleep products, including mattresses (Martins et al., 2019 ; David et al., 2020). Additionally, changing consumer preferences and evolving lifestyles have driven demand for innovative mattress designs and features that cater to individual needs and preferences. Furthermore, advancements in technology within the industry, such as smart mattresses and sleep tracking devices, have contributed to the growth of the market by offering enhanced comfort and personalized sleep experiences (Costa, 2022 ; Sousa, 2022). The mattress market is poised for continued expansion in the coming years, as these factors continue to shape consumer behaviour and drive market growth.

In Portugal, this is a sector composed mainly of small and medium-sized enterprises, with microenterprises accounting for 86.7% of the total. The companies are largely concentrated in the Northern region of the country, representing 64% of the sector's total, followed by the Central region with 20% (Catarina & Albuquerque, 2017).

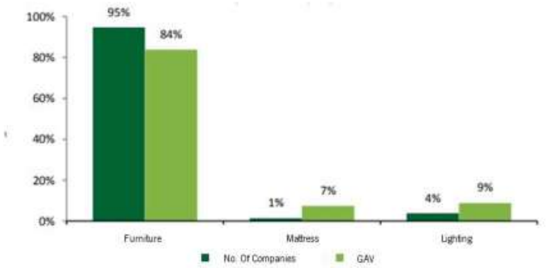

Figure 1 - Distribution of Companies by Sector, (DGAE, 2016)

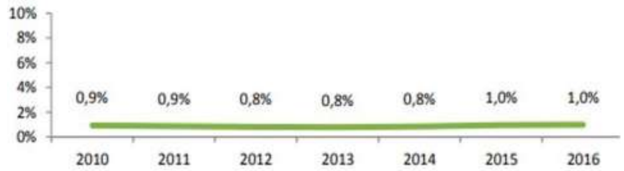

Figure 2 - Evolution of Turnover (% of GDP), (DGAE, 2016)

After understanding the basics of the industry where this study is developed, the research will be directed to a more specific framework, with the introduction to the characteristics of the Inventory Management Policy of the company.

1.2.2. Inventory Management Policy

Inventories exist because of variations in the flow and quantities of supply and demand (Slack et al., 2013). Managing inventory is not linearly straight-forward, and supply chains can be considerably floatable and unpredictable, influenced by the variability of demand over time, relatively to the predictive forecast, or by the uncertainty of supply comparing with the established agreements or negotiations (Poorvaezi-Roukerd et al., 2021).

In one hand, increasing uncertainty in demand tenderly requires rising inventory levels to maximize profits (Porteus, 1990). On the other hand, ascending uncertainty in supply provokes the increase of inventory levels as well (Song et al., 2010).
To deal with uncertainty and unforeseen events, inventory policies come up to support the definition of safety buffers, which represent levels or thresholds of inventory to limit its analysis and improve accurate decision-making (Bertazzi et al., 2002).
According to Strohhecker & Größler (2019), there is not a "one-size-fits-all approach to inventory management". The study found situations where assuming high inventory levels and holding costs was better than incurring in stock-outs, loosing demand or contribution margin, while slight changes of the characteristics of the products would favour lean inventories to become more advantageous.
Periodic Review and Order-Up to Level (R, S) is the policy followed in the context of the study and requires that ordering products occurs periodically, based on a fixed review period and up to a previously defined inventory level. That is, at the beginning of each review period there is an order in variable quantity, so that the desired target is reached (Vandeput, 2020).
The inventory policy requires that in constant intervals of r periods, a replenishment order that raises the inventory position to the target order level S is launched (POM Prof. Tempelmeier GmbH, 2018). In this way, the quantity to be ordered can be described by Equation 4, and the curve that better describes the pattern of inventory can be seen in Figure 37, both in the Appendix 1 – Introduction and Literature Review.
Regarding the scope of this study, the unit measure of the variables of the previously mentioned formula is in weeks, meaning that the current stock represents the stock coverage, which is defined by the number of weeks the stock will last, according to the forecast (Mecalux, 2022).
As summary, this type of policy is advantageous since it allows the company to group orders with each of the suppliers. The planning of orders and distribution of work occurs in a more organized and anticipated way. However, it might be insufficient because it does not allow review - and its order - in the interval between two periods. If there is a stock outage between review periods, there is a likelihood that the company will not be able to meet demand (Vandeput, 2020).
As mentioned previously, the most relevant actions of the IP Team – where this study is inserted – are related to the definition and analysis of inventory targets, with the aim of maximizing service levels and minimizing holding inventory. The current Inventory Management Policy of the company is intimately connected with this purpose, being the most significant foundation of the work of the team. To understand several concepts and measures that might influence the Inventory Management System, the basis of the Inventory Management Policy must be understood.

1.3. Objectives

The global challenge in which the dissertation focuses on consists of improving the company's Inventory Management System, which can be defined as the set of processes and measures applied to **improve the overall efficiency of stocks' management**. The main focus of the study will target NVA Inventory. The broad goals of inventory management can be described as aiming an accurate definition of the inventory parameters, while achieving the target service levels and minimizing holding costs of inventory. Keeping this vision in mind, the overall problem statement can be translated as follows:

- What measures should be applied to minimize inefficiencies on the Inventory Management System, that historically led to difficulties in facing high-demand peaks, contributing to holding significant costs of inventory and insufficient capacity to storage new stock?

The problem statement above can be segmented in the following Research Questions (RQ). Research Questions 1 and 2 are subdivided into more specific questions.

RQ1: How can inventory optimisation be pragmatically implemented and what are the options when trying to reduce inventory and increase storage capacity?

- **RQ 1.1:** What is the academic perception on inventory optimisation and what are the common strategies suggested to foster inventory reduction?
- **RQ. 1.2:** What criteria or tools should be utilized for inventory classification and what is the potential impact of such categorization?

RQ2: What factors can be currently contributing to the low efficiency of the Inventory Management System applied by Emma?

- **RQ 2.1:** What is the current situation of the study regarding the improvement fields highlighted in the Literature Review?
- **RQ 2.2:** Which constraints might be causing the inefficiency of the Inventory Management System and what relation do they have with the improvement fields highlighted from the Literature Review?

RQ3: How impactful can be targeting NVA Inventory, in order to increase capacity and reduce stock cost?

By addressing the problem statement and the research questions, the following sub-objectives should be achieved.

- Understanding the traditional journeys of investigation of inventory management inefficiencies from an academic framework;
- Understanding the company's current replenishment processes, meaning the current definition of inventory parameters and target service levels;
- Analysis of operational constraints, such as inbound and outbound capacities, and warehouse storage capacities;
- Identification of the most significant causes that currently deviate the company from achieving the desired capacity and costs;
- Development of a tool that automates the categorization of products according to their ABC Analysis, to quantitively define the service level inputted for the definition of inventory parameters.
- Identification and Categorization of NVA Inventory;
- Definition of action plans to mitigate the impact of the highlighted root causes and to improve the operational and financial situation of inventory;
- Implementation of a pilot-project with the designed action plans and identification of risks and opportunities for the future of the strategy.

As mentioned previously, it is mainly expected that this study understands and evaluates the impact that the identification and targeting of NVA Inventory can have in the improvement of the efficiency of an Inventory Management System.

1.4. Methodology

To achieve the outlined objectives of the dissertation, a suitable research methodology needs to be pre-defined, tailored to the nature of the study. Considering the need to bridge scientific knowledge with existing organizational knowledge and tackle real-world problems, the chosen methodology is Action Research, which combines theory and action in a research approach (Morrison, 2017).

It is particularly relevant to this study as it allows for the integration of scientific knowledge with existing organizational knowledge, aiming to tackle practical challenges. By employing Action Research, one can bridge the gap between theory and practice, leading to transformative processes within the company. According to McNiff & Whitehead (2011) it promotes active engagement and collaboration between researchers and stakeholders, ensuring that the research outcomes are not only academically rigorous but also practically relevant.

Through ongoing participation and dialogue, Action Research enables the co-creation of knowledge and fosters a sense of ownership among those involved. This participatory and collaborative approach facilitates transformative processes within the company (Morrison, 2017).

The Action-Research cycle encompasses three crucial phases: a **diagnosing**, a **cycle of action** (action planning and action taking), and a **meta-phase** (evaluation and learnings), with each step in the action cycle having a corresponding meta-phase (Susman & Evered, 1978).

The **initial phase** involves understanding the research context and the intentions behind conducting the work. It also includes the critical analysis and characterization of the current situation. During the **cycle of action**, data collection, feedback, data analysis, action planning, action implementation, and evaluation take place. This iterative process ensures a continuous improvement loop. The **meta-phase**, known as monitoring, plays a vital role in assessing the knowledge generated throughout the Action Research process.

To execute the proposed topic effectively, various tasks are performed within the action cycle. The diagnostic phase is the starting point, involving data collection, stakeholder engagement, and a comprehensive analysis of the current situation. This phase is crucial for identifying key problems and their root causes. Following the diagnostic phase, the next step involves reviewing relevant literature and identifying specific subjects for in-depth study. These subjects encompass logistics, inventory management policies, inventory categorization, or excess and obsolete management. A diverse range of sources, such as scientific journals, articles, websites, and books, will be used during the research process. Based on the findings from the diagnostic phase and the literature review, action plans will be developed, according to the targeted inefficiencies. The implementation phase will put the planned actions into practice. This stage aims to optimise the performance measures identified during the diagnostic phase, enhancing productivity and overall effectiveness. The final phase involves evaluating and discussing the results obtained from the implementation. By comparing the pre- and post-implementation procedures, the effectiveness of the proposed measures can be assessed. If necessary, adjustments will be made to ensure the objectives align with the expected outcomes.

In summary, Action Research offers a powerful framework for the study, aligning the research objectives with the practical context of our dissertation. By adopting this methodology, a bridge between theory and practice is developed, while collaboration is promoted, and transformative processes within the organization are facilitated.

1.5. Structure

This dissertation consists of seven chapters, each serving a specific purpose in addressing the research topic comprehensively. The following provides a brief overview of each chapter:

Chapter 1: Introduction

In this chapter, the project is introduced, presenting the theoretical framework of the proposed topic, its objectives, and the methodology employed. The structure of the dissertation is also outlined, providing a roadmap for the subsequent chapters.

Chapter 2: Literature Review

The second chapter offers a comprehensive literature review necessary for the development of this project. It explores relevant topics that enable the interpretation of problems, their analysis, and the proposal of coherent and effective solutions. By implementing the insights gained from the literature, the viability of the proposed approach is established.

Chapter 3: Contextualization of the Case Study

Company Description, Diagnosis and Analysis of the Current Situation

This chapter focuses on describing the company where the internship took place to support the project's development. It discusses the company's group affiliation, the areas of business it operates in, and provides an overview of the Sales & Operations Planning (S&OP) Team, where the project is developed. Additionally, it presents a detailed analysis of the current inventory management situation and deep dives into the constraints that can affect the whole supply chain in the inventory field.

Chapter 4: Data-Driven Tools to Identify and Quantify NVA Inventory

Chapter four details the creation and implementation of the tools that aim to streamline the process of identifying excess, obsolete, or expiring inventory. It delves into the explanation of the data-driven tools that promote the creation of both Excess & Obsolete and Expiration Risk dashboard reports.

Chapter 5: NVA Inventory Management Holistic Strategy

It is dedicated to introducing and detailly explaining the set of processes that tackles the reduction of NVA Inventory, according to the output obtained from Chapter 4. It presents the complete process map that includes the theoretical approach that each vector of the unnecessary inventory should follow. A multi-criteria analysis allows the conceptual definition of the action plan that describes the pioneer implementation of this strategy, in a ten-week project. The strategy and correspondent pilot-project were thoughtfully designed to tackle the specific issues identified in the study, with the overarching goal of enhancing operational efficiency, reducing costs, and improving overall performance.

Chapter 6: Results and Discussion

The effectiveness and impact of the implemented actions are rigorously evaluated to ensure their alignment with the intended objectives and desired outcomes. This chapter goes through each of the progressive stages that were designed in Chapter 5, evaluating the obtained results by comparing them with the priorly calculated targets. A risk assessment is undertaken, so that the main hazards of the proposed strategy are identified, guaranteeing a solid and successful future implementation of the strategy, following the spotted-out opportunities.

Chapter 7: Conclusions and Future Work

The final chapter summarizes the conclusions derived from the research conducted throughout the dissertation. It highlights the key findings, implications, and recommendations arising from the study. Additionally, the chapter presents future work proposals, suggesting potential avenues for further research and development within the company.

By organizing the dissertation into these seven chapters, a comprehensive exploration of the research topic, its context, analysis, and proposed improvements, as well as future directions, are ensured.

2. Literature Review

This chapter focuses on conducting a literature review specifically centred around the research topic of inventory management. This review serves as a foundation for the current study, guiding the research questions and methodology employed throughout the dissertation.

The purpose of this review is to establish a scientific bridge between the knowledge obtained by the empirical experience of the internship and the theoretical learnings that academic studies provide. The objective of this review is to understand how relevant the identification and categorization of inventory is, particularly NVA Inventory, aiming to build a holistic strategy to improve its management inefficiencies.

It will start with a broader contextualization of the scope of the study, with a brief introduction to inventory management policies, diving forward into a more specific approach to understand the root causes that might avoid optimal inventory management execution.

2.1. Logistics and Supply Chain Management

Logistics and SCM involve the coordination and integration of activities within a network of organizations to ensure the efficient flow of goods, services, and information from the point of origin to the point of consumption. According to Christopher (2016), SCM encompasses the planning, execution, and control of various activities, including procurement, production, transportation, warehousing, and customer service.

Logistics and SCM play a vital role in enhancing overall organizational performance and competitiveness. Through effective management of the supply chain, companies can achieve cost savings, improved customer satisfaction, increased responsiveness, and enhanced profitability. As highlighted by Chopra & Meindl (2016), SCM enables companies to optimise processes, reduce lead times, minimize stockouts, and enhance collaboration with suppliers and customers, resulting in a sustainable competitive advantage.

In today's dynamic business environment, companies face several challenges related to Logistics and SCM. One of the key challenges is achieving supply chain visibility and transparency, as highlighted by Iakovou et al. (2015). Companies need real-time information about inventory levels, order status, and shipment tracking to make informed decisions and respond promptly to disruptions.

Inventory management is a critical pain point within Logistics and SCM. Companies strive to strike a balance between maintaining optimal inventory levels to meet customer demand while minimizing holding costs and obsolescence. The challenges include accurate demand forecasting, demand variability, lead time uncertainties, product range complexity, or coordinating inventory across multiple locations. As identified by Bowersox (2013), effective inventory management is crucial for minimizing stockouts, avoiding excess inventory, and ensuring efficient order fulfilment, thereby contributing to improved customer service and reduced costs.

In the following section, a description of typical measures that literature recommends as highly impactful to reduce inventory will be developed.

2.2. Effective Inventory Management

Inventory Management is critical to the management of an organization, due to the direct influence on profits and meeting customer demand (Beheshti, 2010). As deeply explained previously in the dissertation, the major goal of inventory management can be set as inventory reduction, which can mean space savings, personnel savings, technical equipment savings or simplification of logistics flow control (Krajčovič & Plinta, 2012). Minimizing the investment in inventory, while respecting the desired service levels, can be mentioned as a key objective.

According to Williams (2009), carrying costs accounts to 20-36% of the annual inventory costs. The author states that the most impactful ways to minimize inventory are reducing obsolete inventory, implementing ABC inventory management strategies, and reducing lead times.

Despite being a broad concept, in an article within the topic of inventory reduction, Bower (2011) argues the following practises as the most useful to reduce holding stock.

- Reduction of demand variability/ improved forecast accuracy;
- Examination of the components and parameters that drive inventory;
- Coordination and control of the production or operational capacity according to the inventory levels;
- Structural changes in the distribution and production network;
- Finished-Goods Stock Keeping Unit (SKU) rationalization/ component and raw ingredient reduction;
- Lean/ Just in Time (JIT)/ Theory of Constraints (TOC).

About recommendations, the author suggests the improvement of inventory quality, with its categorization as active, slow-moving, obsolete, and inactive or run-out mode. Low-quality inventory is set to be the common target for inventory consultants and can be classified in the following way:

- **Slow-moving inventory:** low volume of sales or consumption relative to on-hand inventory;
- **Obsolete inventory:** with no demand (residual finished-goods, or leftover components);
- **Run-out inventory:** combination of Finished Goods and Components that are still being sold, but clearly at the end of the product life cycle.

In addition, Beheshti (2010) presents the following corrective actions to target inventory reduction by improving the inventory control system:

- Definition of customer order decoupling point;
- Elimination and prevention of obsolete inventories;
- Increasing the accuracy of forecasting methods;
- Setting the control parameters according to the importance of material items;
- Implementation of control loops in pull inventory control systems.

Gossard (2003) starts by presenting ten actions and the estimated impact each has on inventory reduction. After categorizing and further on analysing the performance of each type of inventory, the study presents some action measures with the most expected impact, based on real case studies, being them:

- Identifying and reducing excess inventory;
- Revising and updating material ordering guidelines, with the analysis of inventory management policies and parameters;
- Using continuous improvement to monitor the progression of the previously mentioned points and to reduce slow moving and obsolete inventories.

When defining an inventory management strategy, Shoshanah & Roussel (2013) enhance the importance of aligning the company's goals with the supply chain strategies applied. Chae (2009) presents an explanation on why it is important to minimize the number of measures and monitoring Key Performance Indicators (KPIs) in order to be operationally effective.

Following these two guidelines, a compilation of the most cited measures to foster inventory reduction was created, so that a concise view on the next topics that this review will cover could be offered:

- Reduction of low-quality-inventory - henceforth nominated as NVA Inventory – and including:
    - **Excess Inventory:** before mentioned as slow-moving inventory;
    - **Obsolete inventory;**
    - **Expiring Inventory:** before mentioned as run-out inventory;
- Implementation of ABC Categorization strategies;

- Optimisation of the parameters related to the inventory management policy presented in Section 1.2.2, such as the reduction of lead times or variation of service levels;
- Migration to a more sophisticated Inventory Management Software System;
- Increasing forecast accuracy.

The following section will dive into the aforementioned measures, delving more detailly into inventory categorization, which embraces actions such as ABC Analysis or targeting NVA Inventory.

2.3. Inventory Categorization

Inventory categorization is the process of classifying or grouping items within a company's inventory based on certain criteria or characteristics. This categorization helps an organization better managing their inventory, by optimising the stock levels or reducing carrying costs. The following sections will approach inventory categorization developed through ABC Analysis and according to the value of the inventory, with a specific target in NVA Inventory: Excess & Obsolete, and Expiring Inventories.

2.3.1. ABC Analysis

Many businesses maintain a wide range of stored products within their inventory. However, not all products hold the same level of importance. The distinguishing factor lies in their higher turnover rate, increased utilization, or sales. Conversely, less important products often represent a significant investment due to their disproportionate allocation within the warehouse. Therefore, it is crucial to differentiate between various products to save money and free up space (Tanwari et al., 2000).

The utilization of ABC analysis in inventory management proves to be highly advantageous when determining the criticality or relevance of products. From this principle, it is possible to derive, for example, that 20% of products represent 80% of the stock value of the company, or 80% of products represent only 20% of the stock value (Kubasakova et al., 2015). By employing this approach, organizations can allocate their resources effectively based on the relative importance of various stock items, in line with the principles of Pareto.

This analysis works then as a tool to evaluate the relevance of inventory to the organization, typically according to the Net Revenue or Demand. Yu (2011) states that the ABC analysis categorizes groups of items based on their monetary volume in descending order. In other words, after building the matrix in descending order according to the significance level of the previous classification criterion, three classes are distinguished (Scholz-Reiter et al., 2012):

Class A: This class comprises critical items that demand meticulous attention, even if they exhibit low variability. Approximately 20% of the items contribute to 80% of the total stock value.

Class B: Items falling under this category are moderately critical and necessitate standard control measures. Around 30% of the items account for 15% of the total stock value.

Class C: These items demonstrate low turnover rates, possess a higher degree of variability, and are of relatively low criticality. Approximately 50% of the items represent merely 5% of the total stock value.

A theoretical visual representation of ABC Chart can be seen in Figure 3.

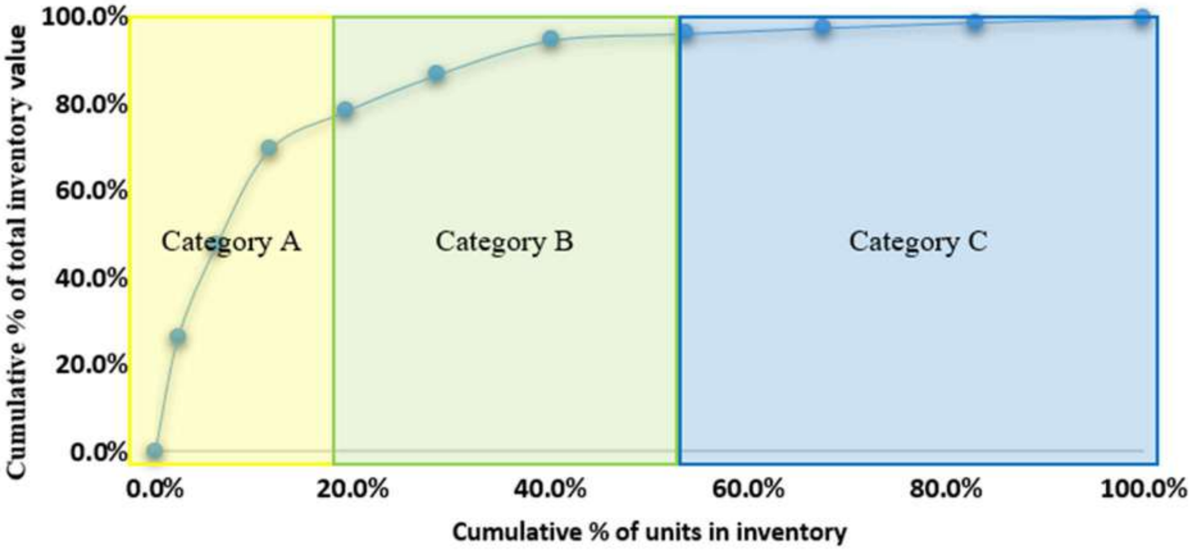

Figure 3 - Visual Representation of ABC Chart

By the culmination of this section, one can synthesize two relevant examples of the utilization of the ABC Analysis, according to the scope of this study:

- Categorization of products according to their financial value. Accordingly, Class A products hold greater significance, while Class C products represent the least financial value and importance (Flores & Whybark, 1987). As follow-up, this information can be useful as input to inventory management policies (e.g.: definition of service levels).
- Definition of clusters in order to optimise the layout of the warehouse, guaranteeing that items with a higher turnover rate - that are critical to the company's operations - have minimum stock and are closer to the expedition area (Janka et al. 2015).

There are more precise and complex tools to categorize inventory according to their forecast accuracy, such as ABC-XYZ Analysis. Besides the analysis according to the ABC categories, the XYZ segregation considers the demand uncertainty of each product, materializing the difficulty to forecast it (Kourentzes, 2017).

2.3.2. Excess & Obsolete Inventory

Excess & Obsolete Inventory can be set as one of the clusters regarding the approach on NVA Inventory. Inventory inaccuracy is a critical issue faced by many companies. Several companies start restructuring their inventory policies in order to minimize obsolete inventory (Jones & Garza, 2011). Grondys et al. (2014) also argue that excess and obsolete inventory constitute one of the key problems of production management, in the specific example of spare parts, since the appearance of this type of spare parts inventory generates unnecessary costs and freezes capital. Excess inventory requires additional space, equipment, and labour for transportation, storage, and management without providing added value (Karabegovic et al., 2023).

When a product is approaching the end of its lifecycle, it can be classified as obsolete and slow-moving (Solomon et al., 2000). The goods that remain unsold for a prolonged period of time, that are continuously handled and moved around from the factory to the warehouse or from the customer back to the warehouse without ever being sold can be considered in the stage to become obsolete, products forecasted with no future demand. Holding obsolete inventory is a significant source for excess, even though the range of factors contributing to the excess inventory is broad and varies as per the industry (Ahmed et al., 2020).

When items become obsolete, they can be considered as unusable, not yielding any value to the services. In turn, they consume valuable storage space in the warehouses plus the impact that have on taxes. These excessive costs may promote the increase in the overall facility costs (Thummalapalli, 2010).

In essence, inventory is not excess when it is the right quantity of the right goods at the right place at the right time. Excess inventory exists when "the potential value of excess stock, less the expected storage costs, fails to match the salvage value" (Crandall & Crandall, 2003).

But it can be difficult for companies to track excess inventory because the management reporting system does not adequately identify where and how much excess inventory exists (Crandall & Crandall, 2003). According to Baker (2021), there are some measures that can be applied to prevent excess or obsolete inventory:

- Accurately forecasting demand;
- Avoiding the use of excess stock to mitigate supply risks, like delays or shortage of raw materials;
- Ceasing to carry unnecessary inventory to prevent stockouts, by applying inventory optimisation techniques;
- Optimising inventory levels throughout the supply chain, promoting redistribution of excess stocks by the several locations;

- Being cautious when purchasing stock, avoiding quantity discounts for slow-moving products.

In order to reduce excess inventory, Faulkner (2023) suggests the implementation of several strategies, being the most relevant cited as follows:

- Returning inventory to supplier to obtain a refund or discount in future purchases;
- Refurbish the excess products and convert them into new products;
- Apply special deals or promotions into excess products and sell them through several channels;
- Liquidate, scrap, recycle or donate the inventory to avoid holding costs and eventually decrease the loss margin.

To this, one can consider the application of reverse logistics processes as well, as a consequence of the consideration of the supply chain as a holistic network where products can migrate between different locations.

There are several methodologies and studies that can be taken into account on the analysis of excess stock and obsolete. Tucker (2014) presents a two-step process, where the first one focuses on the iterative evaluation of the relevance of product features and the second one aims to classify the irrelevant Components as Standard, Nonstandard or Obsolete. Zhao et al. (2021) presents a data-driven approach where Observing Parameters (OPs) are set, and then compared with Desired Levels (DLs) of functional performance, built in a quantitative way according to the will of fulfilling customer requirements. The model works as a predictive measure to identify obsolete functions, according to the dissatisfaction and obsolescence indexes, quantified through the relationship between OPs and DLs. Heydari et al. (2018) proposes a reactive model where the return of obsolete products works as a reward for customers, promoting the refurbishment of materials and reuse in different products.

As a summary, despite the variety of sectors or industries, strategies to target obsolete and excess inventory can be incorporated into two main areas:

- Performance Evaluation models that analyse the already existing excess and obsolete inventory, building action plans upon that.
- Predictive models which aim to project the products that will potentially become obsolete or excess in the future.

2.3.3. Expiring Inventory

Expiring Inventory can be set as the other cluster regarding the approach on NVA Inventory.

Quality is subjective and influenced by consumers' social and economic backgrounds, as well as the product's intended use. It is determined by a combination of various attributes tied to physiological or physical properties, which naturally deteriorate over time. Keeping quality refers to the duration a product remains acceptable under real-life supply chain conditions, while shelf life denotes the period of acceptable quality under specific storage conditions (Hertog et al., 2014).

As the expiration date approaches, consumers' perception of diminishing quality leads to a decrease in the price they are willing to pay for perishable items (Tsiros & Heilman, 2005). In today's rapidly evolving industries, even products that do not deteriorate in quality over time can be viewed as expiring products due to the emergence of newer versions in the market (Herbon, 2017). Pauls-Worm (2016) corroborates, raising that uncertainty in demand can lead to new production while the inventory level is not yet zero.

Several approaches regarding studies about expiration and perishability can be mentioned, to understand what is currently being applied in the market.

Herbon (2017) developed a model to examine the effects of multiple-aged inventory on the shelf, determining the conditions in which they do not provide benefits to either the retailer or the market. Önal et al. (2015) presents a model where backlogging, production capacities and inventory bounds are considered, concluding that First-Expired-First-Out (FEFO) is the least costly procurement plan. Another study focuses on the simultaneous pricing and inventory management of perishable products, considering both new and old units for sale. A sparse model with price-dependent demands is developed, revealing the optimality of the easily implementable myopic policy for maximizing total expected profit and individual profits at each age (Chintapalli, 2015). Ferguson & Koenigsberg (2009) examine the strategic decisions of firms selling goods with deteriorating quality and unsold inventory. They identify conditions under which it is advantageous for the firm to retain or discard leftover inventory, considering competition between new and leftover products. The findings suggest that forward-thinking firms tend to price their new product higher and stock more of it in the first period to capitalize on the benefits of a second selling opportunity, outweighing potential sales cannibalization.

Hertog et al. (2014) emphasize the incorporation of prediction models for product quality changes into warehouse management systems, shifting from a First-In-First-Out (FIFO) approach to a FEFO strategy.

FIFO requires to first ship products that have spent more time stored in the warehouse irrespective of their remaining shelf life and their final destination (Tiwari et al., 2013). FEFO will only ship products depending on their shelf life potential in relation to their end destination (Hertog et al., 2014).

Expiration date models can be of three types (Hertog et al., 2014).

- Statistical Process Control (SPC) monitors and controls conditions within defined limits based on statistical concepts.
- Generic Shelf-Life Models estimate product shelf life based on logistic chain conditions and end user acceptance.
- Specific Quality Attribute models describe specific product properties and processes that affect quality over time.

In addition, it can be mentioned that the decision problem becomes somewhat more complex if stocks can perish or become obsolete, that is, if each item has a stochastic life. There are a number of different possible perishability assumptions (Rosenfield, 1989):

1) All items perish or become obsolete together at a random time;
2) All items perish or become obsolete together at a known time;
3) Each item can perish at a random time,

2.4. Strategic Decision-Making

After the categorization of products, methodologies that promote the evaluation of potential solutions or proposals can be considered as highly relevant assets to consolidate decision-making processes. The following sections will work as a review to methodologies that can support decision-making by considering prioritization of alternatives according to different criteria and risk factors.

2.4.1. Decision-Making Process and Multi-Criteria Decision Analysis

Decision making is the systematic process of identifying and selecting the most suitable alternative among available options. This involves assessing each option based on its likelihood of success and how well it aligns with one's goals, preferences, and values. The goal is to reduce uncertainty and doubt, enabling a rational choice to be made (Harris, 1998).

Modern decision making is increasingly complex due to the abundance of available options. It is a cognitive process that results in choosing a course of action from various alternatives, ultimately leading to a final solution (Lu & Ruan, 2007).

As an example of a decision-making field, Multi-Criteria Decision Analysis (MCDA) serves as a comprehensive term encompassing various formal approaches aimed at systematically considering multiple criteria when assisting individuals or groups in making significant decisions (Belton & Stewart, 2002).

The *International Association for Impact Assessment* (IAIA) (2013) defines MCDA as a comprehensive approach for systematically and transparently addressing complex problems that involve multiple criteria. This term encompasses both advanced methods and simpler tools such as objective hierarchies, strategy tables, consequence tables, and conceptual influence diagrams. MCDA facilitates assessments by integrating information from various sources, including scientists, experts, and local communities, while also accounting for stakeholders' subjective preferences (IAIA, 2013).

Multi-Criteria Analysis techniques aim to make informed decisions by combining various information into a unified measure of value. There are numerous methods available, ranging from complex to simple rating systems (Lebo & Schelling, 2001).

As an example of a MCDA process, one can mention General Electric (GE)/McKinsey matrices, that are typically nine-cell (3X3) matrices that were invented by GE in the 1970s and perfected by McKinsey later on. They work as a multi-factorial analysis technique used in product management to help a company decide what product(s) to add to its portfolio (Tsakalerou, 2015). Grouping problem variables into three categories and analysing their effect on performance provides a systematic approach for decentralized corporations to decide where to invest their cash effectively (Coyne, 2008). Figure 38 shows an example of the matrix, in Appendix 1 – Introduction and Literature Review.

The Analytic Hierarchy Process (AHP) is a technique for converting subjective assessments of relative importance into a set of weights. It enables deductive and inductive thinking, considering multiple factors simultaneously and making numerical trade-offs to reach conclusions (Saaty, 1987). Human's ability to receive, process, and remember information is constrained by the limits of judgment span and immediate memory. However, by organizing information into dimensions and chunks, these limitations can be overcome and effectively manage the flow of information (Miller, 1956).

The AHP involves structuring the decision-making problem into three hierarchical levels, to reduce a multi-criteria decision-making problem to a series of smaller, self-contained analyses: the ultimate goal at the top, a set of independent decision criteria in the middle, and the available options at the bottom (Dean, 2020).

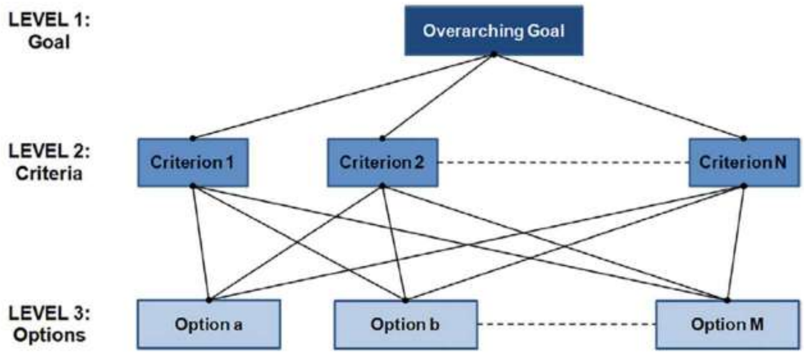

Figure 4 - AHP Structure according to Dean (2020)

Kardi (2006) introduces Cross Tabulation as the simplest method of AHP, describing it similarly to the previously explained, whose materialization represents a cross table of criteria and alternatives, where a score value is set for each cell. An example can be seen in Table 1.

Table 1 - Example of Cross Tabulation Application (AHP Methodology)

Criteria | Options	Option A	Option B	Option C	Range
Criterion 1	4 (8)	4 (8)	4 (8)	0-5
Criterion 2	6	5	8	0-10
Criterion 3	3 (4.29)	6 (8.57)	6 (8.57)	0-7
Sum	13	15	18	-
Adjusted Sum	18.29	21.57	25.57	-
Normalized Score	28.3 %	32.61 %	39.13 %	-
Normalized Score Adj.	27.95 %	32.97 %	39.08 %	-

In this example, different ranges of evaluation were used to assign the scores of each criterion. Two normalized scores were calculated, using a normal average and an adjusted average, that required the transformation of each score to the same standard range (from 0 to 10).

Additionally, each criterion was assumed to have the same importance level for the decision. Simple Additive Weighting methods are also widely used in decision support, working as a complementary feature to develop the previously mentioned AHPs. They employ weighted sums to evaluate the options, with the aim of "closing down" the analysis, with global scores obtained as the weighted sum of the single performance scores (Dean, 2020).

Following the previous example, the significancy of each criterion could be calculated through the following process, described in Table 2.

Table 2 - Example of Importance Weight of each Criterion

Range (0-10)	**Criterion 1**	**Criterion 2**	**Criterion 3**	**Sum**
Significancy Score	5	8	6	19
Significancy Weight	26.3 %	42.1 %	31.6 %	100 %

The overall score would then be adjusted as mentioned in Table 3, assuming the adjustment for the standard range.

Table 3 - Example of an Additive Weighted Method Application (AHP Methodology)

Criteria | Options	**Option A**	**Option B**	**Option C**	**Weight**
Criterion 1	8	8	8	26.3 %
Criterion 2	6	5	8	42.1 %
Criterion 3	4.29	8.57	8.57	31.6 %
Sum	5.98	6.92	8.18	-
Normalized Score	28.4 %	32.8 %	38.8 %	100%

As conclusion, Mohammad (2023) states the step-by-step process to develop a multi-criteria analysis, in a business-oriented perspective.

1. Identification of Criteria;
2. Weighting of Criteria
3. Assessment of Alternatives/ Options
4. Aggregation of Assessments
5. Sensitivity Analysis, to make the final decision.

As summary, it is possible to synthesize strategic decision-making in the following vectors, according to the previously presented in the section:

- Qualitative Multi-Factorial Analysis, that requires a subjective estimation of potential impact for each alternative, according to some broad criteria fields, as GE/ McKinsey matrices;

- Quantitative Multi-Factorial Analysis, that requires a logical attribution of importance to each alternative, according to a standardized criteria-dependent scale, as Cross Tabulation (AHP Methodology);
- Quantitative Multi-Factorial Analysis, that requires a logical attribution of importance to each alternative, according to a standardized criteria-dependent scale, that considers different levels of significancy to each criterion, as the Additive Weighting Method (AHP Methodology).

Each of the vectors can promote a more solid decision-making process, being the detail and accuracy progressively higher from Qualitative Multi-Factorial Assessments to Additive Weighting Methods. Since decision-making generates the prioritization or selection of alternatives, a follow-up evaluation of potential risks can be considered as an important asset to improve the implementation of the desired action plans.

2.4.2. Report on Risk and Opportunities

In the following section, an approach to Risk is going to be developed, according to the academic and business perspective.

Risk is an effect of uncertainty on objectives, meaning a deviation from the expected. It can be positive, negative or both. Risk management constitutes the coordinated activities to direct and control an organization with regard to risk (*ISO 31000:2018*, 2018). Following the International Organization for Standardization (ISO) Guideline, Risk Management can be divided in two main fields: Risk Assessment and Risk Treatment.

Risk Assessment can be divided into three stages.

- **Risk Identification:** Systematic use of available information to identify hazards, which means a list of risks, based on those events that might create, enhance, prevent, degrade, accelerate or delay the achievement of objectives (*ISO 31000*, 2017).
- **Risk Analysis:** Providing the basis for risk evaluation and developing systems to estimate the risk to individuals, property, and the environment (International Electrotechnical Commission, 1995). It represents the criteria to be used to express and measure the consequence and likelihood of a risk (*SA/SNZ HB 436:2013*, 2013).
- **Risk Evaluation:** The purpose of risk evaluation is to assist in making decisions, based on the outcomes of risk analysis, about which risks need treatment and the priority for treatment implementation (*ISO 31000*, 2017).

Risk Treatment can be considered as the set of measures taken to mitigate the impact of risks and promote the implementation of a Continuous Risk Management System (Rausand, 2013). To understand the relevance of the approach of such concepts, some examples of the application of risk management were studied, as follows.

The risk management system from HUGO BOSS AG is centrally coordinated, focusing on implementation and continuous improvement. It engages with relevant departments and group companies, where risk owners and experts identify, assess, and manage risks, including the implementation of mitigation measures. The Supervisory Board of HUGO BOSS oversees the effectiveness of the risk management system (*Hugo Boss Annual Report*, 2021).

Continental has established an internal control system that encompasses all relevant business processes. When risks are identified, the responsible management team takes appropriate countermeasures, documented in the Governance, Risk and Compliance (GRC) System for significant risks. The GRC Committee oversees and centralizes the management of material risks and corresponding countermeasures at the corporate level (*Continental's Internal Control System - Continental Group - Annual Report*, 2022).

By identifying emerging risks, analysing their severity and impact, and offering industry-specific guidance, the *Allianz Risk Barometer (*2023) shows the relevance of risk management, and enables informed decision-making, proactive risk mitigation, and cross-industry collaboration. It empowers organizations to adapt to evolving risk landscapes, enhance their resilience, and communicate effectively with stakeholders.

As a follow-up, Aurubis Group prioritizes opportunity assessment alongside risk management. This involves identifying potential internal and external opportunities that could enhance economic success, evaluating them against associated risks, and developing strategic initiatives to capitalize on these prospects. As consequence, initiatives and measures are taken and integrated in the company's annual strategy and planning approach (*Aurubis AG, Combined Management Report*, 2019).

As summary, Albrecht (2023) suggests the following overall methodology for the implementation of a Risk Management process:

1. **Risk Identification**
2. **Risk Analysis and Evaluation**
    a. Severity-Likelihood Matrix: Severity can be described as the impact of a hazard occurring and not being mitigated, while Likelihood can be described as the chances of something happening (Watson, 2011).

b. Failure Mode Effect Analysis (FMEA): FMEA involves investigation and assessment of the effects of all possible failure modes on a system, where each effect has a Risk Priority Number associated for consequent prioritization of the failure modes for action (Hunt et al., 1995).

3. **Risk Treatment and Opportunities**
   a. Prediction of the impact of the measures and actions identified to mitigate the risks.

This section enhances the relevance of Risk Management, as a set of processes that can evaluate the reliability and potential success of action plans. It allows the deep study of possible failure situations, promoting their prediction and consequent improvement of business strategies.

2.5. Summary of the Literature Review and Lessons Learned

This review constituted an approach to RQ 1, whose interpretation can be split in the answer of the following questions:

- **RQ 1.1:** What is the academic perception on inventory optimisation and what are the common strategies suggested to foster inventory reduction?

The answer to this question is mostly associated with the investigation developed in Section 2.2. The most common fields to improve inventory management efficiency are:

- Inventory categorization and focus on the following vectors:
  - Target and reduction of NVA Inventory;
  - Development of ABC Analysis;
- Improvement of forecast accuracy;
- Studying possible variations in the inventory policy parameters;
- Migration to a more sophisticated Inventory Management Software System.

- **RQ 1.2:** What criteria or tools should be utilized to define the strategy to improve the Inventory Management System, according to the potential impact of such effort?

The answer to this question can be segmented in some steps.

1. Contextualization and analysis of the current situation, with the purpose of understanding if the possible improvement fields match the scope of the project. If that happens, it is relevant to define the stage of each of them, in order to decide if they represent fields that should be targeted.

2. Study of constraints and inefficiencies of the current scenario, to understand if existing issues can be positively impacted by targeting the fields highlighted in the previous research question.
3. Implementation of Multi-Criteria-Decision-Analysis to improve the quality of the follow-up strategies, created to tackle each of the selected improvement fields. This assessment should allow the prioritization of the processes that compose the referred strategies.
4. Application of Risk Management processes to identify and prevent possible failures from the implementation of the processes.

Points (1) and (2) represent main drivers for the development of the following sections from Chapter 3. Points (3) and (4) will further on be developed in Chapter 5. A description of the workflow of the literature review can be seen through the map in Figure 5.

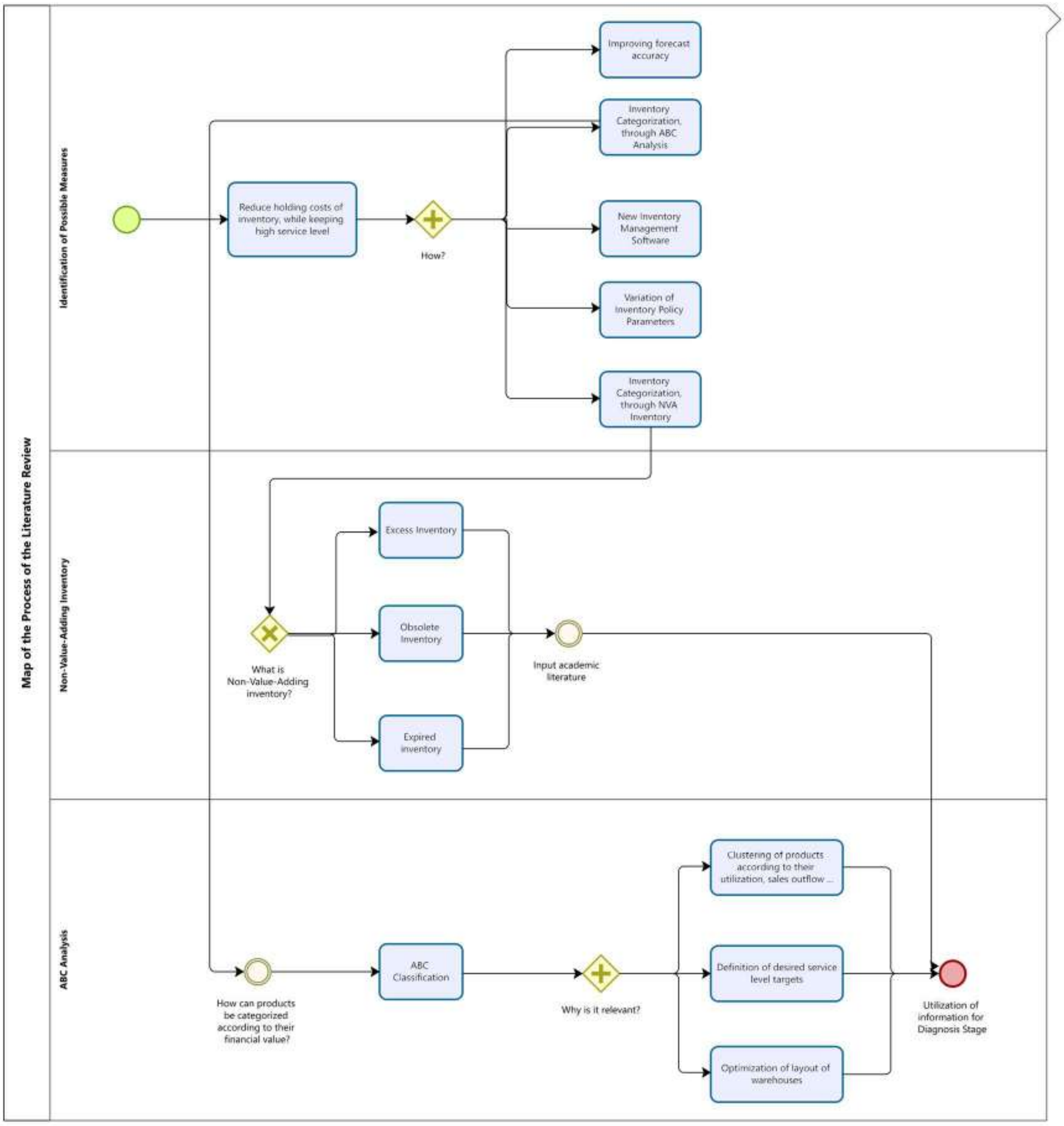

Figure 5 - Process map that structures the content of the Literature Review

3. Contextualization and Analysis of the Case Study

In this chapter, an introduction to the company will be provided, being the business areas described. Subsequently, the outline of the research methodology adopted throughout the project will be explained. By presenting a comprehensive background of the company and delineating the research methodology, this chapter establishes a solid foundation for the subsequent chapters, enabling a deeper understanding of the research context and its findings.

3.1. Description of the Company

Emma - The Sleep Company is a prominent sleep technology company that specializes in the development and provision of innovative sleep solutions. With a commitment to enhancing sleep quality and overall well-being, Emma has established itself as a leading brand in the Sleep Industry. Emma places great emphasis on combining cutting-edge technology with expert craftsmanship to create high-quality sleep products.

With more than 30 active markets, Emma is the most international Direct-to-Consumer (D2C) sleep brand. Having expanded to 18 countries since 2019, Emma prioritized growing its market share in its active markets in 2021, resulting in increased brand awareness in different countries, reaching up to 62 per cent (Krueger, 2022). With over 800M Net Revenue in 2022, Emma has been on a strong growth trajectory to become the number one sleep brand in the world, with more than 240M Net Revenue annual growth (Marcela, 2022). Emma started as an e-commerce mattresses seller in 2013, having evolved in ten years to the idea of approaching the whole Sleep Industry, with a high concern on the impact that good sleep can have on people’s lives.

3.1.1. Product Range of the Company

Emma's product range can be summarized in Table 4:

Table 4 - Product Range of the Company

	Composition	Characteristics
#1 Mattresses	Foam or Hybrid (foam + springs)	Comfort, body support, ergonomic, breathability, durability
#2 Beds	Different designs and materials	Quality reassurance, versatile design, ergonomic, durable
#3 Pillows	Different designs and materials	Adjustable, softness, customizable, thermoactivated and breathable
#4 Accessories	Duvet, weighted blanket, toppers, bed linen, mattress protector	-

Emma's key activities are focused on **Product Development**, **Marketing and Business Development**, since logistical procedures, such as manufacturing, and transportation are outsourced. Emma establishes several synergies to develop a strong network of suppliers, producers, and partners. Following the product range presented, a Cooling Hybrid is a premium product from the category Mattresses, that combines several comfort layers on top with ThermoSync foam. An example can be seen in Figure 6.

Figure 6 - Emma Cooling Hybrid

A Box Bed is a customized Bed where customers can choose the comfort level – rolled slats for standard comfort and slatted frame for premium comfort. An example can be seen in Figure 7.

Figure 7 - Box Bed v2 Scandinavia (Emma Original Medium)

A Cooling Pillow is a customizable Pillow designed to be a more ergonomic product, driver for neck pain. An example can be seen in Figure 8.

Figure 8 - Customizable Cooling Pillow

A Light Duvet is an adaptable duvet that answers basic customer needs on different room temperatures. An example can be seen in Figure 9.

Figure 9 - Emma Lean Light Duvet

3.1.2. Supply Chain of the Company

Mentioning the whole network that allows the delivery of products, it is important to reinforce the core business of the company, which is only focused on the commercialization of products. Processes such as manufacturing, assembly, storage, or distribution are outsourced, which leads to a lower in-site operational level of responsibilities. A scheme of Emma's Supply Chain can be seen in Figure 10.

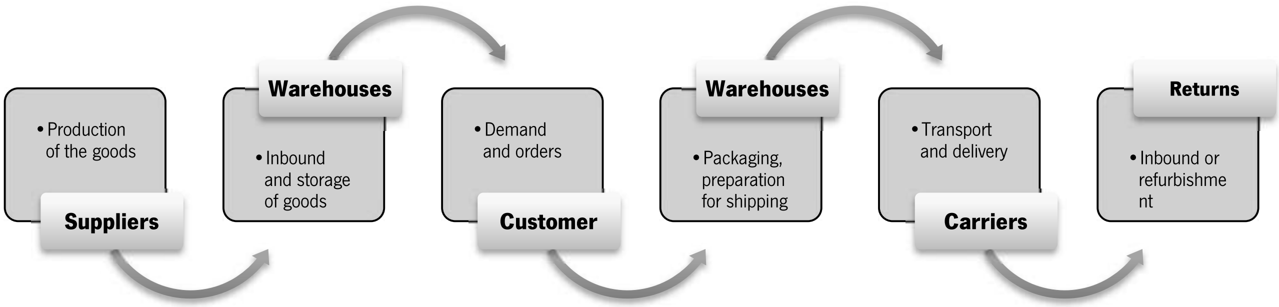

Figure 10 - Emma's Supply Chain Structure

For Europe, there are 20 producers or manufacturers selling supplies, distributed by eight different countries. Regarding storage, 60 warehouses can be quantified, distributed by 16 different countries. While Online D2C still drives most of the revenue – with over **80%** of the total share - Emma also offers products in retail - **11%** of total - and marketplaces, such as Amazon - **8%** of total revenue. Figure 11 shows a visual representation of the network of suppliers and warehouses for Europe, being the distinction between both made by the difference of colour.

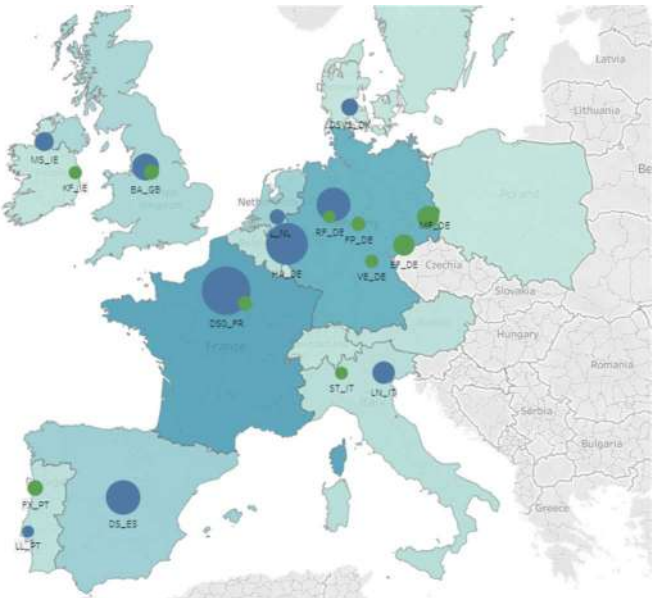

Figure 11 - Warehouses and Suppliers Network

3.2. Description of the Team

The current project is developed under the S&OP Team. The mission of the team is to work as the orchestrators of the company's success by integrating all the company's functions into a single plan: steering the company's success by consolidating the business ambitions, portfolio changes, promotional strategy and operational set-up towards a single and synchronized plan that will guide Operations and Markets. Meeting business objectives of profitability, or productivity with competitive and predictable customer lead times can be mentioned as some objectives, as well as providing a reliable financial outlook.

The big levers of the team can be seen as follows:

1) Review the collaboration and communication model, both internally and externally, by providing clarity and scenario planning for demand, supply, and inventory;
2) Establish a medium to long term planning horizon, by standardizing supply planning processes across all categories and markets;
3) Create a data and system architecture that will enable S&OP process, by transitioning to an automated tool that improves accuracy and allows planners to focus on value adding tasks;
4) Include product lifecycle planning in standard planning processes, by tackling portfolio changes proactively and establishing a phase-in and phase-out process of products.

S&OP is divided in three main teams, being them:

- **Demand Planning** (DP): Providing accurate sales forecast, aligning Business Development and Supply Chain constraints for optimal sales, sustainable supply chain, while meeting customer expectations.
- **Enablement:** Optimisation of inventory levels to minimize working capital and to meet service level targets. The key processes are inventory target definition, obsolete/excess inventory management and cost projections.
- **Supply Planning** (SP): Ensuring timely delivery of products meeting customer expectations. Optimisation of stock turnover and streamlining order fulfilment for efficient shipping.

The current study is within the scope of IP, which is a field inside Enablement.

3.3. Analysis of the Current Situation

The following section will analyse the current situation of the improvement fields highlighted from the Literature Review within the scope of the study. Further on, the subsequent sections will dive into the exploration of possible limitations that might be constituting inefficiencies of the current Inventory Management System, with the end goal of identifying solutions with the most expected impact.

3.3.1. Assessment of the Current Situation within the Improvement Fields Highlighted from Literature Review

According to Literature View, the most common fields to improve inventory management efficiency are:

- Inventory categorization and focus on the following vectors:
    - Target and reduction of NVA Inventory;
    - Development of ABC Analysis;
- Improvement of forecast accuracy;
- Studying possible variations in the inventory policy parameters;
- Migration to a more sophisticated Inventory Management Software System.

Regarding **NVA Inventory**, the analysis can be split into three main categories: Excess, Obsolete and Expiring Inventory. The analysis of Sections 2.3.2 and 2.3.3 brings the need to describe each of the categories of inventory according to the current process of identification and follow-up action plans, as seen in Table 5.

Table 5 - Current Situation for NVA Inventory

	System of Identification and Quantification	**Action Plans**
Obsolete Inventory	There is not a clear quantification of obsolete inventory, but there are teams who have the knowledge about phased-out products	Phased-out products can be followed by clearance sales strategies, but that does not happen every time
Excess Inventory	Supply Planning team develops punctually a process of identification of excess units	There are efforts to reduce excess by creating promotion strategies
Expiring Inventory	There is not a clear quantification of inventory about to expire. Inventory already expired is monitored for one warehouse, through a manual repetitive process	Expired inventory suffers a revaluation to check conformity

Regarding **improving forecast accuracy** or **studying possible changes in the inventory policy parameters**, possible improvement measures are not included in the framework of this study, since they are from the responsibility of other teams or stakeholders. However, it is possible to conclude that the huge effort that would need to be put to enrich those fields would not compensate the impact, especially since it is not coherent with the current organizational stage of the company.

About **ABC Analysis**, it was identified by Section 2.3.1 that it could be a helpful short-term resolution in terms of prioritization or clustering and service levels definition. Currently, there is not an updated ABC Analysis for every product, nor an automated tool or process to calculate it.

About the migration to a new **Inventory Management Software System** that provides more statistical accuracy, a project is being developed to implement Sales & Operations Planning Service Optimiser (SO99+), but it does not interfere directly with the scope of this study. SO99+ is a software that optimises supply chain planning tasks to guarantee product availability.

As summary, the most relevant match between the topics highlighted from Literature Review and the scope of improvement fields of this research is related to inventory categorization, with the target on ABC Analysis and NVA Inventory.

3.3.2. Analysis of Potential Limitations and Inefficiencies

This section will be divided into four subsequent topics and its purpose is to identify potential limitations of the Inventory Management System, that could restrict and reorient the direction of the research. The first one will consist of an **ABC Analysis**, segmenting products into three categories. The following three sections address each of the potential limitations analysed, respectively highlighted by the study of: **sales forecasting bias**, **outbound capacity of the warehouses** and **storage capacity of the warehouses**.

These three possible restriction fields were selected since they represented concerns from involved stakeholders, that could be motivated by deeper non-clear root causes. The categorization through ABC Analysis precedes the constraint-analysis since the existence of patterns according to the ABC clusters can be an object of study. The categorization according to the type of NVA Inventory is not possible to develop in this stage, since such processes do not exist in the current situation, as explained in Table 5.

The following sections will use France as pilot location for the analysis, since its condition is sufficient to understand the current situation of Europe, which is the target region of the study.

1. Inventory Categorization through ABC Analysis

To categorize the products according to their financial relevance for the company, an ABC Analysis was developed with Power Query from Microsoft Excel and an example of the tool can be seen in Figure 41 and Figure 42 (for Accessories and Mattresses) and Figure 43 (for Beds), in the Appendix 2 – Contextualization of the Case Study.

The products were evaluated according to their impact on Net Revenue. Since there was not a previous similar evaluation, an ABC-XYZ Analysis did not seem the most adequate methodology, due to its complexity.

ABC Analysis was iteratively developed by product category, for France, using data from January to September of 2023. The ABC Analysis was segmented by product category because of the discrepant average unitary values per type of product, being all SKU-Classification further on compiled in a merged database.

The ABC Chart for Mattresses can be seen in Figure 12. The process was similar to the other evaluated categories: Accessories and Beds, whose ABC Chart can be seen in Figure 39 and Figure 40, in the Appendix 2 – Contextualization of the Case Study.

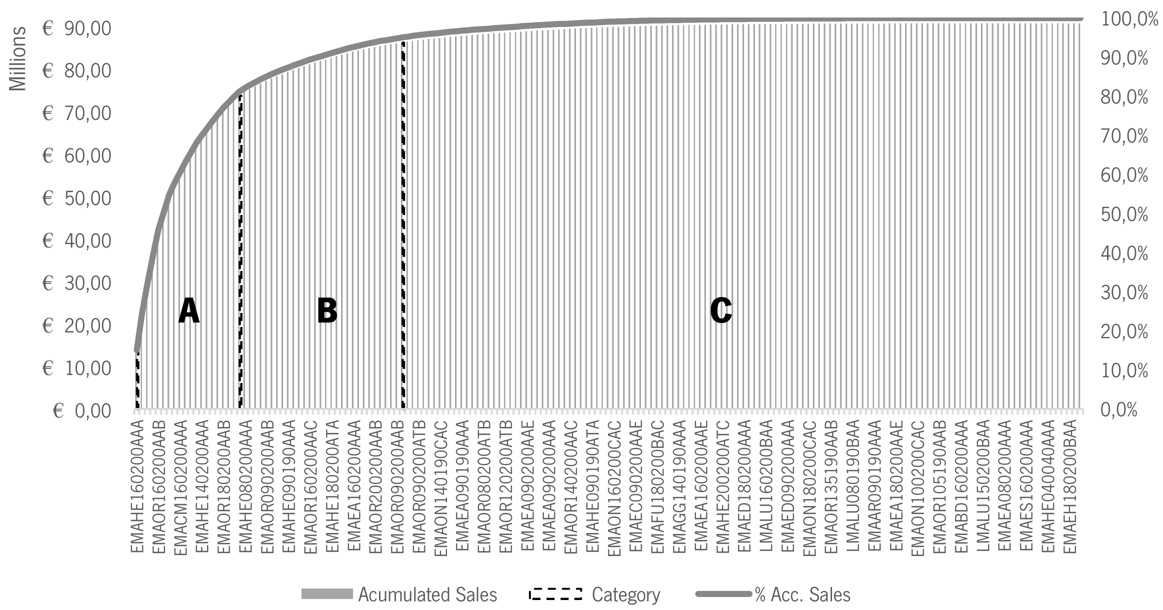

Figure 12 - ABC Analysis for Mattresses

Table 6 summarizes the most relevant information regarding ABC Analysis by category.

Table 6 - Revenue and Inventory per Category and Classification

		Mattresses	Accessories	Beds
A	Net Revenue	81.3%	80.3%	80.5%
	Inventory (%)	11.9%	5.6%	35.8%
B	Net Revenue	13.8%	14.7%	14.6%
	Inventory (%)	17.0%	12.1%	28.4%
C	Net Revenue	5.0%	5.0%	4.9%
	Inventory (%)	71.0%	82.3%	35.8%

From Section 2.3.1, ABC Analysis suggests that Category A items are the most valuable in terms of revenue and demand for an efficient inventory management. Category B items are moderately valuable, while Category C items, despite having high inventory percentages, contribute less to revenue and may require attention to reduce excess inventory.

For Mattresses and Accessories, the quantity of inventory correspondent to 80% of the revenue is significantly lower than the 20% suggested by literature. In fact, one can see that around 70-80% of the inventory of both Mattresses and Accessories represents only 5% of the Net Revenue. Category C items are typically slower-moving items with low value, that tenderly represent excess or unnecessary inventory. As previously introduced, this type of inventory was classified as **NVA Inventory**, and it is possible to induce that **it constitutes a waste or inefficiency** from a storage optimisation and reduction of costs perspective. For Beds, holding unnecessary inventory does not represent such significant waste, which might lead further strategies to the prioritization of Accessories and Mattresses.

In inventory management, companies often focus more resources and attention on Category A items to maximize revenue and minimize holding costs, while **Category C items may require strategies to reduce excess inventory and optimise space utilization**. The pilot analysis for France will proceed by the exploration of possible constraints that might represent inefficiencies of the Inventory Management System, using ABC Clusters to identify patterns and improve conclusion-making.

The following constraints or concerns will be analysed:

- Significant Bias Between Actual Sales and Forecasted Sales;
- Warehouses Outbound Capacity;
- Warehouses Storage Capacity.

2. Sales Forecasting Bias and Performance Indicators

Sales Forecast vs Actual Sales Bias

The objective of demand forecasting is to provide the necessary requirements to make decisions related to the business in the most objective and reasoned way, analysing future events or variables that may come to act. It is essential that forecasting techniques are helpful to make decision-making processes more accurate and reliable (Kurzak, 2012).

Regarding the sales forecasting bias, three different product groups will be analysed, and they were selected since they represent the product groups with highest impact on sales, for each of the respective categories. For the first example, the data analysed refers to the EMAHE*AAA product of the Mattresses category, in France, in the first 15 weeks of 2023. The analysis of this topic was developed using Microsoft Excel.

Currently, the demand forecasting process presents high levels of variability and inaccuracy, as can be seen in Figure 13 and Figure 14.

Figure 13 - Actual Sales vs Forecast Mattress

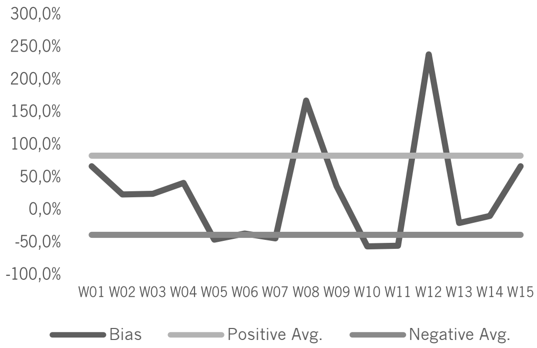

Figure 14 - Bias 2023 Mattress

The calculation of the Bias represented in Figure 14 can be seen in Equation 7, in the Appendix 2 – Contextualization of the Case Study. Overall, there is a tendency to predict above-average sales, with an occurrence of 53.3%. The average of bias when it assumes the positive value is 81.1%, while when it is lower than the sales it is 40.4%. That is, according to the analysis, in addition to the tendency to predict sales higher than the real ones, the discrepancy in this situation is greater than the under-forecasting.

Figure 15 and Figure 16 represent the same analysis for the EBDUB product in the Beds category in France in the first 15 weeks of 2023.

Figure 15 - Actual Sales vs Forecast 2023 Bed

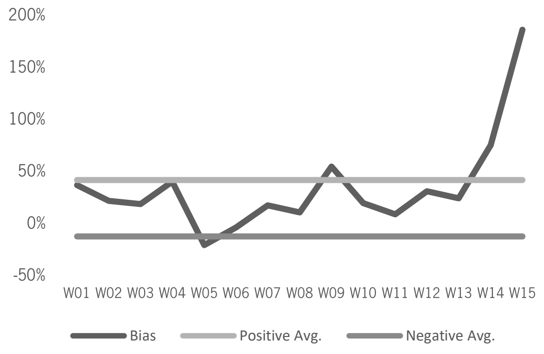

Figure 16 - Bias 2023 Bed

In general, there is a tendency to predict above-average sales, with an occurrence of 93.3%. The average bias when it assumes the positive value is 40.9%, while when it is lower than the sales it is 13.3%. That is, according to the evaluated, in addition to the tendency to predict sales higher than the real ones, the discrepancy in this situation is greater than the under-forecasting.

Figure 17 and Figure 18 represent the same analysis for the EPWFP product in the Pillows category for the first 15 weeks of 2023.

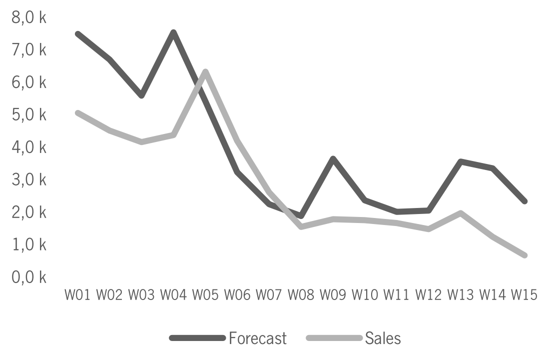

Figure 17 - Actual Sales vs Forecast 2023 Pillow

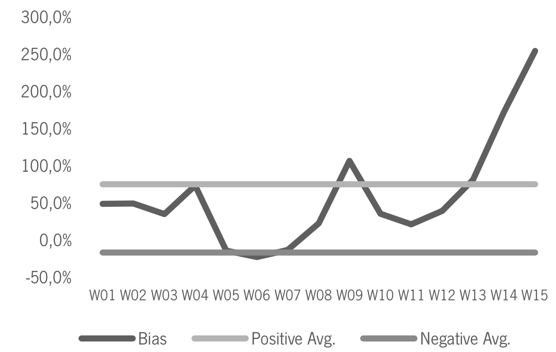

Figure 18 - Bias 2023 Pillow

In general, there is a tendency to predict above-average sales, with an occurrence of 80%. The average of bias when it assumes the positive value is 74.7%, while when it is lower than sales it is 17.3%. That is, according to the analysis, in addition to the tendency to predict sales higher than the real ones, the discrepancy in this situation is greater than the under-forecasting.

In this way, exploring examples from three highly relevant products from each category in terms of revenue, it can then be suggested that in France there is a **tendency to overprediction of demand**, which could be translated into an optimistic approach, that **should lead to higher capability of meeting real demand** and avoiding stockouts.

Total Stock Levels

With the purpose of understanding the capability of the current situation regarding total inventory, Figure 19 was created using Microsoft Excel and represents the existing stocks in France, segmented by the different products previously presented. Each value from the X Axis represents the year and month ('202002' represents February 2022) and the analysis was developed for all the year of 2022 and the first two months of 2023 (which include most of the 15 weeks from the previous Bias analysis).

The tendency to predict more sales than those that occur can imply the accumulation of stock in surplus quantities. On average, it can be said that excess stock exceeds 50% of the total existing stock in almost every month. The conclusion can be extended to the individual analysis of the above-mentioned products, despite of the high variability of excess percentages over the months.

However, it is safe to see that, usually, there is an **accumulation of unnecessary stock**, as already mentioned in Section Inventory Categorization through ABC Analysis.

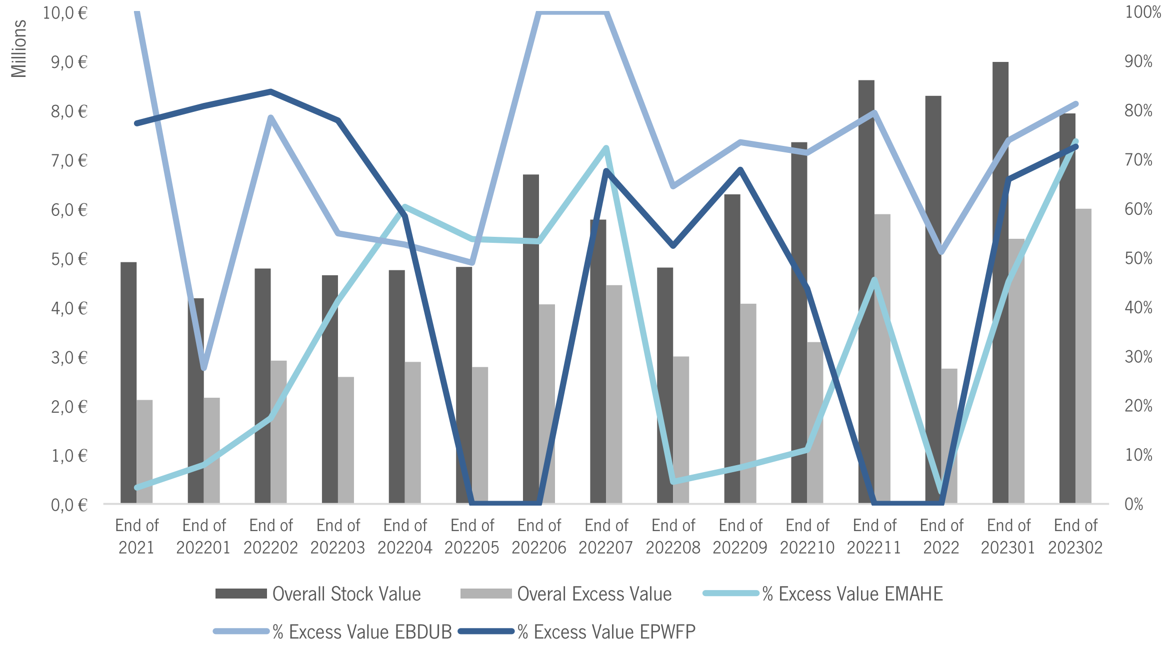

Figure 19 - Comparison between Stock and Excess Values

Capacity to Fulfil the Demand

With such indicators of excess inventory, a high level of service would be expected, corresponding to a significant demand satisfaction capacity (which will be measured as Fill Rate). What is identified, however, is an average capacity of 60% demand satisfaction and 62.2% weighted average, based on the unit cost of each product.

The calculation of the Fill Rate is defined in Equation 1.

Equation 1 - Fill Rate Formula

$$Fill\ Rate = \frac{Net\ Stock\ (Week)}{Demand\ (Week)}$$

The Fill Rate was calculated for all the clusters obtained with the ABC Classification and the information can be summarized in Table 7.

Table 7 - Fill Rate per Class

		Classification		
Weighted Average	Average	A	B	C
62,2%	60,0%	67,7%	61,6%	61,4%

It is possible to confirm that the capacity to fulfil the demand is not as significant as desired. Therefore, even though there is an overall excess of stock, there is a low capacity to meet customer expectations. This can again lead the study to the conclusion that **the current existing stock does not add value enough**, since it is not directly representing stock with demand.

There is not a significant difference in the incapability of fulfilling the demand according to the type of classification, since the three present similar values.

As a summary of this and the previous sections, the following can be mentioned:

1. There is a tendency to over-forecast sales, which is generating overall excess and accumulation of inventory;
2. The accumulation of excess is not representing high capability to fulfil demand, according to the low fill rate for all the product classes;
3. The accumulation of excess inventory and simultaneous incapability to keep high service levels represents an inefficient storage management, with significant accumulation of unnecessary inventory.

3. Warehouses Outbound Capacity

The outbound capacity of the warehouses can be considered as the maximum number of pallets that a warehouse can dispatch per unit of time, being dependent of factors such as the storage capacity of the warehouse and inbound or outbound processes, as the arrangement of products in pallets or the shipping procedure by itself. The analysis of this topic was developed through Microsoft Excel.

To understand if the capacity of the warehouse constitutes a significant restriction at the company, it was developed an analysis of the warehouses PS_DE and DS0_FR, considering historical data of 2022. DS0_FR was selected since it is the warehouse that storages products for the market of France and PS_DE since it is the one with most informal complains regarding outbound limitations. Both warehouses have similar portfolios.

Figure 20 shows the chart for PS_DE Warehouse.

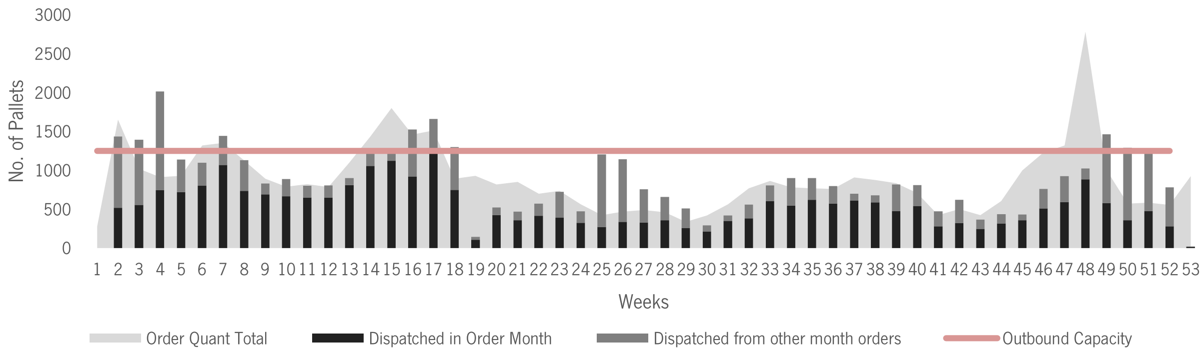

Figure 20 - Dispatches for PS_DE Warehouse

The Outbound Capacity Series represents the theoretical maximum number of pallets that the warehouse can dispatch per week, according to information collected from the Warehouse Staff. The light grey area represents the weekly demand that the warehouse received in 2022, while the scattered column with the dispatches represents the total amount of pallets that left the warehouse. The lighter scattered column represents dispatches that were backlogging in previous months, which means that the order month is not the same as the dispatch month.

From week 45 until week 48 the number of products virtually sold was bigger than the theoretical outbound capacity of the warehouse. This time range represents a high discounts season, which tenderly generates unpredictable fluctuation in demand. This variation was accompanied by a level of effort of the warehouse, which managed to overcome the theoretical outbound capacity. The same happens on a smaller scale from week 14 to 17.

The main conclusion of this analysis is that the outbound capacity of the warehouse does not represent a limitation to the Inventory Management System, because it does not constitute the main factor that avoids demand to be fulfilled. The outbound capacity is generally higher than the demand and the warehouse can even increase it in saturation periods.

The chart for DS0_FR can be seen in Figure 21. Until week 36, the analysis is not significant. There were previously two warehouses for France, which made data for DS0_FR not relevant for a significant period of the year.

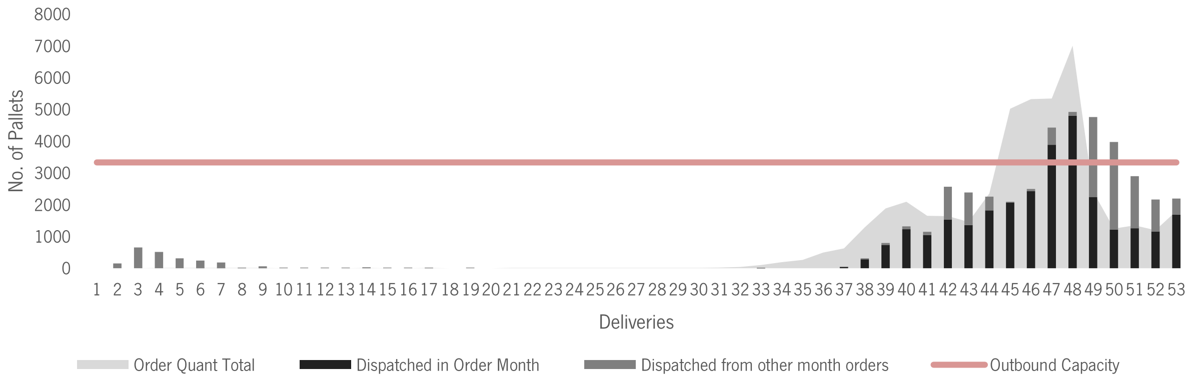

Figure 21 - Dispatches for DS0_FR

From week 45 until week 48 the number of products virtually sold was bigger than the theoretical outbound capacity of the warehouse. This time range represents a high discounts season, as presented and explained in Figure 20. The conclusion for France is similar to the presented before. The outbound capacity does not represent a direct reason that is avoiding demand to be fulfilled, since it only constitutes a **restriction in three weeks** of the year and the warehouse even **manages to increase the theoretical capacity**.

4. Warehouses Storage Capacity

The storage capacity of the warehouses can be considered as the maximum number of pallets that a warehouse can store, which depends on the total area of the warehouse and the organization methods applied by the Warehouse Staff.

To understand if the capacity of the warehouse constitutes a significant restriction at the company, it was developed an analysis of the warehouse DS0_FR, using Microsoft Excel. Contrary to the lack of data for dispatches presented in Figure 21, Figure 22 consists of a predictive analysis, that considers a projection of stock from week 19 of 2023 until the end of the year.

To guarantee the coherence of the analysis, it was decided to develop it for France.

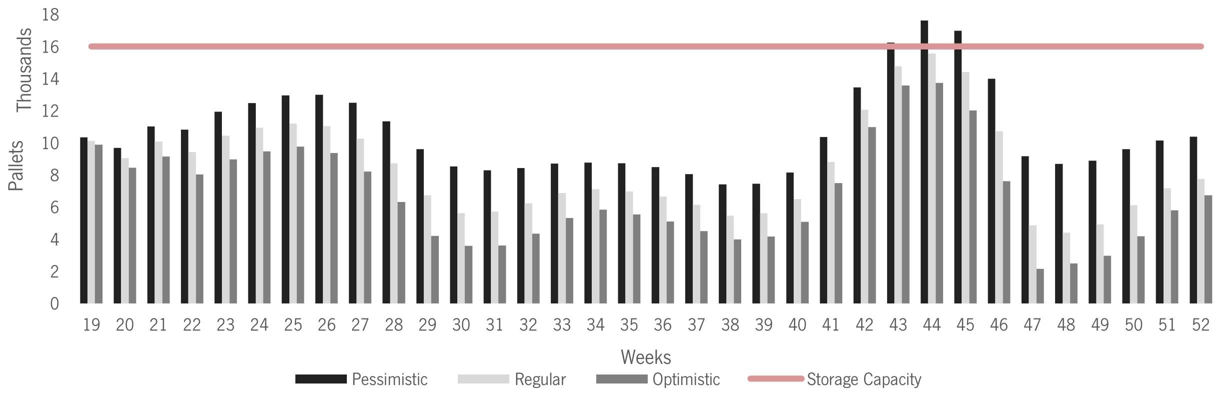

Figure 22 - Storage Capacity for DSO_FR

It can be concluded that the storage of the warehouse does not constitute a problem most of the time. Although, once Black Friday (high discounts season) is reached – around weeks 47 to 49 – one can see a significant increase in the occupancy rates of the warehouse in the previous weeks. In the regular scenario, according to what is exactly forecasted, the maximum level of storage is not reached. But in the pessimistic one, which represents a 20% increase in forecasted sales, the maximum storage capacity is surpassed for three following weeks. Additionally, it is important to consider that this limit is theoretical and that the mathematical conversion of units in pallets can have an error associated.

Despite the fact that it was proved that the **storage capacity of the warehouse is not a problem**, literature shows that inefficient processes of space utilization or resources allocation can lead to a functional reduction of the theoretical limits. Therefore, storage optimisation can always be considered as an improvement field, so that even in saturation periods the company does not face difficulties in storing new stock.

3.3.3. Summary of Main Conclusions and Introduction of the Improvement Measures

The approach developed with this section constituted the answer to the following research questions:

RQ 2.1: What is the current situation of the study regarding the improvement fields highlighted in Literature Review?

From Section 3.3.1, it can be concluded that the most relevant field to improve is related to inventory categorization, with the target on ABC Analysis and NVA Inventory. In general, there are no current standardized processes that tackle these categories of inventory.

RQ 2.2: Which constraints might be causing the inefficiency of the Inventory Management System and what relation do they have with the improvement fields highlighted from Literature Review?
Section 3.3.2 studied possible limitations or inefficiencies of the current Inventory Management System and led to the same conclusions of the answer of RQ 2.1. A brief description of the analysis of the fields that constitute the scope of Inventory Categorization can be summarized as follows:

Inventory Categorization through ABC Analysis

The development of ABC Analysis promoted the conclusion that there is a **significant portion of inventory stored in warehouses that does not add value**, since it represents products with inexistent or low demand. This happens mainly for Mattresses and Accessories, which can lead the analysis for targeting NVA Inventory with the focus on these product categories.

ABC Analysis also showed relevance to the identification of clusters and definition of desired service levels.

Inventory Categorization through Non-Value-Adding Inventory

The study of the sales forecasting bias, that generates general levels of overstock, but non-corresponding low-values of service levels, promoted the conclusion that there is a **tendency to accumulate unnecessary stock**. This conclusion is detailly explained in Section Sales Forecasting Bias and Performance Indicators.
The study of outbound and storage limitations could orient the study to the importance of studying possible changes in the inventory policy or induce the need to enlarge these capacities by increasing the number of resources. It was possible to conclude that these restrictions did not represent a direct factor that could be affecting demand to be unfulfilled.
On the other hand, the proximity of these performance levels with the theoretical limits, combined with the highly significant storage of **NVA Inventory**, promotes the conclusion that **targeting these types of inventories can constitute a highly valuable set of measures** with the following expectations:

- Reduction of holding costs of inventory;
- Storage optimisation;
- Improvement of resources allocation and consequent focusing on A Class products;
- Streamlining unexpected revenue streams, by relighting slow-moving or obsolete inventory.

The following chapter will consist of the explanation of data-driven tools and processes that were created to allow the objective categorization and identification of NVA Inventory. As introduced in Table 5 (Section

3.3.1) NVA Inventory does not have a clear categorization, nor a clear method of calculation for the different levels of granularity – meaning Warehouse, Country, and Europe. It is expected that the improvement proposals concretely target the following problems:

- Lack of a consensual mathematical categorization of products as Excess, Obsolete or Expiring;
- Inexistent capability of quantifying Excess, Obsolescence or Expiration per level of granularity;
- Difficulty of monitoring the evolution of NVA Inventory on a weekly-basis;
- Inefficient storage of inventory, due to holding significant quantities of excess and obsolete inventory;
- Inexistent capability of predicting expiration dates of inventory.

Figure 23 synthetizes the narrative that connects the identification of the causes that are mostly affecting the Inventory Management System with the expectations for the further research.

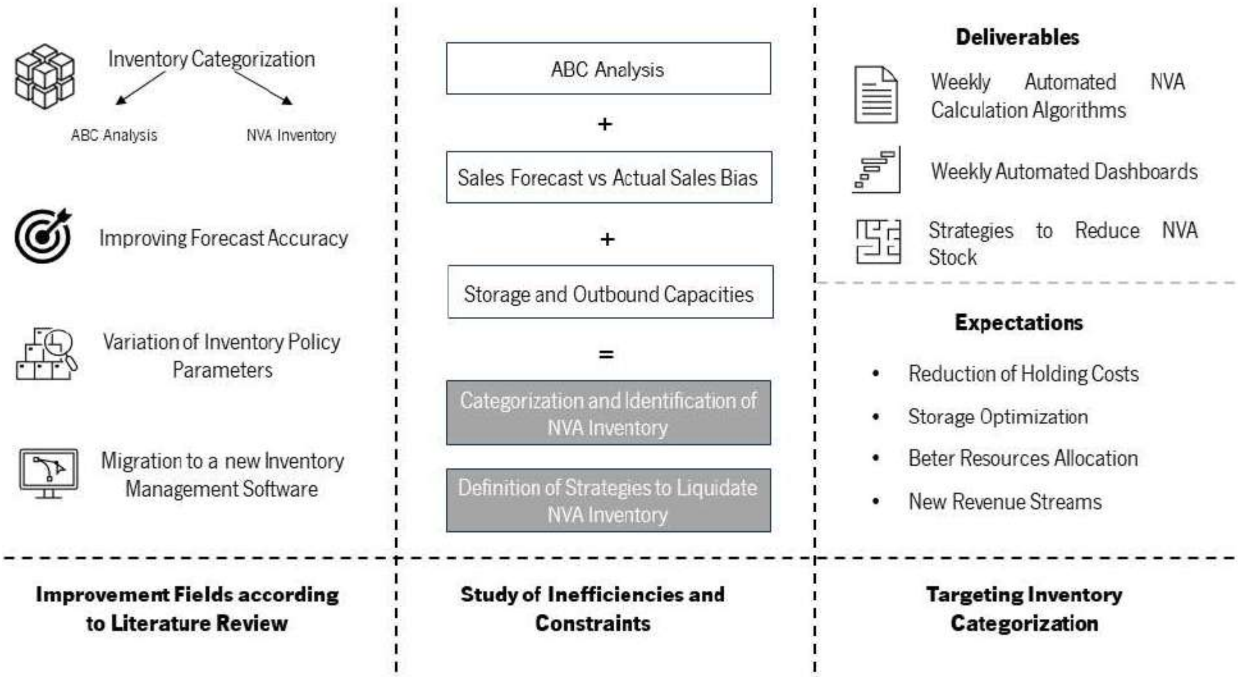

Figure 23 - Map of Process to Support the Solutions

The improvement measures of this study can be divided in three main vectors:

1. **Automation:** identification and categorization of NVA Inventory through the development of algorithms and reporting dashboards (Chapter 4. Data-Driven Tools to Support Non-Value-Adding Inventory Management)

2. **Optimisation:** definition of business strategies materialized through the creation of action plans to reduce NVA Inventory (Chapter 5. Non-Value-Adding Inventory Management Integrated Strategy)
3. **Control:** monitoring results through the implementation of the action plans and definition of future recommendations (Chapter 6. Results and Discussion)

4. DATA-DRIVEN TOOLS TO SUPPORT NON-VALUE-ADDING INVENTORY MANAGEMENT

The present chapter will focus on the technical description of the data-driven tools created to tackle NVA Inventory. The deliverable regarding the data-driven tools consists of an algorithm that automates the quantification of each type of NVA Inventory and that is later transformed into a weekly updated dashboard. The algorithms were developed using Scientific PYthon Development EnviRonment (Spyder) from Anaconda Navigator and the dashboards were built in Microsoft Excel.

Different algorithms and dashboard reports were created, one targeting **Excess & Obsolete Inventory**, another one targeting **Expiring Inventory** and an additional one that calculates excess and obsolescence for the special case of beds. Figure 24 aims to synthetize a generalist overview of the chain of these data-driven tools, meaning their input, output, and business objectives.

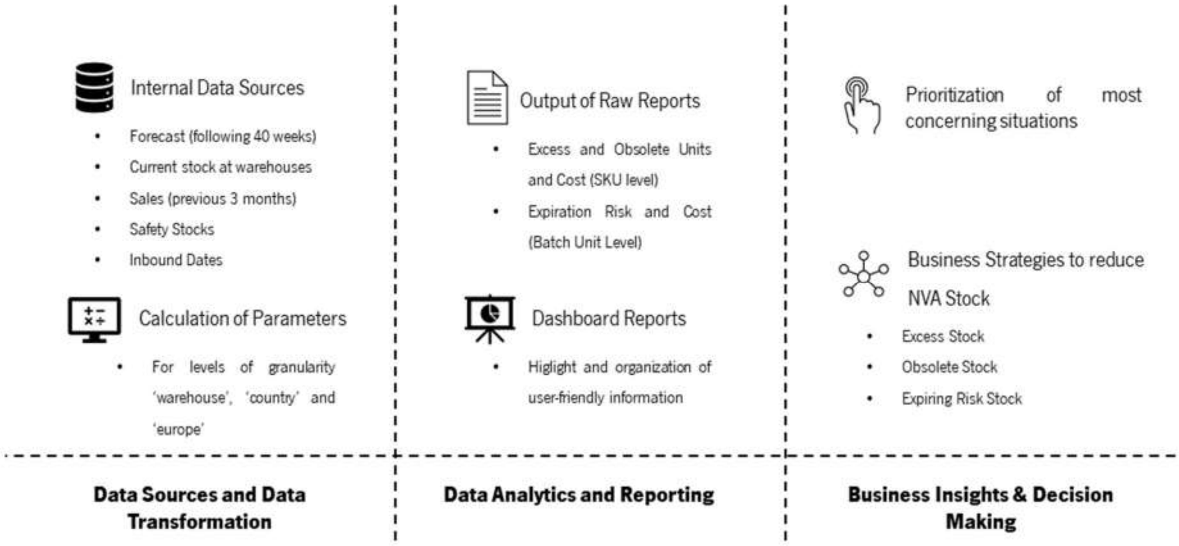

Figure 24 - Flow that supports the understanding of the data-driven tools

When levels of granularity are mentioned, one should understand three geographic segmentations: 'europe', 'country' and 'warehouse'. Despite the coded name, 'country' can sometimes be referred as Region, since both terms are used to name it.

4.1. Tracking and Evolution of Excess & Obsolete Inventory

The purpose of the development of a data-driven tool targeting Excess & Obsolete Inventory comes from the difficulty of overviewing different levels of granularity regarding these categories of inventory. There was not a clear identification of the practical meaning of both concepts of inventory, nor visibility over the different levels of granularity of the company, meaning the 'warehouse', 'country', and 'europe' level.

Since 'europe' has several countries, and one country can have several warehouses, the excess of the same SKU can be different according to the level of granularity.

So, the main purpose of this topic consisted of the development of an automated tool that, combining weekly inputs, could output a detailed report of the excess and obsolete situations, according to the desired level of granularity.

Some initial sub-objectives can be mentioned as follows:

- Recalculation of stock coverages per SKU with a more accurate methodology, considering the exact weekly forecast for each one of the analysed weeks;
- Easily weekly automated report of excess and obsolete quantities, per SKU and level of granularity;
- Construction of a visually interactive dashboard that fosters visibility and collaboration within excess and obsolete inventory;
- Concrete identification of most concerning Product Groups and SKUs, having as follow-up goal their targeting and consequent creation of action plans.

The main definitions and formulas that were considered for the development of the report and that are useful for the understanding of the output results can be seen in Table 18, in the Appendix 3 – Scripts and Backup of the Models.

4.1.1. Description of the Algorithm of Excess & Obsolete Inventory

The algorithm was developed using Scientific PYthon Development EnviRonment (Spyder) from Anaconda Navigator. It has in consideration the integration of nine different data frames, which represent data files from different sources. There are four which have a more significant impact in terms of the weekly update of the report, being them: **forecast of the following 40 weeks**, **current real stock in every warehouse**, **sales from the previous three months** and **safety stocks per SKU**. These files require a weekly update and are inputted from different sources, respectively Tableau, Excel Stock DataBase and SO99+.

The code is presented for the level of granularity Warehouse by Figure 53, in the Appendix 3 – Scripts and Backup of the Models. The detailed description of the code can be found in the same appendix.

4.1.2. The Output of the Algorithm of Excess & Obsolete Inventory

The output of the Python script is an Excel File with three different sheets, each one for a different level of granularity, but all following the same structure and outputting the same variables. The outputted data is then transformed into a dashboard, using Microsoft Excel, to provide a visual representation of the KPIs. That allows users to monitor and analyse trends and patterns, highlighting the most concerning or impactful situations in the current week.

The final goal was to create a better data-driven decision-making process, while improving communication and collaboration among stakeholders.

The dashboard for the level of granularity 'country' can be seen in Figure 25.

Figure 25 - Dashboard of the level of granularity 'country' for the Excess & Obsolete Inventory Report

It aims to generate KPIs that allow the user to have an overview of the status of the analysed location, regarding inventory management. The weighted average of coverage and the total quantities of high and low risk excess promote a generalist view of the country. Although, it is possible to deep dive in the analysis, targeting most concerning Product Groups regarding obsolete and excess quantities.

To develop the analysis further, in a more follow-up plan-oriented view, the dashboard also allows the user to concretely understand what the most impactful SKUs regarding Excess Cost are, as seen in Figure 26. From this moment onwards, confidential data is blurred on purpose.

Item Code	Country	Sales Countries	Sum of WAvg Coverage	Average of Special Cases Coverage (Weeks)	Sum of Excess_Units	Sum of Stock in Pallets	Sum of High Risk Excess Cost	Sum of Low Risk Excess Cost
EBDBB090200B10	France	[('FR', '100.00%')]	17.00	0.0			29,566.8 €	4,067.2 €
LMALU0802005FB	France	[('FR', '100.00%')]	40.00	42.9			25,429.7 €	0.0 €
EBDSG080200CBA	France	[('FR', '100.00%')]	35.00	0.0			21,571.7 €	3,635.1 €
EMAHE160200ATA	France	[('FR', '100.00%')]	29.41	0.0			14,021.1 €	0.0 €
EMAGG140190AAA	France	[('FR', '100.00%')]	40.00	69.6			13,727.0 €	0.0 €
EMAOR090200ATB	France	[('FR', '100.00%')]	21.24	0.0			13,309.9 €	13,620.1 €
EHGWB150200AAA	France	[('FR', '100.00%')]	15.61	0.0			12,726.4 €	37,829.1 €
EBDSF140200FRA	France	[('FR', '100.00%')]	14.06	0.0			11,839.0 €	46,700.5 €
EBLPC070050AWF	France	[('FR', '100.00%')]	40.00	48.5			11,244.3 €	3,905.3 €
EMAGG160200AAA	France	[('FR', '100.00%')]	32.51	0.0			11,100.0 €	0.0 €
Grand Total			23.55	16.1			164,536.1 €	109,757.2 €

Figure 26 - Most Impactful SKUs regarding Excess Cost

In a parallel view, the dashboard allows the user to identify the most impactful SKUs regarding Obsolete Cost, as seen in Figure 27.

Item Code	Country	Sales Countries	Sum of Obsolete_Units	Sum of Stock in Pallets	Sum of Obsolete_Cost
⊟EMAED140200BAA	⊟France	[('FR', '100.00%')]			42,676.5 €
⊟EBLDC240220AWN	⊟France	(blank)			29,328.0 €
⊟EBDUB190LNSB21	⊟France	[('FR', '100.00%')]			20,645.5 €
⊟EBLFT180200AWN	⊟France	(blank)			20,254.7 €
⊟EBDBB090200C10	⊟France	[('FR', '100.00%')]			18,425.0 €
⊟EBDBB160200C10	⊟France	(blank)			15,925.0 €
⊟EBDBB090200A23	⊟France	[('FR', '100.00%')]			12,124.0 €
⊟EBLFT160200AWN	⊟France	(blank)			9,183.2 €
⊟EBLFT140200AWN	⊟France	(blank)			8,109.2 €
⊟EMDCW240220AAA	⊟France	[('FR', '100.00%')]			6,843.8 €
Grand Total					183,514.7 €

Figure 27 - Most Impactful SKUs regarding Obsolete Cost

4.1.3. The Exception for Beds

The basilar purpose of the previously introduced dashboard report consists of the combination SKU – Level of Granularity. Although, this characteristic cannot be linearly followed for Beds, since they represent a Composite Product, integrating several Components.

The main objective of the new script developed for Beds could be summarized as **obtaining an accurate adjustment of the excess and obsolete quantification per Bed Set – Component** combination, instead of just having it per Component.

Table 8 gives an example of the excess of a Component according to the previous model.

Table 8 - Example of the excess quantification according to the previous report

<table>
<tr><th>SKU</th><th>Warehouse</th><th>Region</th><th>Excess Units</th></tr>
<tr><td rowspan="2">EBDBB135190A10</td><td>DS_ES</td><td>Iberia</td><td>150,6</td></tr>
<tr><td>PEGD_GB</td><td>United Kingdom</td><td>660,2</td></tr>
</table>

Considering the explained exception for Beds, the desired output can be translated by Table 9.

Table 9 - Example of the excess quantification according to the new adjustment

<table>
<tr><th>SKU</th><th>Warehouse</th><th>Region</th><th>Composite SKU</th><th>Weight</th><th>Adj. Excess Units</th></tr>
<tr><td rowspan="7">EBDBB135190A10</td><td rowspan="3">DS_ES</td><td rowspan="3">Iberia</td><td>XEMBDBXB135190_00173</td><td>87,23 %</td><td>131,4</td></tr>
<tr><td>XEMBDBXB135190_00182</td><td>12,77 %</td><td>19,2</td></tr>
<tr><td>Total</td><td>100 %</td><td>150,6</td></tr>
<tr><td rowspan="4">PEGD_GB</td><td rowspan="4">United Kingdom</td><td>XEMBDBXB135190_00173</td><td>66,67 %</td><td>440,1</td></tr>
<tr><td>XEMBDBXB135190_00174</td><td>8,33 %</td><td>55,0</td></tr>
<tr><td>XEMBDBXB135190_00182</td><td>25,0 %</td><td>165,1</td></tr>
<tr><td>Total</td><td>100 %</td><td>660,2</td></tr>
</table>

The most significant change consists of the merge between the new Bill of Materials and the Sales per Composite SKU, which allowed the calculation of the Weight per combination Composite SKU – SKU according to the formula described by Equation 2. The calculation of Low and High-Risk Excess follows the same calculation.

Equation 2 - Calculation of adjusted excess per Bed Set - Component

$$Adjusted\ Excess_{\ Parent\ -Componen} = \frac{Demand_{\ Parent}}{\sum Demand_{Set\ of\ Parents}} \times Excess_{\ Component}$$

Appendix 3 – Scripts and Backup of the Models presents detailly the script and contains Table 19, that works as support to the understanding of the distribution of the weight for the calculation.

4.2. Tracking and Evolution of Expiring Inventory

The data-driven tool that was developed to study Expiring Risk Inventory involves the development of an algorithm designed to automate the quantification of this specific inventory type. Subsequently, this algorithm is translated into a dashboard that undergoes weekly updates.

The expiring risk algorithm utilizes the product's validity date as a key input to assess the likelihood of its expiration before sale or usage. By expiration, one means the maintenance of the conditions under which the product is considered in good quality to be sold. It does not mean that the product cannot be used after the validity date, but that it should be inspected, since it is possible that the desired levels and requirements for selling are not maintained.

By analysing the remaining time until the validity date, the process can allow the identification of products at higher risk of expiration – or even already expired - and facilitate proactive inventory management strategies to minimize waste and optimise stock turnover. This approach enhances supply chain efficiency and helps ensure that customers receive products with reduced age.

This algorithm came up due to the lack of visibility regarding the shelf-life of different products, whose root cause is the non-existence of updated and reliable data from warehouses. To better understand the concept in which the model was raised, three main assumptions must be considered:

- Three categories of products – Mattresses, Pillows and Toppers – have an expiration time, after which their selling is not advisable, as can be checked in Table 21, in the Appendix 3 – Scripts and Backup of the Models;
- Most warehouses did not have tools to monitor the inbound dates, which constituted a significant blocker to build a universal algorithm that could directly correlate SKUs between Excess & Obsolete and Expiration Reports;

- The data needed from warehouses requires all the inbound dates of every SKU that is currently hold in the warehouse, with the exact number of units that were inbounded.

The primary objective of this topic was to create an automated tool capable of generating a weekly report about the expiration status of all batches within a chosen warehouse.
Some initial sub-objectives can be mentioned as follows:

- Empowerment of the decision-making process regarding inventory management with the capability of understanding expiration risk status per SKU;
- Pushing and supporting warehouses to create systems to reliably track inbound dates (ideally production dates) per SKU and batch;
- Identification of stock's age and expiration risk;
- Combination of Excess & Obsolete situation with the Expiration Risk status, by defining a strategy to correlate both reports.

The main parameters and calculations that were considered for the development of the can be seen in Table 20, in the Appendix 3 – Scripts and Backup of the Models.

4.2.1. Description of the Algorithm of Expiring Inventory

The algorithm was developed using Scientific PYthon Development EnviRonment (Spyder) from Anaconda Navigator. The most impactful data sources that are inputted to the algorithm can be named as follows: **forecast of the following 40 weeks, quantity of SKU per inbound date (batch**) for the different warehouses and **lead times**. The weekly update of these files requires the utilization of several data sources, coming respectively from Tableau, Excel Files from Warehouse Teams and SO99+.
The explanation of the code for the Hammer Warehouse can be seen in the Appendix 3 – Scripts and Backup of the Models, and it can be assumed that the process is similar to every warehouse. Figure 66 maps the visual flow of the process.

4.2.2. The Output of the Script of Expiring Inventory

The output of the Python script is an Excel File with one sheet that integrates data from three different warehouses. The outputted data is then transformed into a dashboard, using Microsoft Excel, promoting the monitoring and analysis of patterns of expiration, emphasizing the most influential circumstances in the present week. The ultimate objective was to enhance decision-making through data-driven approaches, concurrently fostering collaboration between involved stakeholders.

The dashboard for a Warehouse example week can be seen in Figure 28.

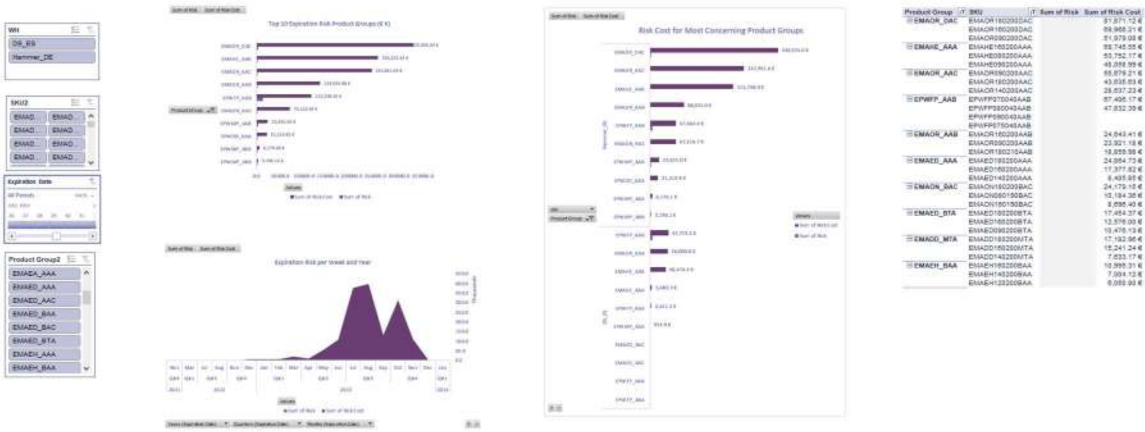

Figure 28 - Dashboard of the Expiration Risk Report

In a quantity perspective, it allows the user to understand what the most concerning Product Groups are, regarding the Expiration Risk Units and Cost. It is possible to deep dive in the analysis, targeting SKU level from most impactful Product Groups. On the other hand, the dashboard also allows the user to have a timely overview of the distribution of expiration risk over time. The decision making-process is then fostered, allowing the user to simultaneously decide on a quantity or time-framed perspectives.

4.3. Summary of the Automated Reports

The previous sections presented three different data-driven tools, whose output allows the construction of weekly automated reports, visually materialized as dashboards. Chapter 4 allowed the understanding of the impact that the aforementioned data-driven tools had on the main challenges or expectations highlighted in Section 3.3.3.

The main impacts of these tools can be summarized as:

- Accurate and consensual categorization and quantification of products as Excess, Obsolete or Expiring;
- Calculation of inventory quantities per category based on different levels of granularity;
- Development of automated reports that allow monitoring the evolution of NVA Inventory on a weekly-basis;
- Improvement of visibility and reliability of data, by providing information that increases business knowledge and promoting data-driven decision making;

While the content of this chapter is mainly descriptive, since it only presents methodologies that arrange and promote visibility of information, the following chapter dives into the conversion of the data outputted from the data-driven tools into business strategies.

5. Non-Value-Adding Inventory Management Integrated Strategy

This chapter aims to elucidate how the outputs of the data-driven tools – meaning the dashboard reports - are used in the definition of business strategies, purposing to design an approach that aims to manage and reduce NVA Inventory.

From the previously mentioned data-driven tools, NVA Inventory could be split in three main categories: Excess, Obsolete and Expiring Inventory. Since Excess Inventory is from the responsibility of the SP team – which means it is out of the scope of the study -, the holistic strategy targets only obsolete and expiring inventory, being each divided into a predictive and a reactive analysis. The set of processes that constitutes the overall strategy is ruled by the following structure:

- **Obsolete Inventory:** there is not prediction for this inventory to be sold, which means there is no forecast for the following 40 weeks. This criterion is weekly updated from the Excess & Obsolete Inventory Report and has as KPIs the quantity of Obsolete Units and, respectively, the associated Obsolete Cost.
- **Risk of becoming Obsolete** *(To-Be Obsolete*): there is an estimation that this inventory will become Obsolete in a near future, since the coverage in weeks is significantly higher than the desired levels. This information comes from the Excess & Obsolete Inventory Report and results of the identification of special cases SKUs, where the coverage is higher than the inputted time frame of forecast (40 weeks). This criterion targets SKUs with low forecast for the real quantity in warehouse, whose associated cost represents the risk of obsolescence.
- **Expired Inventory**: represents inventory which is already expired, because its age is superior than the recommended life expectancy of the product.
- **Risk of Expiring Inventory** *(To-Be Expired)***:** represents inventory which is predicted to be expired by the time it will be sold, according to the forecast for the following weeks.

Figure 29 aims to represent the workflow of the integrated approach to manage NVA Inventory. Having as input the result of the application of the data-driven tools, the first stage of the approach consists of the interpretation and categorization of inventory, represented by (1).

After that step, stage (2) consists of the creation and implementation of business processes to manage each type of inventory, using the data inputted from the data-driven tools.

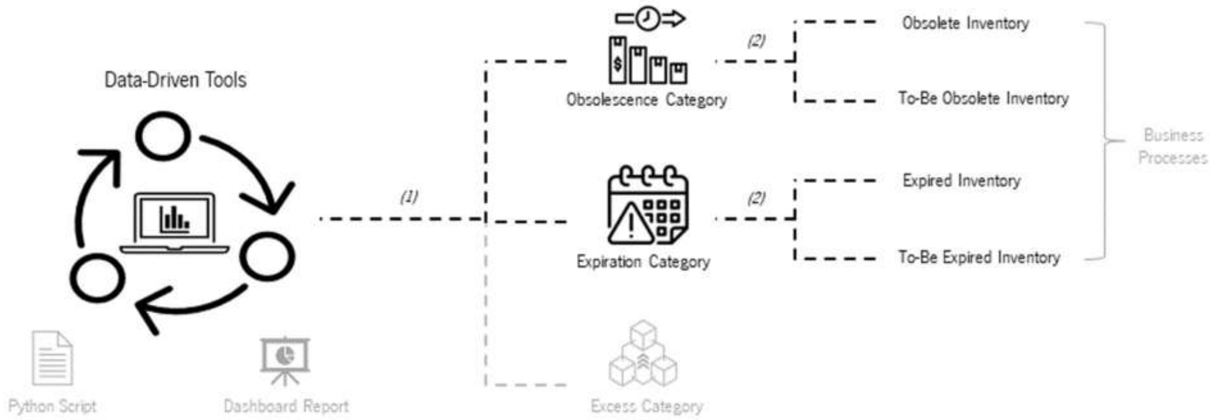

Figure 29 - Visual representation of the holistic strategy to manage NVA Inventory

The following sections will explain each of the business processes that constitute the holistic approach to manage NVA Inventory.

5.1. Obsolescence Category

The vector that tackles the category of obsolescence can be split in two main processes:

- **Predictive Process:** analysis of the impact of holding inventory which will most probably become obsolete in a near future (to-be obsolete inventory).
- **Performance Evaluation Process:** analysis of the inventory which is already considered as obsolete since there is no prediction of sales for the next 40 weeks (obsolete inventory).

Both processes are expected to have the ownership of S&OP, particularly by the IP area. The following sections will dive into the explanation of each process.

5.1.1. Monitoring Obsolete Inventory and Definition of Follow-Up Plans

Initially, the process consists of targeting the most concerning situations regarding obsolete inventory, aiming to reduce the costs associated to that type of unwanted stock. Having no prediction of sales, the accumulation of it only constitutes holding unnecessary costs and occupying space that could be used for other products.

The tool to monitor the most concerning situations regarding the obsolete condition groups SKUs per product group and sorts them from highest to lowest according to their total expiration risk cost. It considers the following indicators from the dashboard reports of the data-driven tools:

- Number of obsolete units per SKU, from the Excess & Obsolete Inventory Report
- Obsolete stock cost per SKU, from the Excess & Obsolete Inventory Report
- Expired stock cost per SKU, from the Expiration Risk Report

The indicator inputted from the Expiration Risk Report constitutes the first moment of integration of both Excess & Obsolete Inventory Report and Expiration Risk Report. The process of identifying the most concerning situations targets the five product groups with the biggest expiration risk cost. As follow-up, action plans are built on a SKU Level, involving the responsible stakeholders from each country where it is sold.

The typical follow-up plans consist of the following:

- **Clearance Sales:** application of discounts or promotions to sell a product until it runs out of stock (*Clearance Sale*, 2023)
- **Depletion Plan:** sale of product until stock is over, by applying different strategies or channels ('Depletion Reports', 2021)

The detail of the process to manage obsolete inventory can be seen in Table 22, in the Appendix 4 – Material to Support the Strategies.

5.1.2. Monitoring To-Be Obsolete Inventory and Definition of Follow-Up Plans

The scope of the study is on to-be obsolete inventory, whose coverage is higher than the 40 weeks' timeframe of forecast, which means there is a high probability of the product to become obsolete. This happens since in most cases a residual forecasted demand does not allow the product to be on-time considered as obsolete, even though the rotation of the product is significantly low.

The tool used to monitor the five most concerning situations regarding to-be obsolete inventory organises SKUs per product group and sorts them from highest to lowest according to their estimated obsolete cost. It considers the following indicators from the dashboard reports of the data-driven tools:

- Estimated coverage per SKU, from the Excess & Obsolete Inventory Report
- Estimated obsolete units per SKU, from the Excess & Obsolete Inventory Report
- Estimated obsolete cost per SKU, from the Excess & Obsolete Inventory Report

The predictive analysis of obsolescence constitutes an ambitious and long-term objective since it is dependent of a significant reduction of the on-time quantities of obsolete units. It only makes sense to invest time in predicting future obsolescence when there is a relevant outflow of the current obsolete units.

The main objective with this strategy is to allow inventory planners to act *a priori*, instead of a *posteriori* by reacting to eventual emergences of newly obsolete product groups. As a practical example, this strategy can anticipate the definition of a follow-up plan to a product group which is only going to become obsolete in the upcoming week. If it represents a significant value in costs of inventory, it will be highlighted by this KPI.

Since the timeframe of the inputted forecast is limited to 40 weeks, the estimated coverage assumes as weekly forecast for the following weeks an average of the weekly forecast of the previous 40 weeks. There are situations where the estimated coverage can be postponed over years, which means the prediction of demand is highly residual for the quantity of stock in warehouse, representing a high probability of obsolescence.

The calculation of the estimated coverage can be seen in Equation 3:

Equation 3 - Prediction of Estimated Coverage after limit of 40 Weeks

$$Estimated\ Coverage = \frac{Physical\ Stock\ - \Sigma\ Forecast\ (40\ Weeks)}{\frac{\Sigma\ Forecast\ (40\ Weeks)}{40}} + 40$$

The detail of the process to manage to-be obsolete inventory can be seen in Table 23, in the Appendix 4 – Material to Support the Strategies.

5.2. Expiration Category

From the integrated approach to manage NVA Inventory, the field that targets expiration can be split in two main processes:

- **Predictive Process:** analysis of the future risk of expiration, having in consideration the gap between the predicted sales and real inbounds of the warehouse. This strategy focuses on inventory that is not expired yet (to-be expired inventory).
- **Performance Evaluation Process:** analysis of the already expired inventory, proceeding with inspections to re-check the quality of the stock (expired inventory).

The Predictive Process was previously not implemented in any warehouses. Regarding the Performance Evaluation Process, it was already an existing responsibility for one of the warehouses, even though the methodology was non-automated and significantly erratic since it depended on several subjective assumptions. The aforementioned proposal consists of two different monitoring processes, developed by two different teams. The IP Team from S&OP - having the responsibility of inventory management -, oversees the Predictive Strategy, targeting the most concerning situations in a broader level of granularity ('europe' level). On the other hand, the Performance Evaluation Process is expected to be from the responsibility of the Quality Team, who must target the most concerning situations in a more specific level of granularity, tackling the weekly evolution of stock age per warehouse.

5.2.1. Monitoring Expired Inventory and Definition of Follow-Up Plans

As mentioned, the identification of expired inventory is expected to be from the responsibility of the Quality Team. The maintenance of the desired levels of performance represents a significant process regarding the achievement of the customers' expectations.

The tool used to monitor the five most concerning situations regarding expired inventory aggregates SKUs per product group and they are sorted from highest to lowest according to their expired stock cost.

- Number of expired units per SKU, from the Expiration Risk Report
- Expired stock cost per SKU, from the Expiration Risk Report

This process is developed in a warehouse level and after identification of the critical expired inventory, the Quality Team must interact with the Warehouse Staff to communicate the specific batches that are already expired. The Warehouse Staff has the responsibility of developing inspections on the maintenance of the desired levels of performance of the products and then to communicate sufficient information to the Quality Team, owner of the final decision of what to do with the products.

If the Quality Team advocates that the products are fulfilling the levels of performance, the typical follow-up plans consist of the following:

- **Pushing FEFO:** being the products already expired, it is important to sell them as soon as possible, because holding them longer means higher probability of not keeping the desired levels of selling performance. It represents a good impact in logistic efficiency and better product quality (Mendes et al., 2020).
- **Promotions or Discounts:** the application of strategies to increase products' rotation and outflow can work as a good methodology to decrease their probability of not being sold.

If the Quality Team advocates that the products are not fulfilling the levels of performance, the typical follow-up plans consist of the following:

- **Disposal:** process by which the goods a company produces are destroyed or disposed of (DeVroom, 2020)
- **Donation:** donating finished goods to a worthy cause, to provide them a second life instead of disposal.

The detail of the process to manage expired inventory can be seen in Table 24, in the Appendix 4 – Material to Support the Strategies.

5.2.2. Monitoring To-Be Expired Inventory and Definition of Follow-Up Plans

In this section, the focus is oriented to To-Be Expired Inventory, whose tool to monitor concerning situations considers the following indicators:

- Number of to-be expired units per SKU, from the Expiration Risk Report
- To-be expired stock cost per SKU, from the Expiration Risk Report
- Expiration date, from the Expiration Risk Report

SKUs are organised per batch of the same product group and the expiration date predicts the future day of expiration of the specific batch. The predictive analysis of the expiring risk includes the excess and obsolescence situation of the concerning highlighted situations as factor of evaluation, since a significant part of them can simultaneously be considered as excess or obsolete. The detail of the process to manage to-be expired inventory can be seen in Table 25, in the Appendix 4 – Material to Support the Strategies.

5.3. Summary of the Non-Value-Adding Inventory Management Strategy

Briefly, the complete workflow of the NVA Inventory Management Strategy can be seen in Figure 30. It is split in each of the processes in the Appendix 4 – Material to Support the Strategies, to be visually more understandable.

The map contains both the performance evaluation and predictive strategies of Obsolete and Expiring Inventory. Despite the fact that excess inventory is included in this broad workflow, it is important to reinforce that it is not from the ownership of the IP team, so it is not within the scope of this study.

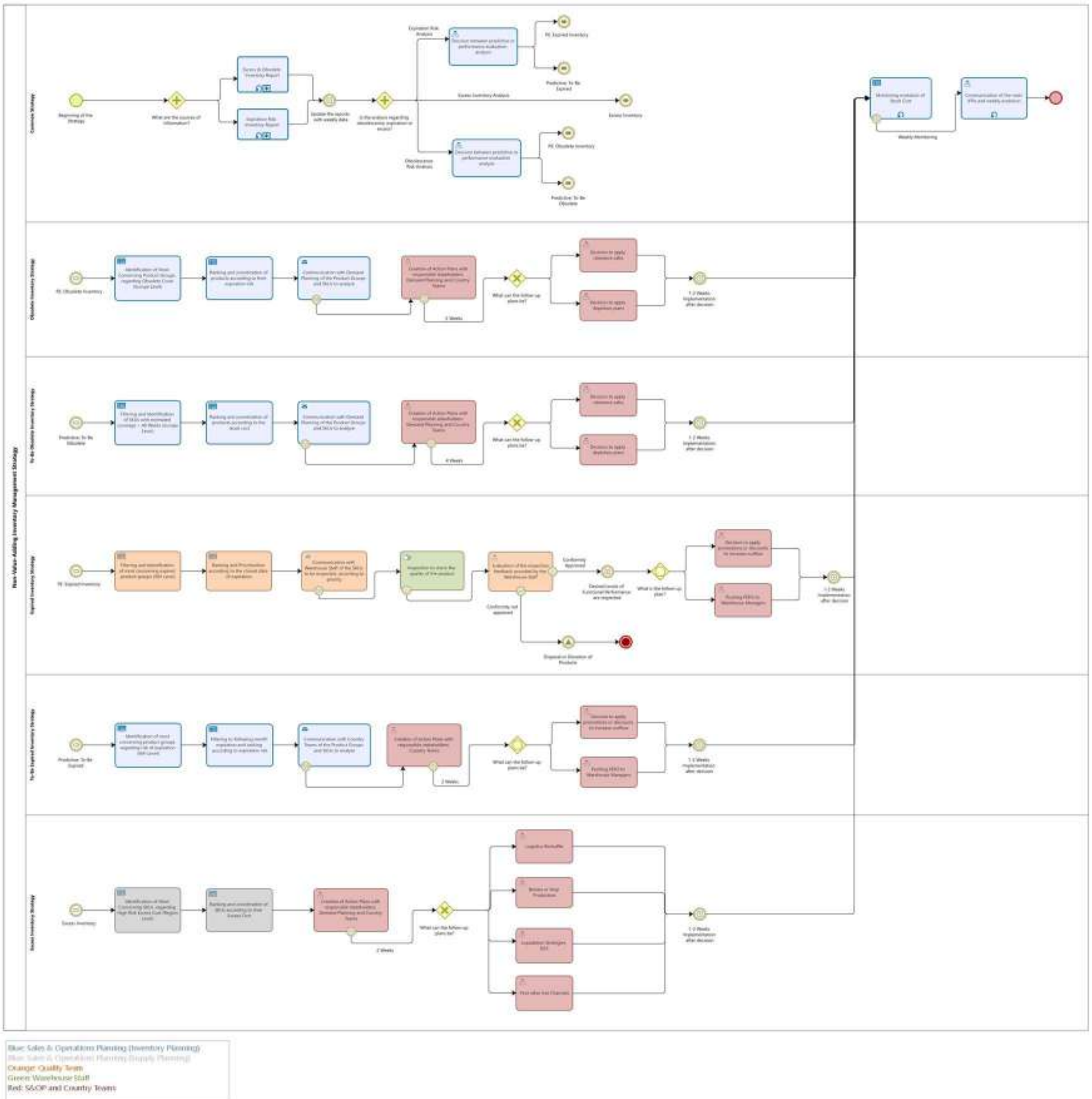

Figure 30 - NVA Overall Inventory Strategy

The process map was developed in BPMN Language, using the software Bizagi Modeler. The overall strategy is designed by the pool, which is segmented in five processes, corresponding to the two analyses for Obsolete and Expiring Inventory, and complemented by the Excess Inventory management algorithm.

5.4. Multi-Criteria Decision Analysis and Scenarios Evaluation

This section has the objective of describing the prioritization methodology to address the implementation of the four business processes presented in Sections 5.1 and 5.2. Since the project has limited resources and a finite timeframe, an assessment of the effort and correspondent impact of each process was designed. The end-goal is to understand if all the processes are worth to be implemented and which should be the order of implementation, according to their expected impact. If this section was not included in the project, the scope could, for example, be oriented to the implementation of the process with the lowest effort associated. However, this decision could not be the one providing more impact, which is not coherent with the mindset of delivering the most impactful results with the current constrained scenario that exists.

In business words, the objective is to minimize holding costs of inventory, by maximizing the potential impact of the implementation of the integrated approach that targets NVA Inventory. A MCDA is further on developed, so that the prioritization of the implementation of each process follows quantitively-objective criteria, according to the learnings from the literature reviewed in Section 2.4.1.

Considering the research developed in Section 2.2, the following criteria were defined to evaluate the success and applicability of the business processes.

Holding Costs of Inventory: being all the processes related to NVA Inventory, holding it constitutes a significant hindrance. This criterion should be measured by the relative reduction of the stock cost.

Storage Capacity: the decrease in holding costs of inventory is intimately related to the reduction in inventory quantities, which consequently allows the emptying of the warehouse. This criterion should be measured by the relative reduction of inventory units.

Potential of Revenue: the reduction of NVA Inventory allows the company to store more relevant inventory and promote ways to sell it. This criterion should be measured by the relative increase in the outflow of the product, before and after the implementation of the strategy.

Effort and Complexity: the implementation of a strategy consists of a significant allocation of human resources and should predict the subjective receptivity of the new methodologies applied. This criterion should be measured by the number of involved stakeholders and the perception of the receptivity for the involved ones.

Table 10 consists of a framework that aims to indicate the meaning of the scale of scores for each criterion in business words. The description of each level of the different criteria was developed through a collaborative meeting led by the IP Team that involved different stakeholders from the S&OP Team.

Table 10 - Description of the scores used to assess the expected impact of the solutions

		Reduction of Costs	**Increase Storage Capacity**	**Potential of Revenue**	**Effort and Complexity**
1	Negligible	No reduction of costs	No reduction of inventory	No increase in product's outflow	The strategy is unfeasible due to complexity
2	Low	Residual impact in stock cost, from **1-2 %**	Residual reduction of inventory, from **1-2 %**	Residual impact in product's outflow, from **1-2 %**	Involvement of **10+** stakeholders and too much innovation
3	Moderate	Reasonable impact in stock cost, from **2-10 %**	Reasonable reduction of inventory, from **2-10 %**	Reasonable increase in the outflow, from **2-10 %**	Involvement of **5-10** stakeholders and challenging innovation
4	High	Significant reduction of stock cost, **10-20 %**	Significant reduction of inventory, **10-20%**	Significant increase in outflow inventory, **10-20%**	Involvement of **2-5** stakeholders and few new improvements
5	Very High	High reduction of stock-cost, **> 20 %**	High reduction of inventory, **> 20 %**	High increase of outflow, **> 20 %**	Involvement of **1** stakeholder and no inertia expected

On the other hand, Table 11 represents the significancy levels assigned to each criteria. These values were determined collaboratively by the IP and SP teams, attributing scores based on an empirical evaluation of their relevance to the study.

Table 11 - Importance Level of each criterion

Range (0-10)	**Reduction of Costs**	**Increase Storage Capacity**	**Potential of Revenue**	**Effort and Complexity**
Significancy Score	10	8	3	5
Significancy Weight	38.5 %	30.8 %	11.5 %	19.2 %

The assignment of scores for each of the processes presented in Sections 5.1 and 5.2 process follows an AHP methodology using an additive weighting method and can be seen in Table 12. The assignment of scores was developed through a similar collaborative process as the one implemented for the definition of the support guidelines provided by Table 10 and Table 11. The score of each cell represents the expected impact of the strategy, meaning that the highest value of the normalized score represents the most expected impactful process. The different colour values represent the weighted scores.

Table 12 - Overall assessment of the solutions according to the weighted criteria

	Obsolete Inventory	**To-Be Obsolete**	**Expired Inventory**	**To-Be Expired**	**Weight**
Holding Costs of Inventory	4 (1,54)	2 (0,77)	2.5 (0,96)	3 (1,15)	38.5 %
Storage Capacity	4 (1,23)	2.5 (0,77)	3.5 (1,078)	3 (0,92)	30.8 %
Potential of Revenue	4 (0,46)	2.5 (0,29)	1.5 (0,17)	2.5 (0,29)	11.5 %
Effort and Complexity	3 (0,58)	2 (0,38)	4 (0,77)	2.5 (0,48)	19.2 %
Sum	15 (3,81)	9 (2,21)	11.5 (2,99)	11 (2,85)	46.5 (11,85)
Normalized Score	**32.3 %** (32,1 %)	19.4 % (18,7%)	24.7 % (25,2%)	23.7% (24 %)	100 %

According to the evaluation, the process that **focuses on obsolete inventory should be targeted as first priority**, followed by the process oriented to expired inventory and the process that tackles to-be-expired inventory, respectively. The processes from the expiration category have close normalized scores, which means that their expected impact is similar. The last process to be prioritized is the one that focuses on to-be obsolete inventory. The order of implementation according to the MCDA can be summarized as:

1. Obsolete inventory process
2. Expired inventory process
3. To-be expired inventory process
4. To-be obsolete inventory process

The approach to target NVA Inventory should **iteratively start with process number 1 and end with number 4**, but the limitations of time and resources might be blockers to avoid the implementation of all the processes.

5.5. Introduction to the Three-Stage Pilot Project to Implement the Non-Value-Adding Inventory Management Improvement Processes

To ease the flow of the implementation, it was decided to follow a phased implementation, splitting the four processes in three main stages.

- **Stage 1, prioritization of the #1. obsolete inventory process**, since the implementation of methodologies to reduce NVA Inventory will focus only in obsolete inventory.
- **Stage 2, integration of the #2. expired** and **#3. to-be expired inventory processes**, with the inclusion of these methodologies in the holistic approach to manage NVA Inventory. The focus of this stage consists of the incorporation of the expiration processes, but the obsolete inventory process remains being applied.
- **Stage 3, integration of the #4. to-be obsolete inventory process**, with the incorporation of this methodology in the overall process. The target of this stage consists of the inclusion of this process, but the previously presented ones remain being applied.

The three stages can then be materialized in a ten-week project, which results from the consideration of the duration of the internship where the project is inserted and from the estimation of the workflow of the project, according to the experience gained within the company.

The Gantt chart that describes the distribution of the three stages can be seen in Figure 31.

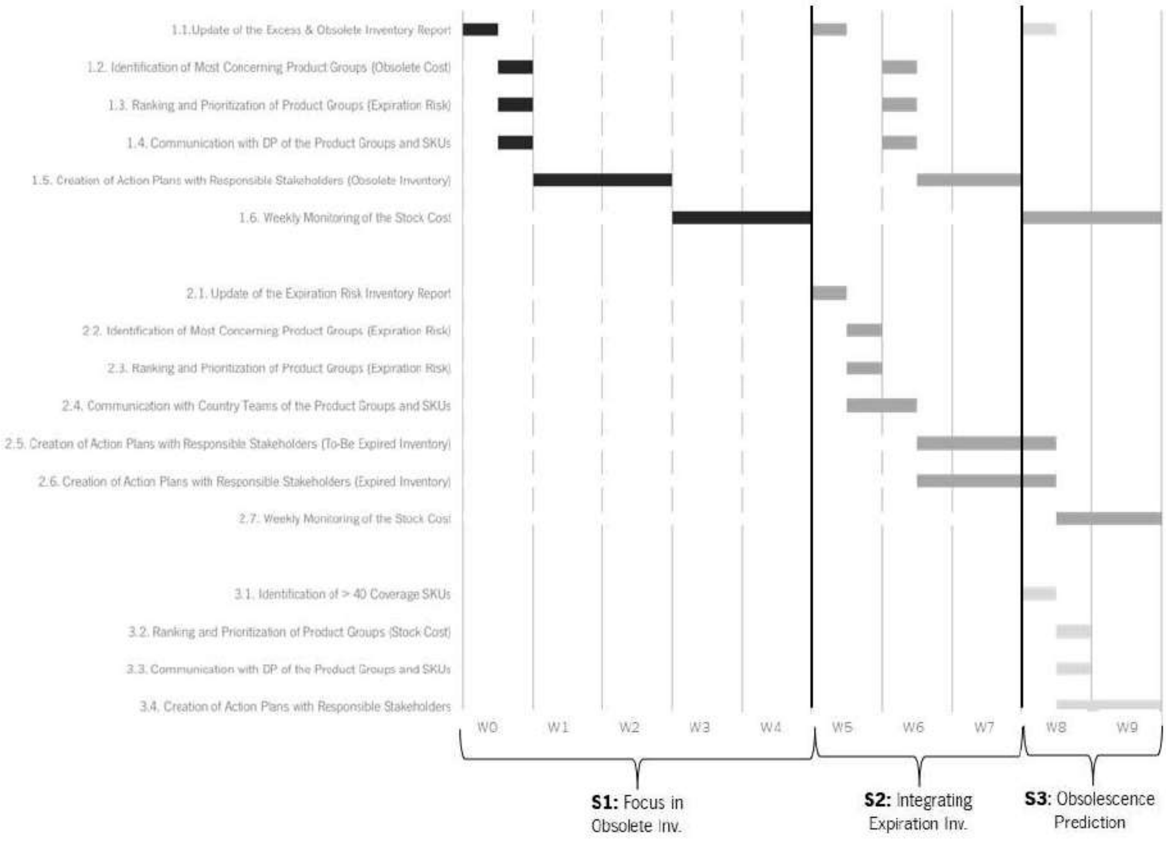

Figure 31 - Gantt Chart for the 10 Week Implementation of the Project

It is important to refer that the three different stages are characterized by the three different colours, but not necessarily for the date. As one can see, there are overlapping objectives between stages two and three, which leads to two main clarifications:

- The stages of the project are purely conceptual, not representing a strictly and immutable structure of the plan. They mostly represent distributions of effort, so that the orientation flag that leads the project can easily be understood.
- While the first stage is a solid adding-value methodology - where the application is believed to have a strong short-term impact - the second and third stages are more experimental, since the focus switches to a trial-and-error orientation.

A detailed description of the micro-objectives of each stage can be seen in Figure 73 – in the Appendix 4 – Material to Support the Strategies-, where KPIs are created to monitor the progression of the project.

6. RESULTS AND DISCUSSION

The following sections present results obtained by the pilot test that implemented the three-stage strategy created to manage NVA Inventory. The implementation was done in the last ten weeks of the internship and the focus was oriented to obsolete inventory in the first seven weeks and to the integration of the expiration category in the last three weeks.

6.1. Stage 1, Focus in Obsolete Inventory

Initially, the update of the Excess & Obsolete Inventory Report and consequent identification of the most concerning product groups were developed, and can be seen in Table 13. The sorting of product groups was made following the obsolete cost of each of them, since the expiration risk KPI was not embedded in the obsolete inventory analysis yet.

Table 13 - Target of Most Concerning Product Groups for Stage 1

Product Group	Country	Priority	Obsolete Units	Stock Cost
EMAHE_ATA	Germany	Critical		775,801.7 €
EMADD_MTA	Switzerland	Medium		158,334.1 €
EMAED_BTA	Switzerland	Medium		103,834.0 €
EMAHU_AAA	United Kingdom	Low		22,187.3 €
EMAUH_AAA	United Kingdom	High		346,637.8 €

After identification of the most concerning product groups, the following step of the process of managing obsolete inventory consisted of defining the action plan that would most impactfully reduce the stock cost of the product groups. The description of the action plan per product group can be seen in Table 14.

Table 14 - Action Plans per Product Group

Product Group	Week of Implementation	Action Plan Description
EMAHE_ATA	W0	Clearance Sales, by applying promotion in Website ("Last Chance to Buy")
EMADD_MTA	W6	Clear target of depletion before Black Friday. Sales in Wholesale (Flashsale partners) and eventual compensation of Out of Stock (OOO) for other products
EMAED_BTA	W6	Clear target of depletion before Black Friday. Aggressive clearance starting in October.
EMAHU_AAA	W2	Clearance sales applied.
EMAUH_AAA	W5	Aggressive clearance strategy starting in W8, regular sales before.

The weekly monitoring of the stock cost evolution can be seen in Table 26 in the Appendix 4 – Material to Support the Strategies. A visual summary of it can be seen in Figure 32.

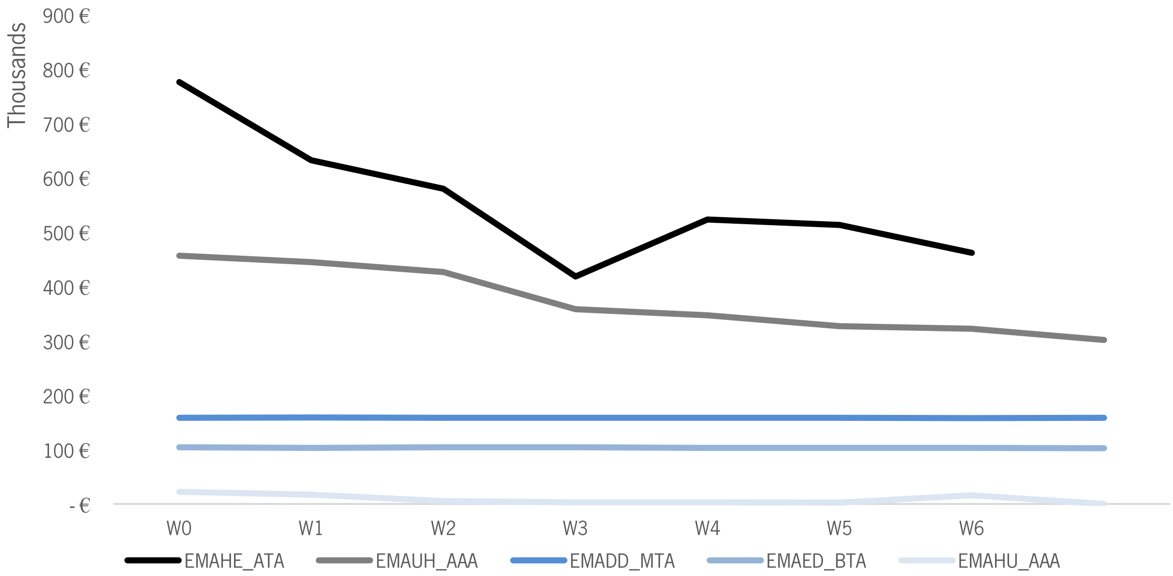

Figure 32 - Stock Cost Evolution over the Stage 1 of the Project

It is possible to understand that EMAHE_ATA and EMAUH_AAA were the product groups with the most significant variation regarding stock cost, respectively **40,5%** and **29.5%**. For the other product groups, the impact was considerably lower, with an average of reduction of 3%. The percentual reduction of stock cost can be seen in Table 27, in the Appendix 4 – Material to Support the Strategies. Additionally, one can see the percentual variation for each of the criteria, which is calculated through the weighted average of the percentual variation of the five product groups.

To convert the percentual results obtained in scores - respecting the scale of the MCDA applied -, the actual values were compared with the ranges defined in Table 10 (Section 5.4). After the implementation, these were the results obtained:

- **Reduction of Costs:** High reduction of stock cost, corresponding to **29,9 %**.
- **Storage Capacity:** High reduction of inventory, **34,1 %**.
- **Potential of Revenue:** Available data not significant to assign a score.
- **Effort and Complexity:** Involvement of **5-10** stakeholders and challenging innovation.

These scores obtained with the execution of Stage 1 are compared with the scores estimated in Table 12 (Section 5.4), which represent the expected impact of the implementation of this process, developed before the actual implementation. The detailed comparison can be seen in Table 28, in the Appendix 4 – Material to Support the Strategies.

In general, it can be concluded that the execution of Stage 1 exceeded the expectations – which gives the perception of a well-oriented project - considering the 13,8% increase from the estimated to the obtained overall results. Despite that, one must be aware of the contextual purpose of this analysis, which mainly works as a generalist-overview assessment of the first sprint of this project. Data quantity is low, with only five product groups being analysed over seven weeks. This makes the obtained scores quite volatile, even though the study is always following percentual calculations and weighted averages, to indeed make the criteria more valuable and reliable according to the context. For this reason, the obtained score for Potential of Revenue was considered null, as explained in Note 2 from Appendix 4 – Material to Support the Strategies.

A comparison between the initially idealized Gantt Chart (Figure 31) and the actual implementation can be seen in Figure 33, for Stage 1, where it can be concluded that the actual execution took more time than what was expected. The study of delays can further on be used as source to identify limitations of this study.

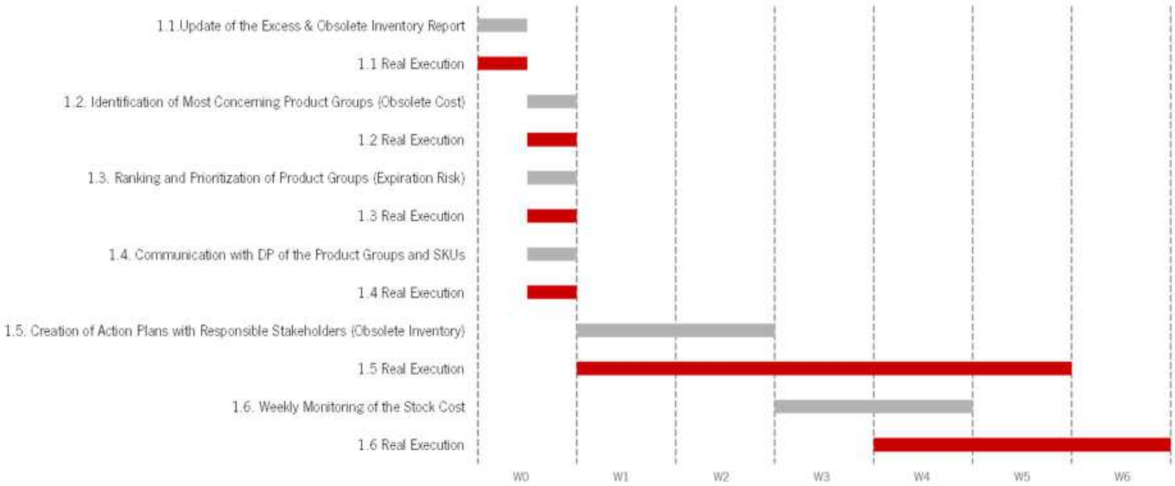

Figure 33 - Comparison between the theoretical approach and the actual implementation of Stage 1

In general, the implementation of Stage 1 was positively successful. The process **confirmed to be high adding-value**, and the **focus on obsolete inventory was an appropriate selection for first stage**, considering the effort and impact that it brought – which validates the prioritization suggested from Section 5.4.

6.2. Stage 2, Integration of Expiration Risk

The update of the Expiration Risk Inventory Report and consequent identification of the most concerning product groups can be seen in Table 15. The sorting of SKUs was made following the Expiration Risk

Cost of each of them, considering products that were already expired or would become expired in the following month. After sorting five SKUs per Warehouse, a merge with the Excess & Obsolete Inventory Report was applied, to understand if the highlighted situations with higher expiration risk costs consisted of excess or obsolete situations.

Table 15 - Target of Most Concerning Product Groups for Stage 1

SKU	Country	Priority	Expiration Risk Units	Expiration Risk Cost
EPWMP060070ABA	Germany	Low		1.267,67 €
EMAED090200AAA	France	Medium		20.835,98 €
EMAED160200BAA	France	Medium		12.340,83 €
EMAOR160200AAB	Spain	High		76.196,29 €
EPWMP040070ABA	Spain	High		7.940,46 €

Following the Gantt Chart presented in Figure 33, the implementation of the second stage only started in the beginning of Week 7, when three weeks remained until the end of the internship. Due to the delay according to what was predicted, the implementation of Stage 2 did not allow the collection of variations in costs.

For EPWMP070070ABA, from Germany, the SKU was considered as Excess and the application of a discount to increase sales outflow was aligned with the Country Team. After that, the list of expiration dates per batch was shared with the Warehouse Managers, to guarantee that FEFO would be followed, and that the validation of the quality of products would occur. The approach was the same for the SKUs from Spain and France, but the process of alignment with the respective stakeholders was still under development.

The practical implementation of the second stage consisted of the application of the theoretical approach presented in Section 5.5.

A comparison between the idealized Gantt Chart and the actual implementation can be seen in Figure 34, for Stage 2, and the delays can further on be utilized to understand the limitations of the study.

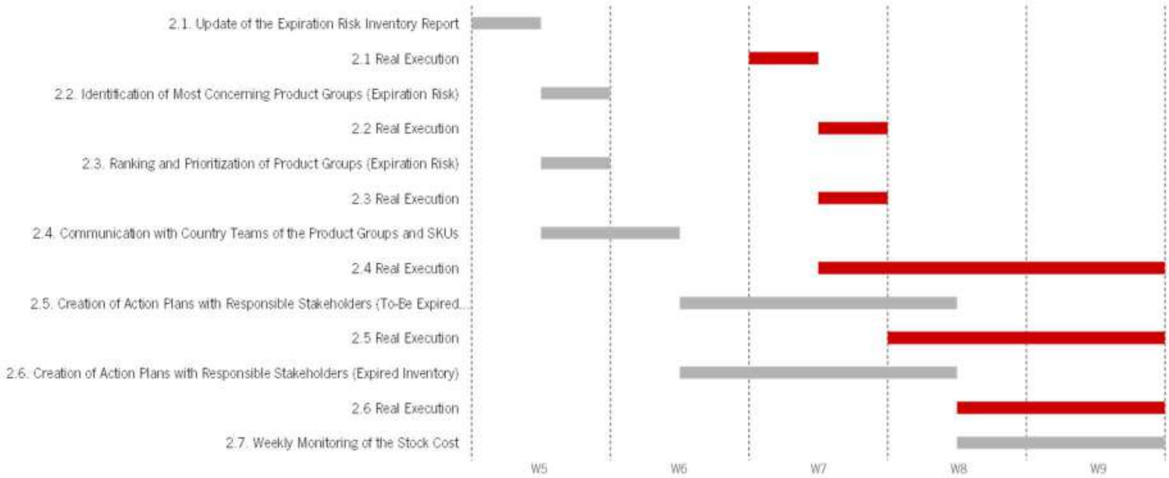

Figure 34 - Comparison between the theoretical approach and the actual implementation of Stage 2

In an overall analysis, the implementation of Stage 2 could have been more successful. It was possible to apply the process to manage Expired and To-Be Expired Inventory, and to identify the main inefficiencies of it. Although, the process did not confirm itself as high adding-value. The process is relevant, but it depends on quality assumptions that were not a priority in the moment of analysis, or that were not consensually and standardized applied. The process has potential to become high adding-value, but several stakeholders need to present commitment and availability to tackle it as priority, in order to establish *a priori* measures to avoid expiration. The next section will explore the implementation of the third stage.

6.3. Stage 3, Prediction of Obsolescence

The implementation of Stage 3 was an ambitious objective, whose overall strategy did not consider as highly relevant, in a short-term perspective. It was exposed throughout the solution due to its expected relevance in a long-term perspective. In fact, being the current situation regarding already obsolete inventory so significant, it did not make sense to implement an approach whose concept resides in the prediction of inventory which is estimated to become obsolete in the future.

That being said, this explanation does not intend to reduce the potential impact of this process, but just to present the logical decision of postponing its implementation. As can be seen in Figure 35, risk of obsolescence is a significant topic, and targeting it *a priori* can add significant value regarding inventory management. The chart identifies the distribution of stock cost over the years for SKUs that are expected to become obsolete, according to the estimation of the coverage explained in Equation 3, in Section 5.1.2.

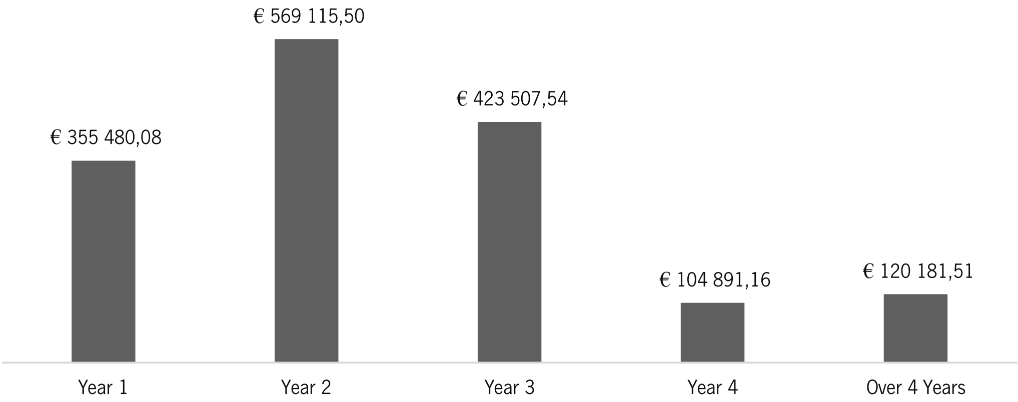

Figure 35 - To-Become Obsolete Stock Cost Over the Years

It is possible to understand that this approach can allow the company to be predictive, instead of reactive, while managing inventory. Targeting obsolescence *a priori* can positively impact the definition of clearance strategies, since they will be aligned with the phasing-out of products and liquidation results will be more successful. Storage is expected to be optimised, and the quality of existing inventory consequently improved.

6.4. Description of the Main Blockers Identified

The following sections will deep dive into the main blockers identified with the implementation of the pilot project to test the NVA Inventory Management Strategy designed. The blockers will be divided by stage of the strategy, but since Stage 3 was not implemented, no blockers were identified for it. Although, it is expected that the already identified problems constitute the most significant potential constraints for the implementation of Stage 3 as well.

6.4.1. The Main Blockers for the Implementation of the Stage 1

The main blockers of the implementation of Stage 1 will be described individually, with the reference to specific situations that occurred for each of the product groups.

Implementation of the Action Plans:

The strategy described in Figure 31 (Section 5.5) was assuming a straightforward-unconstrained project, where no obstacles would allow an almost mathematically proportional execution of the different objectives. Naturally, dealing with multiple product groups and SKUs requires the communication with multiple teams and stakeholders. So, instead of considering the ideal implementation of a uniform strategy, one must consider the implementation of five different strategies, highly variable between each other. Initially, it was expected that every product group would have an action plan defined by the end of Week 3. Regarding the stock cost KPI, which represents the one with the most significance level, a uniform evolution rate was also expected, culminating in an average 10% reduction of the stock cost after the seven weeks of the first stage. Table 16 represents the actual evolution of the cumulative stock cost reduction rate over the seven weeks, considering the real moment of definition of the action plan.

Table 16 – Actual cumulative stock cost reduction rates during Stage 1

SKU	W0	W1	W2	W3	W4	W5	W6
EMAHE_ATA		18,6%	26,9%	54,7%	29,7%	31,6%	41,6%
EMADD_MTA							0,6 %
EMAED_BTA							1,2 %
EMAHU_AAA							7,8 %
EMAUH_AAA				22,7%	25,8%	31,6%	33,1%

By the analysis of the table, one can conclude that three types of implementations occurred. **EMAHE_ATA** had a fast implementation of a clearance sales strategy, which led to the greatest achievements regarding the defined targets. On the other hand, **EMADD_MTA**, **EMAED_BTA** and **EMAHU_AA** had a late definition of the action plan, due to different reasons which will further on be presented and analysed. **EMAUH_AAA** had a stable definition of action plan, which led to a good achievement of results regarding the estimated impact from Week 3 onwards. Before Week 3, the variation for this product group was not due to the liquidation action plan, therefore it was considered as residual.

Dependence on Human Resources:

The criteria defined in Table 10, in the Appendix 4 – Material to Support the Strategies, considers the evaluation of Effort and Complexity according to the number of involved stakeholders. Indeed, stakeholders show up as being a high relevant factor for the implementation of the process. Since the analysis is done for Europe in general, and no country or region is filtered, the highlighted product groups can all be sold in different countries or channels, which represents necessarily different stakeholders.

EMADD_MTA and **EMAED_BTA** represent an inefficient implementation of the process because of the lack of responsiveness and proactiveness to prioritize the situation of one of the involved stakeholders from which the flow of communication was dependent. The definition of the action plan was only visible in Week 6, which represented a change in the responsible stakeholder. Both product groups represent low variations of sales and stock reduction due to that reason.

Quality and Reliability of Data:

The high margin of improvement and automation of the integration of data in the company's systems represents a significant issue that can compromise the detailed analysis of concerning situations. The integration of real stock data from warehouses is considerably erratic, being highly dependent on manual and repetitive tasks. The company does not own warehouses and does not have the ownership of production and manufacturing processes. This leads to high variability regarding the integration of data, since each warehouse has different tools and methods to quantify and communicate data, and each internal person responsible for the integration of that data can have a non-standardized way of doing it.

EMAHU_AAA represents a clear situation of lack of reliability and visibility of data. A significant reduction of the quantities of inventory in Week 1 led to the conclusion that a unique process of moving old stock to a long-term storage location inside the warehouse was being applied, without communication to the team who is responsible for quantifying stocks.

In a short-time frame, it was assumed that the clearance strategy was already being applied, with successful rates of outflow. Although, the comparison with the actual sales – that come from a different source – did not confirm that the units were being sold. The processes implemented were useful to flag and monitor this situation, even though the access to the real stock data, considering the long-term storage, was only available in Week 6. There was a reduction in the costs of inventory, but not as high as what was wrongly perceived in the initial analysis.

Lack of Communication and Visibility within Teams:

Due to the complexity of processes and the involvement of a significant number of stakeholders, from different teams and work environments, the establishment of standardized processes, with clear and recognized owners of each step, constitutes a consensual challenge.

Regarding the NVA Inventory Strategy, even though the complete flow of the map was designed, with clear attribution of responsibilities and owners to each step, one must understand that an efficient implementation of it requires considerable time and effort. The full implementation of a strategy with several new methodologies and tools demands numerous attempts of creating visibility, especially in a highly mutable environment, where experience and stability are not the most common assets.

For the cases of **EMAHE_ATA** and **EMAUH_AAA**, regardless of the good evolution of stock costs, improvement measures of the collaboration process could be identified. For **EMAHE_ATA**, clearance sales suffered an interruption by Week 6 for most of the sizes, due to an illusional liquidation of the stock. After detailed investigation, it was possible to identify that the Country Team was not aware of the existing stock hold by Suppliers. Since they were only considering the stock in Warehouses, they decided to end the clearance for those sizes before the stock was over. Legally, in the country where the product was being sold, it was not possible to reinsert for sale sizes which were already communicated as not available. This deep analysis managed to increase the outflow of some sizes that were still available on the website but was not able to liquidate all the obsolete cost. For **EMAUH_AAA**, the clearance strategy was not properly evident to all the involved stakeholders. It did not negatively affect the evolution of the stocks, but more visibility should have been provided.

6.4.2. The Main Blockers for the Implementation of the Stage 2

All the blockers identified during the first stage were confirmed in the second stage and can be considered as factors that negatively affected the execution of the plan. Additionally, the following blocker can also be mentioned, highlighted from the implementation of the second stage.

Non-Prioritization of Inventory Planning:

Due to the closeness to Black Friday, a high-saturation period, historically marked by intense operational constraints and difficulties, the focus of the S&OP Team progressively switched to the short-term resolution of inefficiencies that were provoking shortage of stocks and delivery delays. The priority of the team was in getting more stock and capacity of production, instead of leaning stock by identifying lack of optimisation.

The scope of this study was designed in a more long-term horizon, with a mindset of continuous improvement, while the mindset of the team was changing to a short-term problem-resolution mindset, which constrained the flow of the strategies built within this project, since they require the intervention of several stakeholders. With finite resources, the shift of mindset might seem the most logical decision, but one must be aware of the need to target inventory management, so that current concerns which can be solved with improvement measures, do not become fracturing short-term resolution needs. As example, if standardized processes to manage inventories are not applied, the maximum limits of storage capacity can be reached, creating the need to implement reactive measures.

6.5. Risk and Opportunities Management Process

According to the methodology explained in Section 2.4.2 and to the inefficiencies highlighted throughout the Section 6.4, a Severity-Likelihood Matrix was developed, with the purpose of building a framework that could identify the most significant risks for the holistic strategy to manage NVA Inventory. The risk analysis will mostly focus on the blockers identified in Stage 1, since it tackles the most significant and adding-value process within the whole strategy. Stage 1 allowed the identification of the most relevant risks, constituting a better source for analysis.

It is relevant to reinforce that it is expected that in future works these risks are considered when a strategy to mitigate NVA Inventory is applied. Table 29, in the Appendix 4 – Material to Support the Strategies, represents how levels should be assigned for the evaluation of each risk according to each field evaluated. The analysis and evaluation of risks according to the framework provided by the Severity-Likelihood Matrix presented can be seen in Table 17 and its development had the ownership of the IP Team.

Table 17 - Summary and Description of the Risks

#	Risk	Severity	Likelihood	Index
#1	Uncertainty of the Execution of the Action Plans	2	2	4
#2	Lack of Responsiveness or Proactiveness from Stakeholders	3	3	9
#3	Issues in Quality and Reliability of Data	5	3	15
#4	Lack of Communication and Visibility within Teams	4	4	16

One can conclude that risks #3 and #4 represent higher relevance in terms of prioritization, according to the Severity – Likelihood Matrix.

As a step-forward process, a detailed Failure Mode Effect Analysis Process (FMEA) was developed, where some potential failure events were studied for each risk. Table 30, in the Appendix 4 – Material to Support the Strategies, presents the complete and detailed FMEA.

The three most potentially impactful failures are inserted in the higher relevance risks highlighted in Table 17, respectively #3 and #4. The breakdown analysis of the most important potential failure events can be seen then.

Risk #3: Issues in Quality and Reliability of Data

- **Potential Failure Event #1:** Erratic quantification of inventory in the warehouse

Typically emerging as a consequence of the complexity of the supply chain, the constitution of the network with such high number of stakeholders, makes the standardization of processes harder and less organized. This leads to higher error propensity, which can eventually be translated into erratic decision-making, a deeply non-desirable occurrence. Even though the mindset of the company is on the right track, with a strong vision to automate and structure strategies - by transforming processes into tech-friendly – there are still some improvement measures that could be applied, especially to mitigate the short-term inefficiencies.

- **Potential Failure Event #2:** Mismatch between forecast and phased-out of products (forecast = 0 when phased out)

Tenderly coming up as a consequence of the lack of communication between teams, the specific mentioned potential failure represents a type-figure of how repetitive tasks dependent on human or manual work can foster a biasing factor for final decision-making. This technical detail would make products not being considered as obsolete in the IP perspective, since the mathematical calculation of it requires no future prediction of sales - meaning no forecast. As a consequence, IP would not be able to provide visibility regarding the obsolete situation of the product, which could remain as non-obsolete for undetermined time, increasing the probability of expiration and the costs of holding inventory. There is an active effort to implement meetings with S&OP and Country Teams to implement this weekly discussion routine about NVA Inventory, but it is still an ongoing non-standardized process.

Risk #4: Lack of Communication and Visibility within Teams

- **Potential Failure Event #1:** Country Team is not aware of obsolescence/ expiration condition of a product.

Since the automated and reliable identification of NVA Inventory represents a recently implemented innovation – with the implementation of the Excess & Obsolete and Expiration Risk reports -, the optimisation of the process has still a huge margin of progression. A significant switch in the focus was applied, by the transformation of a warehouse/ country level punctual-reactive assignment to a broad-level weekly-predictive strategy. Many people and teams are still lacking visibility and the ownership and distribution of responsibilities is still not totally fluid.

6.6. Summary of Main Impacts

The purpose of this section is to summarize the main KPIs obtained with this study, which can answer the following research question:

RQ3: How impactful can be targeting NVA Inventory, in order to increase capacity and reduce stock cost?

Regarding Financial KPIs, the monitoring of the evolution of Stage 1 was developed at the end of Week 6. Although, the strategy kept being implemented, even though the focus shifted to the expiring inventory. In the end, after the implementation of a three-stage pilot project distributed by ten weeks, the **total savings of stock accounted for 766K €** corresponding to a **50% weighted average reduction of stock quantities** for the targeted product groups, regarding the obsolete cost – according to calculations applying Equation 9. With the purpose of deep diving into the indicators, a brief introduction to the main changes from Week 7 onwards is going to be developed.

There was a total liquidation of the product group EMAHU_AAA, with 3% of the inventory being donated and the rest sold to a business partner. Monitoring EMAHU_AAA led to the creation of a highly profitable revenue stream, since several other obsolete SKUs were flagged. In total, around **40K € on sales** were streamlined as a consequence of the implementation of the obsolete management process.

For EMAHE_ATA, a risk analysis was developed, where the benefit of the reinsertion of some previous deleted sizes in the market would be beneficial. This led to a final liquidation of **76% of the stock quantities**, corresponding to 273K € reduction of stock cost since the previous analysis in the end of Stage 1.

For EMAUH_AAA the impact was less significant, but still allowed a **reduction of 20K €** on inventory. For EMAED_BTA and EMADD_MTA, the action plans were not implemented before the end of the project.

As summary of operational KPIs, it is important to mention the categorization of NVA Inventory and concrete identification through the development of **three automation algorithms**. The output of those consisted of **three dashboard reports**, the aforementioned Excess & Obsolete Inventory Report, Excess & Obsolete Inventory Report for Beds and Expiration Risk Inventory Report.

A holistic strategy to manage NVA Inventory was created, with the **establishment and mapping of seven processes**, including each type of inventory. A **pilot project to implement the theoretical strategy** was applied throughout the last ten weeks of the internship, and the success of the implementation can be measured through the KPIs in the beginning of this section.

7. Conclusion and Future Work

As previously explained, this master thesis started as a wide improvement study of the abstract concept of Inventory Management Optimisation. The beginning of the study was mainly focused on the identification of key inefficiencies, that would allow its orientation into a more concrete scope. To conclude this work, it is important to remember the initial problem statement.

- What measures should be applied to minimize inefficiencies on the Inventory Management System, that historically led to difficulties in facing high-demand peaks, contributing to holding significant costs of inventory and insufficient capacity to storage new stock?

The problem statement was broken down into three research questions, whose approach allowed the identification of the most accurate set of measures to positively mitigate the inefficiencies identified in the initial Inventory Management System. The **main business and scientific contributions** that the development of this study allowed can be understood with the summary of the approach of the research questions.

7.1. Conclusions from the Approach of the Research Questions

RQ1: <u>How can inventory optimisation be pragmatically implemented and what are the options when trying to reduce inventory and increase storage capacity?</u>

There are a lot of information sources regarding inventory management optimisation, and despite of the different strategies that one might define to achieve it, inventory reduction is always the final goal – given a predefined service level. Holding inventory has significant costs associated - and especially if it is considered as unneeded, the investment can be seen as waste.

After studying common measures from Literature and understanding the previous context of the company, the research direction was steered towards the objective of targeting **NVA Inventory**, understood as a pivotal concern in contemporary inventory management. Other methodologies related to Inventory Categorization were approached, and possible changes in parameters or even the implementation of new Inventory Management Software Systems were studied, but they were not selected as key improvement fields.

RQ2: What factors can be currently contributing to the low efficiency of the Inventory Management System applied by Emma?

Targeting NVA Inventory and consequently building a holistic strategy to reduce it came up as the solution with most impact for the previous situation of the company, since it represented the most significant factor of inefficiency within the scope of the study. This journey led to the development of sophisticated data-driven tools, offering methodologies that promoted the identification and visibility into **Excess & Obsolete Inventory** as well as **Expiring Inventory**. Nevertheless, it is still crucial to highlight the precedent effort put into the categorization of NVA Inventory, which did note have consensual definitions before this study.

Furthermore, the research carefully promoted the design and application of an integrated approach to reduce overall NVA Inventory, comprising three progressive stages that respectively address the issue of current obsolescence, delving into the integration of expiration risk, and culminating with a brief exposure of the potential of predicting obsolescence.

RQ3: How impactful can be targeting NVA inventory, in order to increase capacity and reduce stock cost?

The project of implementation of the three-stage strategy had the duration of **ten weeks** and generated **total savings of stock accounted for 766K €** and **50% weighted average reduction of stock quantities.**

7.2. Limitations and Future Work

Diving into the scope of **limitations and future work**, key risks have been identified, that can potentially damage the positive impact of this strategy in the future. First and foremost, the integrity of **data quality and reliability** emerged as a critical concern. Ensuring that the data used for planning processes is accurate is highly important, as inaccurate data can lead to misguided decision-making, potentially resulting in excessive inventory or stockouts, on the other side.

To address this challenge, there is an evident conclusion on the need to improve the collection and integration of data in the internal systems, process which should be **less manual** and **error prone**. A significant effort should be made in **standardizing the process** in which data is quantified and then inputted into the systems. Even though requiring third parties to processes such as manufacturing or storage allows the company to hold less costs and promotes more flexibility, it is important to guarantee that **sufficient quality-check steps** are normalized in the processes to provide reliable information.

Secondly, the study underscored the vital importance of fostering **effective communication** and enhancing **visibility among cross-functional teams**. In a collaborative business environment, failure to communicate seamlessly across various departments can result in disjointed efforts, making it challenging to align inventory management strategies effectively.

To face this risk, there should be a significant investment of time to define an **optimal workflow of communication** within teams. The current agile system, based on the independent capability of creating channels of communication, does not seem the most ideal situation to promote organized problem-solving. What happens quite often is the spontaneous non-standardized creation of channels of communication, that lacks structure, fundament, or even necessary stakeholders. **More guidelines** should be developed to guarantee that the communication inside and outside teams follows a similar structure, the most efficient in **avoiding loss of information**, while promoting a **fluid problem-solving** map.

Improving processes of collaboration between teams is the last recommendation for the future success of the Inventory Management System, where the **ownerships and responsibilities** of each task or assignment should be **clearly and undoubtedly visible and known**. Overlapping work is frequently occurring, which should not be desired, since it might even lead to different calculations for the same topic. Multiple meetings exist with the purpose of fostering collaboration, but there are short-term objectives that can more easily be consolidated with the **higher-level input of leadership**, by proactively sharing knowledge about the existing processes from other teams. Several projects and processes are built, but there is not a realistic and reasoned **definition of KPIs**, nor a **map of the processes**, which are short-term easily achievable resolutions that can have a tremendous impact in what regards to collaboration.

As **final considerations**, this research contributed with valuable insights and practical methodologies to the domain of inventory management, offering a structured view on how to navigate the complexities of reducing NVA Inventory. These findings underline the importance of agile, data-driven, and collaborative approaches in achieving optimal inventory management, thereby enhancing operational efficiency.

It is possible to conclude that all the objectives defined in Section 1.3 were achieved (as can be seen by Table 31 in the Appendix 5 – Conclusion and Objectives) and a detailed answer to each Research Question was provided, allowing the understanding of the concrete measures that allow to positively impact the fields highlighted in the problem statement. The pilot project was followed by a careful definition of KPIs, whose rate of achievement was already embraced by the exposure and elaboration of the respective blockers.

As a conclusion, it was indeed understood that IP plays a pivotal role in the broader context of SCM. Effective IP helps businesses strike a delicate balance between meeting customer demand, minimizing holding costs, and optimising operational efficiency. In today's competitive landscape, where customer expectations are high, and resources are finite, proficient IP is not just an advantage but a necessity. It empowers organizations to enhance customer satisfaction, reduce waste, maintain healthy cash flow, and ultimately achieve a sustainable and efficient supply chain ecosystem.

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Indústria do Mobiliário		3.
Caracterização da Indústria		**3.a.**
Nome do Setor	**Subsetores em análise**	**CAE**
Indústria do Mobiliário	**Mobiliário**	
	Fabricação de mobiliário para escritório e comércio	3101
	Fabricação de mobiliário de cozinha	3102
	Fabricação de mobiliário para outros fins	3109
	Colchões	
	Fabricação de colchoaria	3103
	Iluminação	
	Fabricação de lâmpadas elétricas e de outro equipamento de iluminação	274

Notas: (a) Para efeitos desta análise apenas foram consideradas as rúbricas de CAE indicadas. | (b) Esta ficha deve ser analisada em conjunto com a Ficha Tecido Empresarial de Portugal e Indústrias (Indústria Transformadora).

Figure 36 - Categorization of the Mattress Industry in Portugal

Equation 4 - Calculation of the Quantity to Order

$$Qty.Order = Order\ Level - Current\ Stock$$

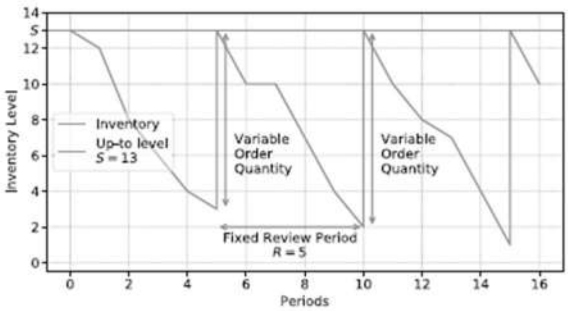


Figure 37 - Inventory Variation according to Policy (R, S), (Vandeput, 2020)

To calculate the Order Level, one must understand the following procedure:

1) Input Demand Variability and Logistics Parameters;
2) Calculation of ABC Classification to be inputted in the Definition of the Service Level, according to the Section 2.3.1. Service levels are frequently used to assess system performance due to challenges in measuring stockout costs. They can indicate the frequency, size, and duration of stockouts (Inderfurth & Minner, 1998);
3) Calculation of Inventory Parameters, meaning Inventory Safety Stock according to Equation 5
4) Calculation of Order Up-to-Level, also described as Target Stock, according to Equation 6.

Equation 5 - Calculation of Safety Stock according to Inventory Policy applied

$$SS = Z \times \sqrt{L \times \sigma_{demand}^2 + \mu_{sales}^2 \times \sigma_{lead\ time}^2}$$

Note 1: Z is the desired service level factor inputted from the ABC Analysis. Each cluster from the ABC has a different desired service level (e.g.: Class A has 80 % target service level).

Note 2: σ_{demand} represents demand standard deviation.

Note 3: $\sigma_{lead\ time}$ represents lead time standard deviation.

Equation 6 - Calculation of Order Up-to-Level Target

$$S = d_L + d_R + SS$$

Note 4: d_L means demand over the lead-time, which is equal to $d \times L$

Note 5: d_R means demand over the review period, which is equal to $d \times R$

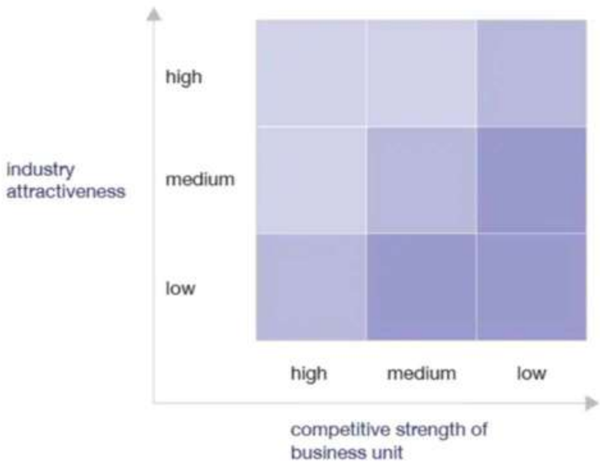


Figure 38 - GE/ McKinsey MCDA Matrix Example

Appendix 2 – Contextualization of the Case Study

ABC Analysis

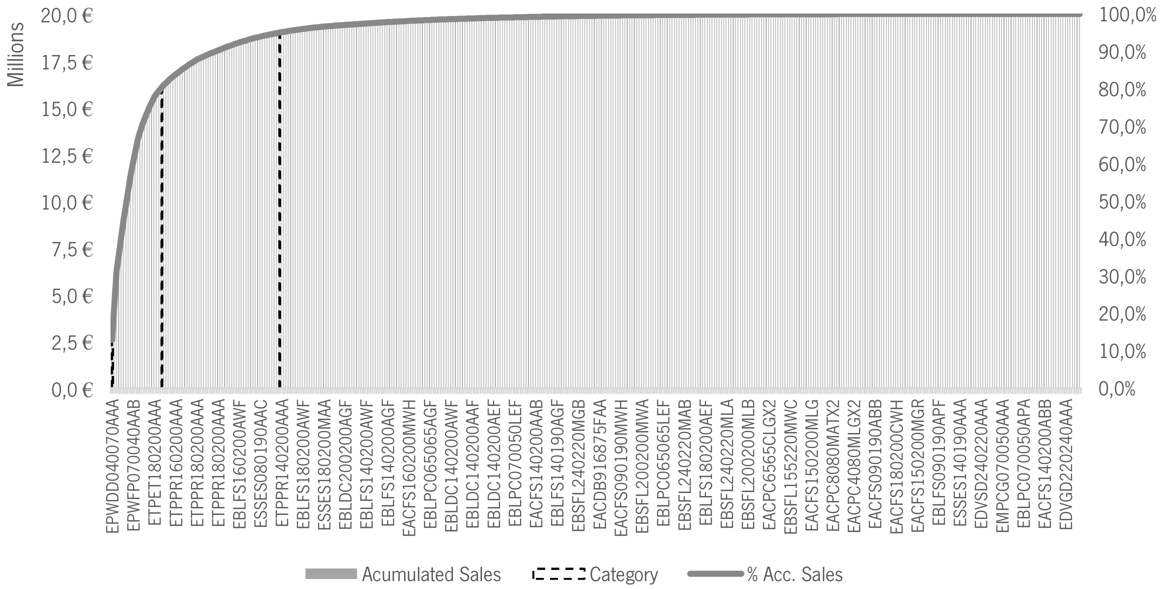


Figure 39 - ABC Analysis for Accessories

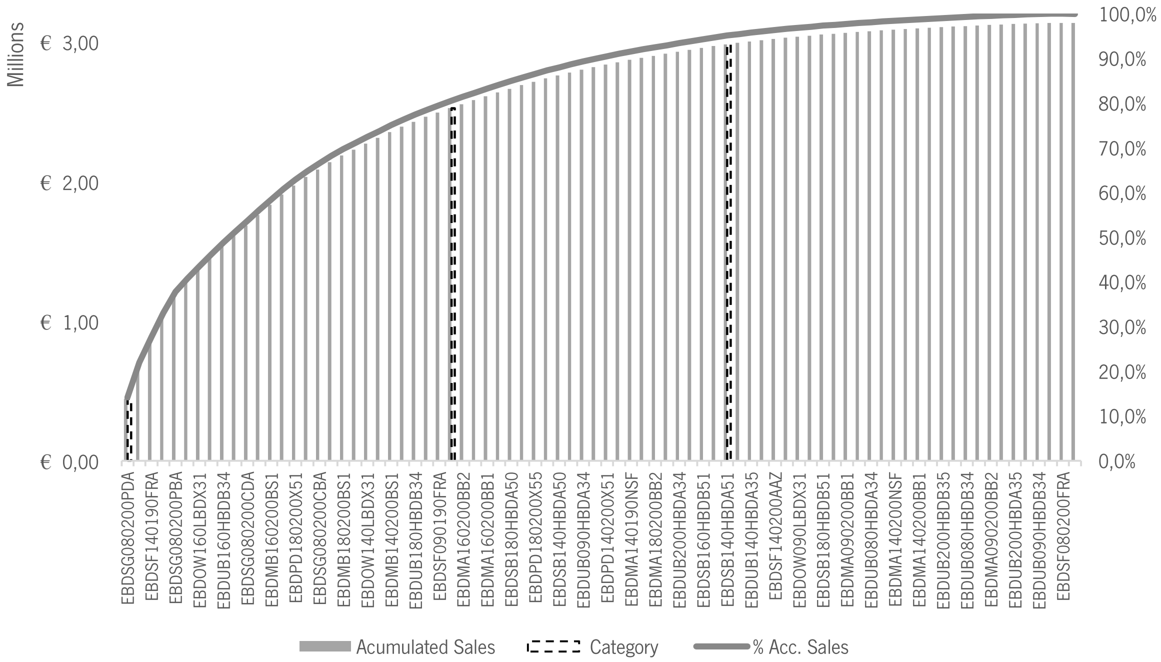


Figure 40 - ABC Analysis for Beds (D2C)

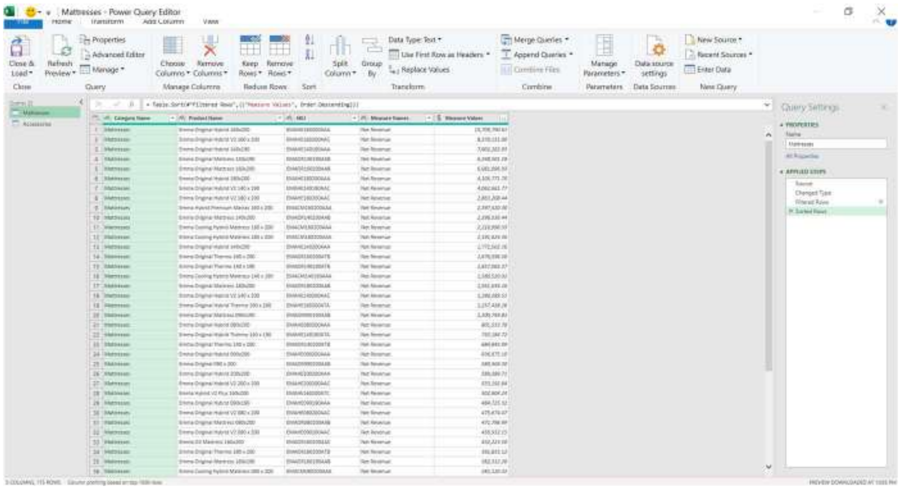


Figure 41 - Power Query for ABC Analysis Automated Tools (Accessories and Mattresses)

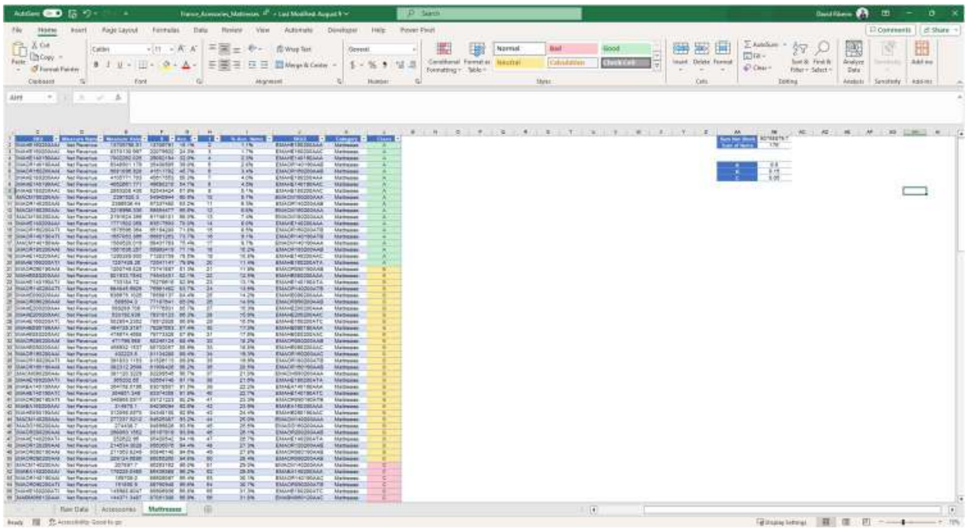


Figure 42 - Output of ABC Analysis (Accessories and Mattresses)

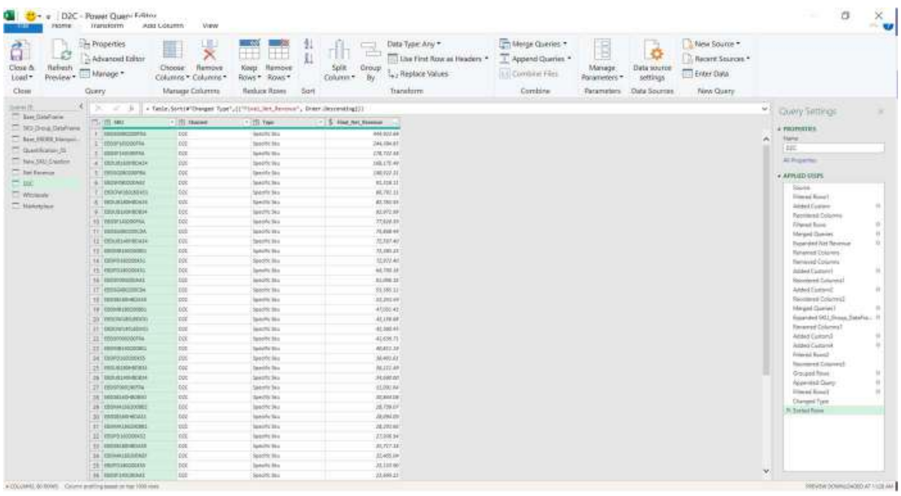


Figure 43 - Power Query for ABC Analysis Automated Tools (Beds)

Note 1: The ABC Classification for Beds represents a more complex process. Since Beds are a Composite Product - composed by several Components – the ABC attribution is done for the Specific SKU that identifies the Bed Set. Each Component assumes the highest ABC from the Bed Sets where it is included.

Analysis of Possible Constraints

Equation 7 - Calculation of Weekly Bias

$$Bias = \frac{(Forecast - Sales)}{Sales}$$

APPENDIX 3 – SCRIPTS AND BACKUP OF THE MODELS

Excess & Obsolete Inventory Report

Table 18 - Parameters and Definitions that support the Excess & Obsolete Inventory Report

Variable	Description	Formula
Coverage (Weeks)	Coverage consists of the number of weeks that the current Physical Stock that exists will last, according to the Weekly Forecast	if Cumulative Forecast <= Net Stock Coverage [Weeks] += 1
Safety Stock (Weeks)	Minimum buffer that minimizes costs of inventory, while keeping Service Level according to the defined target. It is calculated through SO99+.	Input from SO99+
Excess in Weeks	It consists of the excess weeks of a certain SKU. **High Risk Excess** is considered when weeks of excess is above 10. **Low Risk Excess** is considered when there is excess, but below or until 10 weeks.	Coverage in Weeks [Weeks] – Safety Stock [Weeks]
Safety Stock (Units)	It consists of the target units that must be bought according to the Safety Stock in Weeks. The calculation consists of the sum of weekly forecast for a number of iterations equivalent to the safety stock in weeks.	if Coverage [Weeks] < Physical Safety Stock [Weeks]: Cumulative Forecast Target [SS] += Weekly Forecast
Excess (Units)	It consists of the excess units of a certain SKU, being the difference between the Net Stock and the Safety Stock in Units	Net Stock [Units] – Physical Safety Stock [Units]
Low Risk Excess (Units)	The calculation is similar to Excess in Units, but the threshold is set as the Cumulative Forecast at iteration Safety Stock (Weeks) + 10.	if Coverage [Weeks] < Physical Safety Stock [Weeks] + 10: Cumulative Forecast Target [Low Risk] += Weekly Forecast

		Low Risk Excess [Units] = Cumulative Forecast Target [Low Risk] - Cumulative Forecast Target [SS]
High Risk Excess (Units)	Consists of the difference between the total stock and the cumulative forecast target at the threshold of Safety Stock (Weeks) + 10	Physical Stock [Units] - Cumulative Forecast Target [Low Risk]
Obsolete	It consists of the units that are no longer predicted to be sold, because of a strategic decision or product outdating	Cumulative Forecast = 0

Note 1: Coverage [Weeks] += 1 is the simplification for Coverage [Weeks] = Coverage [Weeks] + 1, which consists of the recalculation of the variable Coverage [Weeks] iteratively, when the 'if' condition is matched. The reasoning is the same for every similar calculation.

Note 2: The code can be divided into the following sections:

1. Importation of input files that will be used in the calculations of the script (Figure 44)

```
import os
import glob
import pandas as pd
import math
import numpy as ne

#Import the Excel Files exported from S099

dataframes = []
directory = 'C:\David\Python\Try - Copy'
file_paths = glob.glob(os.path.join(directory, '*.xlsx'))


for file_path in file_paths:
            df = pd.read_excel(file_path)
            dataframes.append(df)


#Define how to name each dataframe

df_extensive = dataframes[0]
wh_code = dataframes[1]
real_stock = dataframes [2]
forecast = dataframes [3]
sales = dataframes [4]
description = dataframes [5]
specific_skus = dataframes[6]
batch_life = dataframes[7]
pocs = dataframes[8]
palletization = dataframes[9]
```

Figure 44 - Importation of input files

2. Iterative outer loop that goes through all the rows from the base data frame new_wh (Figure 45)

```python
#General loop that iterates each row from new_wh
for index, row in new_wh.iterrows():
    sku = row['Item Code']
    location = row['Location code']
    physical_stock = row['Net stock']
    unitary_cost = row['Unit Cost (Effective)\n[EUR]']
    country = row['Country']

    if pd.isna (physical_stock):
        physical_stock = 0
    elif physical_stock < 0:
        physical_stock = 0

    target_weeks_wh = row['Physical Safety Stock\n[Days]']/7
    if pd.isna(target_weeks_wh):
        target_weeks_wh = 0
    elif target_weeks_wh < 0:
        target_weeks_wh = 0
    high_target_weeks = target_weeks_wh + 10

    if pd.isna(unitary_cost):
        unitary_cost = 0
```

Figure 45 - Outer loop that iterates base data frame

3. Iterative inner loop that goes through all the rows from the data frame fc_calculation for each matching row of the base data frame new_wh (Figure 46)

```python
    # Start the loop to iterate the dataframe with the forecast per week
    for fc_index, fc_row in fc_calculation.loc[(fc_calculation['SKU'] == sku) & (fc_calculation['Location'] == location)].iterrows():
        fc_week = fc_row['Forecast Week']
        fc_year = fc_row['Forecast Year']
        fc = fc_row['Forecast']
        cumulative_forecast += fc
```

Figure 46 - Inner loop that iterates forecast data frame

4. **Calculation 1** *(Units to Weeks):* Calculation of coverage in weeks, using as inputs Cumulative Forecast and Physical Stock, according to the formula described in Table 18 (Figure 47)

```python
#CALCULATION 1 (Units to Weeks): Calculation of Coverage (Weeks), using as inputs Cumulative Forecast and Net stock

#Creation of conditions that assigns 0 to the calculation of coverages when there's no Net stock
        if physical_stock == 0:
            weeks = 0
        else:
# Create the condition that keeps summing the variable cumulative forecast while it is lower than the current Net stock
            if cumulative_forecast <= physical_stock:
                weeks += 1

# Calculation made to get decimal numbers on coverages
            else:
                if fc != 0 and remaining_quantity == 0:
                    remaining_quantity = physical_stock - cumulative_forecast + fc
                    remaining_weeks = remaining_quantity / fc
                    weeks += remaining_weeks
```

Figure 47 - Calculation of Coverage in Weeks

5. **Calculation 2** *(Weeks to Units):* Calculation of the Safety Stock in Units, using as inputs the Safety Stock in Weeks, according to the formula described in Table 18 (Figure 48)

```python
#CALCULATION 2 (Weeks to Units): Calculation of Physical Safety Stock (Units), using as inputs Physical Safety Stock (Weeks) and Cumulative Forecast

#Creation of condition to calculate the integer lower nearest number from Physical Safety Stock (Weeks)
        if weeks_ < math.floor(target_weeks_wh):
            cumulative_forecast_target += fc
            weeks_ += 1
        else:

            if perc_target_weeks_decimal == 0:
                perc_target_weeks_decimal = target_weeks_wh - math.floor(target_weeks_wh)
                cumulative_forecast_target += fc*(perc_target_weeks_decimal)
```

Figure 48 - Calculation of Safety Stock in Units

6. **Calculation 3** *(Weeks to Units)*: Calculation of Low Risk Excess and High Risk Excess Units, according to the formula described in Table 18 (Figure 49, Figure 50)

```
#CALCULATION 3 (Weeks to Units): Calculation of Maximum Low Risk Excess Units (Units), using as inputs High Target Weeks (Physical SS + 10) and Cumulative Forecast
    #This variable will be used to calculate the number of units in High Risk Excess (Net stock - Maximum Low Risk Excess Units, when there is High Risk Excess)

        if weeks_high_risk < math.floor(high_target_weeks):
            high_cumulative_forecast_target += fc
            weeks_high_risk += 1
        else:
# Calculation made to get decimal numbers on Units
            if perc_target_weeks_decimal_ == 0:
                perc_target_weeks_decimal_ = high_target_weeks - math.floor(high_target_weeks)
                high_cumulative_forecast_target += fc*(perc_target_weeks_decimal_)
```

Figure 49 - Threshold to further calculate Low Risk Excess in Units

```
    if class_ == 'Obsolete':
        status_excess = ''
    elif excess_weeks > 10:
        status_excess = 'High Risk Excess'
        high_excess_weeks = excess_weeks - 10
        high_excess_units = physical_stock - high_cumulative_forecast_target
        low_excess_units = high_cumulative_forecast_target - cumulative_forecast_target
    elif 0 < excess_weeks <= 10:
        status_excess = 'Low Excess'
        low_excess_units = excess_units
```

Figure 50 - Calculation of High Risk Excess in Units

7. Calculation of Excess Units and definition of the criteria for products to be considered as Obsolete (Figure 51)

```
    if cumulative_forecast == 0:
        class_ = 'Obsolete'
        weeks = 0
    else:
        pass

    excess_units = physical_stock - cumulative_forecast_target_europe
    if excess_units < 0:
        excess_units = 0
        low_excess_units = excess_units
```

Figure 51 - Calculation of Excess Units and Categorization as Obsolete

8. Integration of all the calculated variables into the base data frame new_wh

```
        new_wh.at[index, 'Class'] = class_
        new_wh.at[index, 'Coverage_Weeks'] = weeks
        new_wh.at[index, 'Special Cases Coverage (Weeks)'] = special_coverage
        new_wh.at[index, 'Cumulative Forecast'] = cumulative_forecast
        new_wh.at[index, 'Excess_Weeks'] = excess_weeks
        new_wh.at[index, 'Excess_Units'] = excess_units
        new_wh.at[index, 'Status of Excess'] = status_excess
        new_wh.at[index, 'Excess_Cost'] = excess_cost
        new_wh.at[index, 'Stock_Cost'] = stock_cost
        new_wh.at[index,'Obsolete_Cost'] = obsolete_cost
        new_wh.at[index,'Obsolete_Units'] = obsolete_units
        new_wh.at[index, 'Cumulative Forecast Target'] = cumulative_forecast_target
        new_wh.at[index, 'Physical Safety Stock[Weeks]'] = target_weeks_wh
        new_wh.at[index, 'High Risk Excess Units'] = high_excess_units
        new_wh.at[index, 'Low Risk Excess Units'] = low_excess_units
        new_wh.at[index, 'High Risk Excess Cost'] = high_excess_cost
        new_wh.at[index, 'Low Risk Excess Cost'] = low_excess_cost
        new_wh.at[index, 'Coverage * Stock'] = coverage_stock_cost
        new_wh.at[index, 'Target * Stock'] = target_stock_cost
        new_wh.at[index, 'Net Stock Updated'] = physical_stock
```

Figure 52 - Integration of all the variables in the base data frame

Note 3: The purpose of this note is to explain the conversion of the calculation for the levels of granularity 'country' and 'europe', from the detailly explained level of granularity 'warehouse'. Being several Warehouses inserted mandatorily in one country, the aggregation consists of the sum of the Net Stock and Cumulative Forecast Target for the new levels of granularity.

Since the Safety Stock (Weeks) is defined per SKU – Warehouse level, the input of Safety Stock (Weeks) in level of granularity 'country' just could be possible by the calculation of an average value, which would not be the most mathematical accurate conversion.

According to that, for levels of granularity 'country' and 'europe', Safety Stock in Weeks is calculated, and Safety Stock in Units is inputted from the previous level of granularity. Since 'country' and 'europe' are broader levels of granularity, they can progressively contain more than one SKU – Warehouse combination. To input the Safety Stock in Units from the previous level of granularity, the calculation consists of a sum of all the existing combinations SKU – Warehouse that are part of the desired country or country.

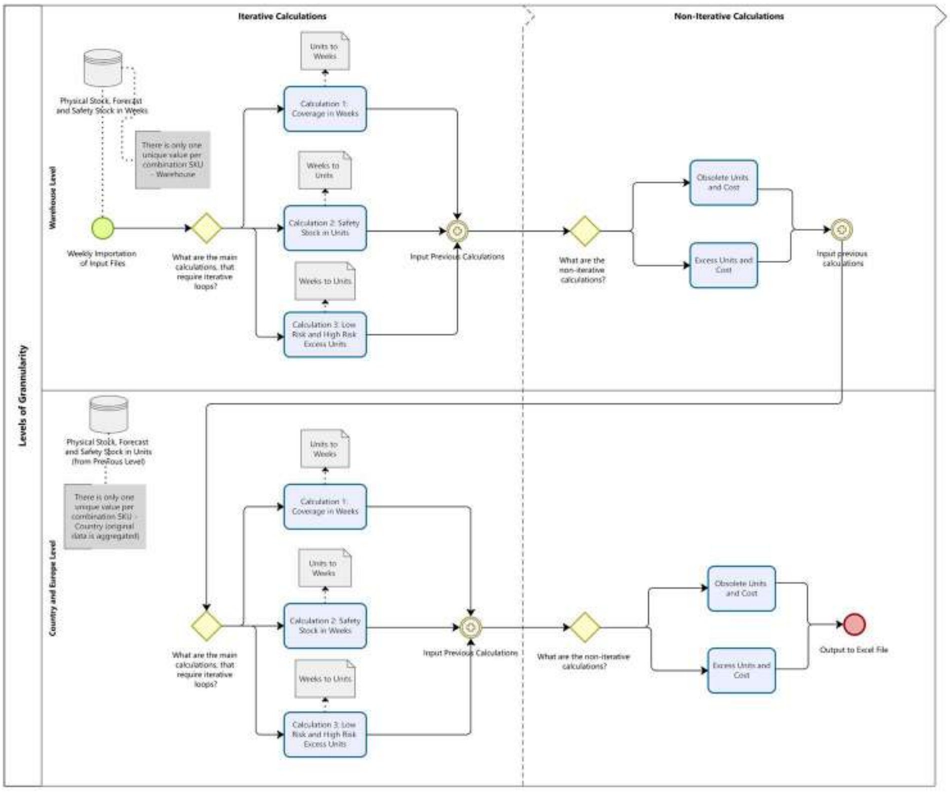


Figure 53 - Map of the Process for the different levels of granularity of the algorithm

Note 4: By iterative calculations one means calculations that require two loops, the outer one to go through all the rows from the base data frame and another one to go through the forecast data frame, by matching indexing combinations.

Excess & Obsolete Inventory Report for Beds

Note 1: Introduction to the need of the adjusted algorithm

Each SKU from the Excess & Obsolete Inventory Report represents a Component, but there was not a clear identification of the Composite SKUs. Being a Composite SKU a complex product composed my multiple Components, the number of different possibilities of combinations is enormous. A Bill of Materials that would accurately associate every Composite SKU and its Components was only available for utilization in the end of this study's timeframe.

As explained in Section 4.1.1, the weekly update of the script requires the input of variables such as forecast, safety stocks or sales. The switch in the calculation of forecast from Component-Oriented to Composite-Oriented was an on-going process during the development of the project. The referred switch for safety stocks was not even planned in a short-term horizon, since itself required the input of several variables whose adaptation was not easily achievable. Sales was then the only variable whose value per Composite SKU could be objectively accessed. It was not possible to have Bed Sets coming out directly from the original report.

A complementary algorithm for the calculation of excess in Beds was built, using Scientific PYthon Development EnviRonment (Spyder) from Anaconda Navigator. The input files were the newly created **Bill of Materials**, **Sales per Bed Set** and the **Excess & Obsolete Inventory Report** from the respective week.

The main issue with the previous identification of excess for Components was linked to the impossibility of identification of the problem-causing product. On a customer perspective, the purchase is made per product, meaning per Composite SKU (Bed Set). On a S&OP perspective, the analysis of Excess was only possible by Component, not by Bed Set. The definition of action plans was not possible to happen in an efficient and impactful manner.

Note 2: The code can be divided into the following sections:

1. Importation of input files that will be used in the calculations of the script (Figure 54)

```python
import pandas as pd
import glob
import os


dataframes = []
directory = directory = 'C:\David\Python\Bed Sets Excess\Input Files'
file_paths = glob.glob(os.path.join(directory, '*.xlsx'))

for file_path in file_paths:
    xls = pd.ExcelFile(file_path)

    for sheet_name in xls.sheet_names:
        df = pd.read_excel(file_path, sheet_name=sheet_name, header=0)
        dataframes.append(df)

new_bom = dataframes [0]
monthly_demand = dataframes[1]
excess_wh = dataframes[2]
excess_country = dataframes[3]
excess_europe = dataframes[4]
wh_codes = dataframes [5]
```

Figure 54 - Integration of Input Files for the Excess & Obsolete Report for Beds

2. Manipulation of BOM and Demand data frames, to provide the desired elementary combination Composite – Component for the further merge (Figure 55)

```python
#Manipulation of DataFrames of Excess
excess_wh = excess_wh.rename(columns = {'Location code':'Location Code'})
excess_country = excess_country.rename(columns = {'Location code':'Location Code'})
excess_europe = excess_europe.rename(columns = {'Location code':'Location Code'})

#Manipulation of DataFrames to have Sales per Item Code per WH
total_demand = monthly_demand[~monthly_demand['Location Code'].isin(['DUMMY'])]
total_demand2 = total_demand.groupby(['Item Code','Description (Item Code)','Product Family','Location Code'],as_index = False)['Quantity\n[Unit]'].sum()
total_demand2 = total_demand2.rename(columns = {'Item Code':'Composit_SKU'})
wh_codes = wh_codes.rename(columns = {'Location code' : 'Location Code'})
total_demand2 = pd.merge(total_demand2, wh_codes, on = 'Location Code', how = 'Left')

#Manipulation of DataFrames to have Composit SKU - Item Code with units used of components + appearances of component in Composit_SKUs
new_bom = new_bom.rename(columns = {'Kit Item Code':'Composit_SKU', 'Component Item Code': 'Item Code'})
new_bom2 = new_bom.groupby('Item Code')['Composit_SKU'].agg(list).reset_index()
new_bom2 = new_bom2.rename(columns = {'Composit_SKU':'Composit_SKU_Set'})
new_bom = pd.merge(new_bom, new_bom2, on = 'Item Code', how = 'Left')
new_bom['Product Group'] = new_bom['Item Code'].str[:5] + '_' + new_bom['Item Code'].str[-3:]

column_order = ['Composit_SKU', 'Planning Group', 'Item Code',
        'Units of Component used in Kit\n[Units/Units]', 'Composit_SKU_Set',
        'Product Group']

new_bom = new_bom.reindex(columns = column_order)
```

Figure 55 - Manipulation of BOM and Demand data frames to prepare the merge

3. Iterative loop that goes through all the rows from the base data frame bom_demand and calculates the total demand for the set of Composite SKUs that are parents of the iterated Component – Warehouse combination (Figure 56)

```python
#Warehouse Level

#Merge of both dataframes
bom_demand = pd.merge(total_demand2, new_bom, on = 'Composit_SKU', how = 'Left')
bom_demand = bom_demand.rename(columns = {'Quantity\n[Unit]':'Demand_Composit'})
bom_demand['Demand_Composit'] = bom_demand['Demand_Composit'].fillna(0)

#Creation of dataframe to inner iterate through bom_demand
demand_composit_per_location = total_demand2.groupby(['Composit_SKU','Location Code'])['Quantity\n[Unit]'].sum().reset_index()
demand_composit_per_location = demand_composit_per_location.rename(columns = {'Quantity\n[Unit]':'Demand_Composit_per_Location'})


for index, row in bom_demand.iterrows():
    total_quantity = 0
    bed_set_list = row['Composit_SKU_Set']
    location = row['Location Code']
    parent = row['Composit_SKU']

    if not isinstance(bed_set_list, list):
        bed_set_list = [bed_set_list]



    for index_a, row_a in demand_composit_per_location.iterrows():
        parent2 = row_a['Composit_SKU']
        quantity2 = row_a['Demand_Composit_per_Location']
        location2 = row_a['Location Code']

        if parent2 in bed_set_list and location2 == location:
            total_quantity += quantity2

    bom_demand.at[index, 'Total_Qty_Multiple_Composit'] = total_quantity
```

Figure 56 - Iterative loop that allows the calculation of the total demand for the set of parents

4. Calculation of the **Weight of the Composite**, which represents the quotient between the demand of the Composite Parent for the analysed Component – Warehouse combination, by the sum of the demand for all the composite parents of the same combination. Recalculation of excess according to the weight of the combination (Figure 57)

```
#Calculation of the weight per Composit - Component
bom_demand['Weight_Composit'] = (bom_demand['Demand_Composit'] / bom_demand['Total_Qty_Multiple_Composit']).fillna(0)
bom_demand['Weight_Composit'] = (bom_demand['Weight_Composit'] * 100).round(2).astype(str) + '%'

#Integration of the excess for wh level
beds_excess_wh = pd.merge(bom_demand, excess_wh[['Item Code', 'Location Code','Excess_Units', 'High Risk Excess Units', 'Low Risk Excess Units', 'Obsolete_Units', 'Excess_Cost', 'High Risk Excess Cost',
'Low Risk Excess Cost', 'Obsolete_Cost']], on = ['Item Code','Location Code'], how = 'left')
beds_excess_wh['Excess_Units'] = beds_excess_wh['Excess_Units'].fillna(0)
beds_excess_wh['High Risk Excess Units'] = beds_excess_wh['High Risk Excess Units'].fillna(0)
beds_excess_wh['Low Risk Excess Units'] = beds_excess_wh['Low Risk Excess Units'].fillna(0)
beds_excess_wh['Obsolete_Units'] = beds_excess_wh['Obsolete_Units'].fillna(0)

#Recalculation of Excess and Obsolete Quantities according to the distribution
beds_excess_wh.loc[beds_excess_wh['Weight_Composit'] != 0, 'Excess_Units'] = (beds_excess_wh['Weight_Composit'].str.rstrip('%').astype(float) / 100) * beds_excess_wh['Excess_Units']
beds_excess_wh.loc[beds_excess_wh['Weight_Composit'] != 0, 'High Risk Excess Units'] = (beds_excess_wh['Weight_Composit'].str.rstrip('%').astype(float) / 100) * beds_excess_wh['High Risk Excess Units']
beds_excess_wh.loc[beds_excess_wh['Weight_Composit'] != 0, 'Low Risk Excess Units'] = (beds_excess_wh['Weight_Composit'].str.rstrip('%').astype(float) / 100) * beds_excess_wh['Low Risk Excess Units']
beds_excess_wh.loc[beds_excess_wh['Weight_Composit'] != 0, 'Obsolete_Units'] = (beds_excess_wh['Weight_Composit'].str.rstrip('%').astype(float) / 100) * beds_excess_wh['Obsolete_Units']

beds_excess_wh.loc[beds_excess_wh['Weight_Composit'] != 0, 'Excess_Cost'] = (beds_excess_wh['Weight_Composit'].str.rstrip('%').astype(float) / 100) * beds_excess_wh['Excess_Cost']
beds_excess_wh.loc[beds_excess_wh['Weight_Composit'] != 0, 'High Risk Excess Cost'] = (beds_excess_wh['Weight_Composit'].str.rstrip('%').astype(float) / 100) * beds_excess_wh['High Risk Excess Cost']
beds_excess_wh.loc[beds_excess_wh['Weight_Composit'] != 0, 'Low Risk Excess Cost'] = (beds_excess_wh['Weight_Composit'].str.rstrip('%').astype(float) / 100) * beds_excess_wh['Low Risk Excess Cost']
beds_excess_wh.loc[beds_excess_wh['Weight_Composit'] != 0, 'Obsolete_Cost'] = (beds_excess_wh['Weight_Composit'].str.rstrip('%').astype(float) / 100) * beds_excess_wh['Obsolete_Cost']
```

Figure 57 - Calculation of the readjustment of excess and obsolete quantities

Note 3: The purpose of this note is to explain the conversion of the calculation for the levels of granularity 'country' and 'europe', from the detailly explained level of granularity 'warehouse'.

The differences consist of the aggregation of the demand per Region and Europe, respectively, having as base data frame the Demand file per Warehouse. Instead of inputting the Excess & Obsolete Report per warehouse, levels of granularity 'country' and 'europe' are inputted. The output of the script is similar and can be seen in Figure 58.

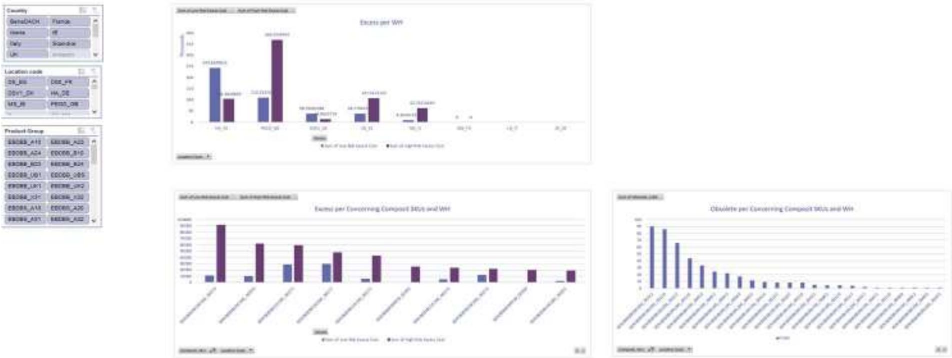


Figure 58 - Dashboard for Beds Excess & Obsolete Adjustment

Table 19 - Explanation of the distribution to support the calculation of the adjusted excess

SKU	Warehouse	Region	Composite SKU	**Demand** *(Parent Composite)*	**Demand** *(Set of Parents)*	**Weight** *(Parent – Component)*
EBDBB135190A10	DS_ES	Iberia	XEMBDBXB135190_00173	82	94	87,23 %
			XEMBDBXB135190_00182	12	94	12,77 %

Expiration Risk Inventory Report

Note 1: The level of granularity of the report is defined per warehouse, constituting the individual elements the unique combination SKU – batch. This means that each batch – which corresponds to a specific inbound date - does not have more than one assigned value of a certain SKU. Although, a certain SKU can be present in different batches in the same warehouse, due to different inbound dates.

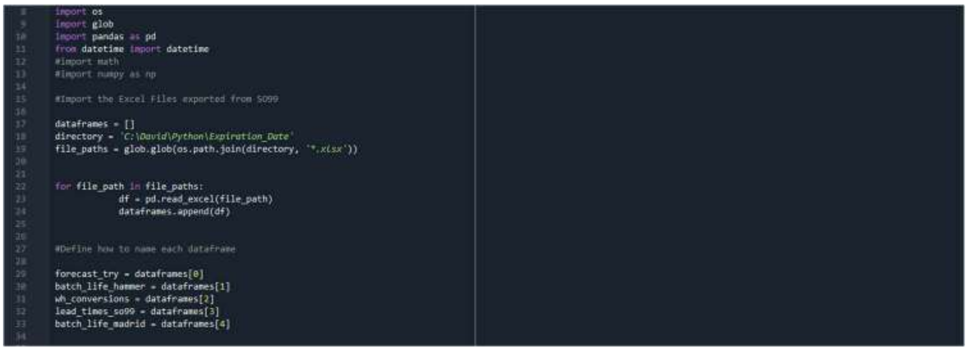
Table 20 - Formulas and Definitions that support the Expiration Model

Variable	Description	Formula
Expiration Time (Weeks)	Consists of the time under which products can keep the desired levels of functional performance required to be sold	Expiration Time = 6 months/ 26.1 weeks (example of an expiration time)
Shelf Life (Weeks)	Represents the total shelf life of the product, by considering the lead time and the life-time since it was inbounded	Lead Time [input from SO99+) + (Current Date – Inbound Date [input from Warehouse Data])
Expiration Date	It is represented by the ISO Week and Year when the product is going to be expired	Current Date + (Expiration Time – Shelf Life)
Cumulative Forecast (Units)	Cumulative weekly forecast of the SKU until the Expiration Date	if (Forecast Week <= Expiration Week) and (Forecast Year <= Expiration Year) Cumulative Forecast [Units] = sum (Forecast [Units])
Period Forecast (Units)	Represents the cumulative forecast between two consecutive batches from the same SKU (batches are sorted by lower expiration date)	Cumulative Forecast [Units, i] – Cumulative Forecast [Units, i -1)
Period Net Stock (Units)	Consists of the net stock of the SKU for that specific batch, according to the Cumulative Forecast of that period	Qty. in Batch [Units, i] - Period Forecast [Units, i]
Cumulative Net Stock (Units)	Consists of the cumulative net stock, which is equal to the Period Net Stock	Period Net Stock [Units, i] + Cumulative Net Stock [Units, i-1]

	for the first index row and keeps iteratively cumulating Period Net Stock for next rows	
Risk (Units)	Consists of the units of the batch that are predicted to be expired in the moment of expiration week. In the expiration week, the shelf-life of those units is predicted to be superior to the expiration time.	**If** (Cumulative Net Stock [Units] < 0): Risk = 0 **Else if** Qty. in Batch [Units] > Cumulative Net Stock [Units]: Risk = Cumulative Net Stock **Else** Risk = Qty. in Batch

Note 2: The code can be divided into the following sections:

1. Importation of input files that will be used in the calculations of the script (Figure 59)



```
import os
import glob
import pandas as pd
from datetime import datetime
#import math
#import numpy as np

#Import the Excel Files exported from SO99

dataframes = []
directory = 'C:\David\Python\Expiration_Date'
file_paths = glob.glob(os.path.join(directory, '*.xlsx'))


for file_path in file_paths:
            df = pd.read_excel(file_path)
            dataframes.append(df)


#Define how to name each dataframe

forecast_try = dataframes[0]
batch_life_hammer = dataframes[1]
wh_conversions = dataframes[2]
lead_times_so99 = dataframes[3]
batch_life_madrid = dataframes[4]
```

Figure 59 - Importation of Input Files for the Expiration Report

2. Iterative loop that goes through all the rows from the base data frame batch_life_hammer2 (Figure 60)

```
#Loop for Hammer WH

for index, row in batch_life_hammer2.iterrows():
    origin_date = row['WE_DATUM']
    origin_date = datetime.strptime(origin_date, '%Y-%m-%d')
    inbound_date = origin_date.strftime('%d/%m/%Y')
    week_string_origin = origin_date.strftime('%U')
    week_number_origin = int(week_string_origin)
    lead_times_days = row['Real Lead Time']
    validity_time = 26.1
```

Figure 60 - Outer loop that iterates base data frame batch_life_hammer2

3. **Calculation of Shelf Life in Weeks:** Calculation of shelf life in weeks, using as inputs Real Time Date, Lead Times and Inbound Dates, according to the formula described in Table 20 (Figure 61)

```python
#1: Calculation of Shelf Life (Weeks)

    today = datetime.now()
    week_string_today = today.strftime('%U')
    week_number_today = int(week_string_today)
    current_date = datetime.now().date()
    shelf_life = current_date - origin_date.date()
    total_life_days = lead_times_days + shelf_life.days
    total_life_weeks = total_life_days / 7
```

Figure 61 - Calculation of shelf life in weeks

4. **Calculation of Expiration Date:** Calculation of the Expiration Week and Expiration Year, using as inputs Real Time Date, Expiration Time and Shelf Life, according to the formula described in Table 20 (Figure 62)

```python
#2: Calculation of Expiration Date

    time_left = validity_time - total_life_weeks
    expiration_week = int(time_left + week_number_today)
    year_string_expiration = today.strftime('%Y')
    year_number_expiration = int(year_string_expiration)

    #2.1: Calculation of Expiration Year
    if expiration_week >= 0:
        expiration_year = year_number_expiration

    #2.2: Calculation of Expiration Week
    elif (expiration_week >= - 52 and expiration_week < 0):
        expiration_year = year_number_expiration - 1
        expiration_week = 52 + expiration_week

    elif (expiration_week >= - 104 and expiration_week < -52):
        expiration_year = year_number_expiration - 2
        expiration_week = 104 + expiration_week

    else:
        expiration_year = -1
        expiration_week = -1

    #batch_life_hammer2.at[index, 'Total Life (Weeks)'] = total_life_weeks
    #batch_life_hammer2.at[index, 'Time Left'] = time_left
    #batch_life_hammer2.at[index, 'Current Week'] = week_number_today
    #batch_life_hammer2.at[index, 'Origin (Weeks)'] = week_number_origin
    batch_life_hammer2.at[index, 'Expiration Year'] = expiration_year
    batch_life_hammer2.at[index, 'Expiration Week'] = expiration_week
    batch_life_hammer2.at[index, 'Inbound Date'] = inbound_date
```

Figure 62 - Calculation of the Expiration Week and Expiration Year

5. **Calculation of Cumulative Forecast in Units:** Calculation of Cumulative Forecast per combination SKU – Expiration Week, according to the formula described in Table 20 (Figure 63)

```python
#3: Calculation of Cumulative Forecast in Units

# Merge batch_life_hammer3 and forecast_hammer2 based on SKU
merged_df = pd.merge(batch_life_hammer3, forecast_hammer2, how='left', left_on='ARTIKELNR', right_on='Sku')

# Filter merged_df to include only relevant forecasts
filtered_df = merged_df[(merged_df['Forecast Week'] <= merged_df['Expiration Week']) &
                        (merged_df['Forecast Year'] <= merged_df['Expiration Year'])]

# Calculate the cumulative forecast by grouping and summing the forecasts
cumulative_forecast = filtered_df.groupby(['ARTIKELNR', 'Inbound Date','Expiration Week', 'Expiration Year'])['Forecast'].sum().reset_index()

# Merge the cumulative forecast back to batch_life_hammer3 based on SKU, Expiration Week, and Expiration Year
batch_life_hammer3 = pd.merge(batch_life_hammer3, cumulative_forecast, how='left', on=['ARTIKELNR', 'Inbound Date','Expiration Week', 'Expiration Year'])

# Rename the 'Forecast' column to 'Cumulative Forecast'
batch_life_hammer3 = batch_life_hammer3.rename(columns={'Forecast': 'Cumulative Forecast'})

# Fill missing cumulative forecast values with zeros
batch_life_hammer3['Cumulative Forecast'] = batch_life_hammer3['Cumulative Forecast'].fillna(0)

# Sort the dataframe by SKU and Expiration Year
batch_life_hammer3.sort_values(by=['ARTIKELNR', 'Expiration Year'], inplace=True)
```

Figure 63 - Calculation of Cumulative Forecast per combination SKU - Expiration Week

6. **Calculation of Period Forecast, Period Net Stock and Cumulative Net Stock, in Units:**

   Calculation of the variables according to the formulas described in Table 20 (Figure 64)

```python
#4: Calculation of Period Forecast in Units

# Calculate the difference between consecutive values of 'Cumulative Forecast' for each SKU
batch_life_hammer3['Period FC'] = batch_life_hammer3.groupby('ARTIKELNR')['Cumulative Forecast'].diff()

# Replace missing difference values with the corresponding 'Cumulative Forecast' value
batch_life_hammer3['Period FC'] = batch_life_hammer3['Period FC'].fillna(batch_life_hammer3['Cumulative Forecast'])

#5: Calculation of Period Net Stock in Units
batch_life_hammer3['Period Net Stock'] = batch_life_hammer3['MENGE_IST'] - batch_life_hammer3['Period FC']

#6: Calculation of Cumulative Net Stock in Units
batch_life_hammer3['Cumulative Net Stock'] = batch_life_hammer3.groupby('ARTIKELNR')['Period Net Stock'].cumsum()
```

Figure 64 - Calculation of Period Forecast, Period Net Stock and Cumulative Net Stock

7. **Calculation of Expiration Risk Units:** Calculation of the units that will be in risk of expiration in the expiration date, according to the formula described in Table 20 (Figure 65)

```python
#7: Calculation of Risk of Expiration Weeks per combination SKU - Expiration Week

# Iterate over rows in batch_life_hammer3
for index, row in batch_life_hammer3.iterrows():
    if row['Cumulative Net Stock'] < 0:
        batch_life_hammer3.at[index, 'Risk'] = 0
    else:
        if row['MENGE_IST'] > row['Cumulative Net Stock']:
            batch_life_hammer3.at[index, 'Risk'] = row['Cumulative Net Stock']
        else:
            batch_life_hammer3.at[index, 'Risk'] = row['MENGE_IST']
```

Figure 65 - Calculation of Expiration Risk in Units

8. Integration of all the calculated variables into the base data frame batch_life_hammer3

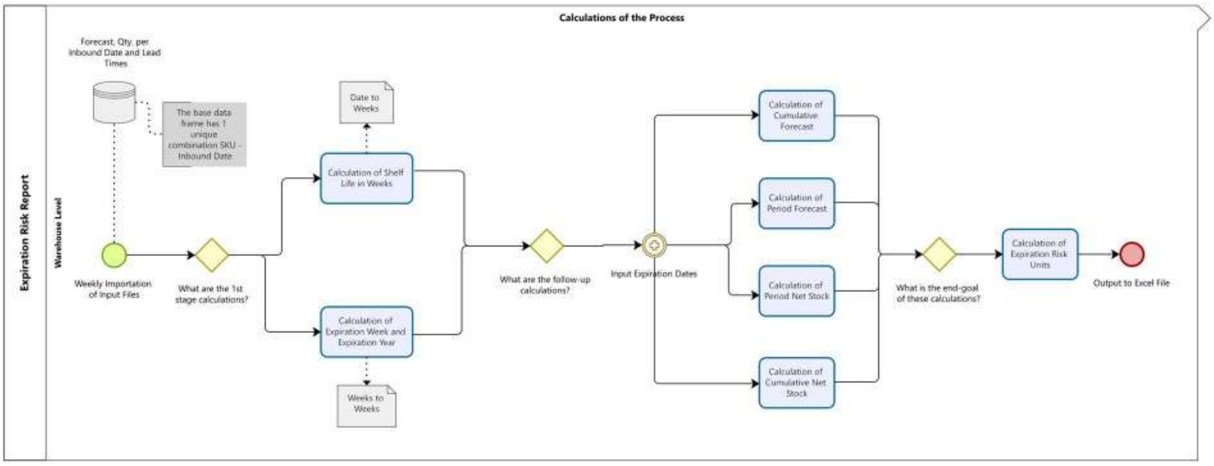


Figure 66 - Map of the process of the Expiring Risk Report for a warehouse

Table 21 - Expiration Time per Product Category

Product Category	Expiration Limit
Mattresses	4 months
Foam Pillows	12 months
Microfiber Pillows	6 months
Toppers	12 months

APPENDIX 4 – MATERIAL TO SUPPORT THE STRATEGIES

Obsolete Inventory Management Process

Table 22 - Process to manage Obsolete Inventory

1. Excess & Obsolete Inventory Report Update
1. Running the code script, analysing the output raw report and weekly updating the output dashboard report 2. Inform involved stakeholders of the update of the report with new data from current week – through Teams Channel
2. Identification and Management of Obsolete Most Concerning Product Groups
1. Weekly identification of most concerning product groups 2. Ranking and prioritization of product groups according to their expiration risk 3. Creation of action plans with responsible stakeholders from the respective countries – through Teams Channel
3. Monitoring evolution of Obsolete Costs
1. Monitoring changes in Obsolete Costs Savings and tracking evolution of SKUs from previous weeks 2. Weekly collaboration with involved stakeholders through Teams Channels and project management tools
4. KPIs Briefing Report
1. Monthly steering e-mail with overview of different regions current situation regarding obsolete inventory 2. Monthly team update with most significant KPIs, such as Total Savings (€), Average Savings (%), Most Impactful SKUs

To-Be Obsolete Inventory Management Process

Table 23 - Process to manage To-Be Obsolete Inventory

1. Excess & Obsolete Inventory Report Update
1. Running the code script, analysing the output raw report and weekly updating the output dashboard report 2. Inform involved stakeholders of the update of the report with new data from current week – through Teams Channel
2. Identification and Management of To-Be Obsolete Most Concerning Product Groups
1. Filtering and identification of SKUs which have the estimated coverage higher than 40 weeks 2. Ranking and prioritization according to the stock cost 3. Creation of action plans with responsible stakeholders from the respective countries – through Teams Channel
3. Monitoring evolution of Obsolete Costs
1. Monitoring changes in Obsolete Costs Savings and tracking evolution of SKUs from previous weeks 2. Weekly collaboration with involved stakeholders through Teams Channels and project management tools

Expired Inventory Management Process

Table 24 - Process to manage Expired Inventory

1. Expiration Risk Inventory Report Update
1. Running the code script, analysing the output raw report and weekly updating the output dashboard report 2. Inform involved stakeholders of the update of the report with new data from current week – via E-mail
2. Identification and Prioritization of Most Concerning Product Groups
1. Weekly identification of most concerning product groups 2. Ranking and prioritization of product groups according to their expiration risk 3. Communication with Warehouse Staff to inform need of inspection
3. Inspection and Quality Evaluation
1. Quality inspection developed by Warehouse Staff to check if product respects levels of performance 2. Final decision done by Quality Team
4. Definition of Action Plans
1. Alignment of selling strategies with country teams or disposal solutions, if the product does not respect the desired levels of performance

To-Be Expired Inventory Management Process

Table 25 - Strategy to manage To-Be Expired Inventory

1. Expiration Risk Inventory Report Update
1. Running the code script, analysing the output raw report and weekly updating the output dashboard report 2. Inform involved stakeholders (Warehouse, Quality and S&OP Teams) of the update of the report with new data from current week – via E-mail
2. Identification and Prioritization of Most Concerning Product Groups
1. Weekly identification of most concerning product groups 2. Filtering to next-month expiration and prioritization of product groups according to their expiration risk 3. Creation of action plans with responsible stakeholders from the respective countries – through Teams Channel
3. Monitoring Evolution of Expiration Costs
1. Monitoring changes in Expiration Costs Savings and tracking evolution of SKUs from previous weeks 2. Weekly collaboration with involved stakeholders through Teams Channels and project management tools

Overall Inventory Strategy

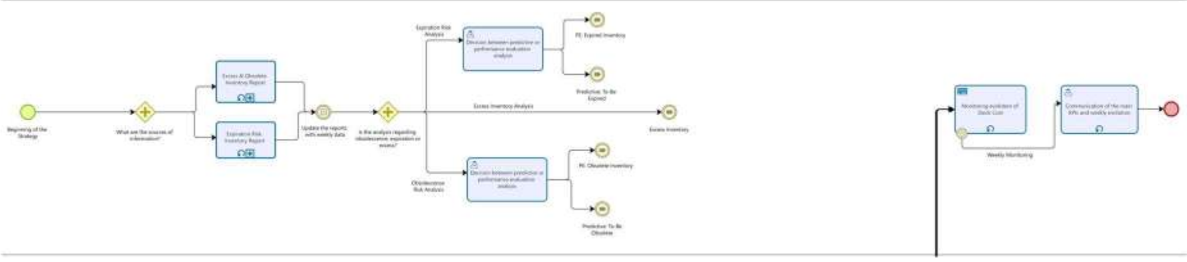


Figure 67 - Common Strategy for NVA Inventory

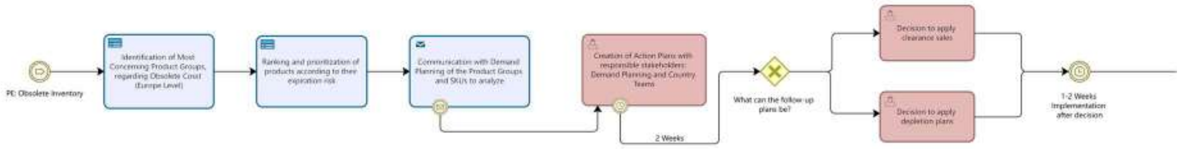


Figure 68 - Obsolete Inventory Sub-Process

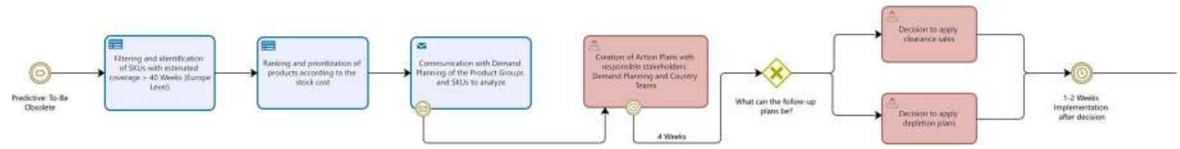


Figure 69 - To-Be Obsolete Inventory Sub-Process

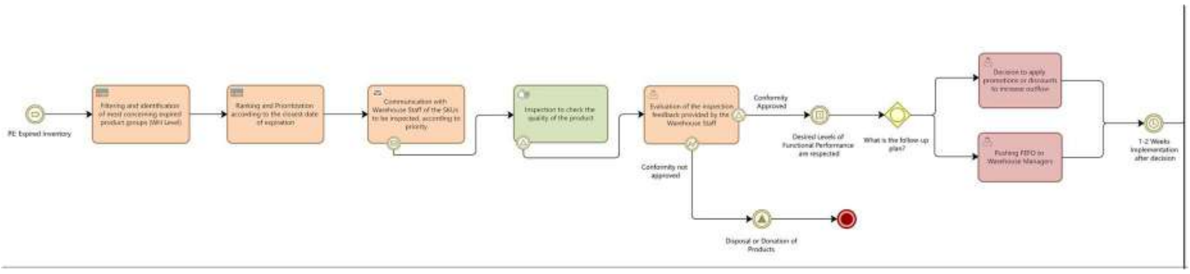


Figure 70 - Expired Inventory Sub-Process

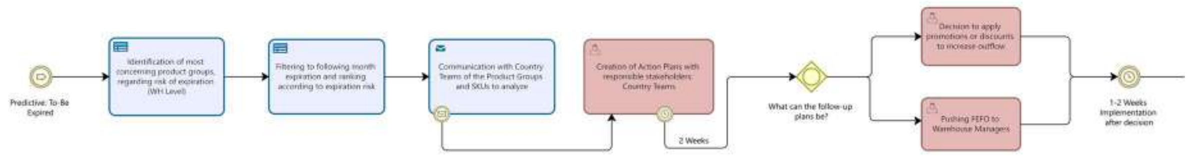


Figure 71 - To-Be Expired Sub-Process

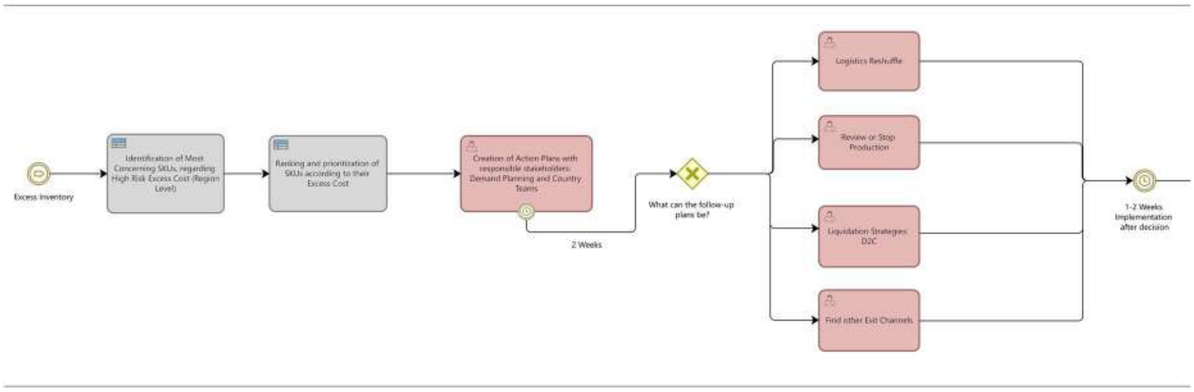


Figure 72 - Excess Sub-Process

Stage 1, Focus in Obsolete Inventory

#	Stage	Objective	Ownership	KPI	Comments
1.	**Stage 1:** Focus in Obsolete Inventory	1.1.Update of the Excess & Obsolete Inventory Report	Inventory Planning	**Repetitive:** Weekly	Update of the input files and running the Python script
		1.2. Identification of Most Concerning Product Groups (Obsolete Cost)	Inventory Planning	3 Stages of Identification	**1st stage** means higlighting 5 most concerning product groups. **2nd stage** assumes definition of action plans for all product groups from 1st stage and stable weekly reduction of stock cost **3rd stage** only to higlight to-be obsolete
		1.3. Ranking and Prioritization of Product Groups (Expiration Risk)	Inventory Planning	5 Product Groups	The 5 most concerning product groups are **sorted by expiration risk**
		1.4. Communication with DP of the Product Groups and SKUs	Inventory Planning	-	-
		1.5. Creation of Action Plans with Responsible Stakeholders (Obsolete Inventory)	Demand Planning and Country Teams	**Deadline:** 2 Weeks	**2 Weeks Deadline** to create the action plans for all the product groups
		1.6. Weekly Monitoring of the Stock Cost	Inventory Planning	**Repetitive:** Weekly	-
2.	**Stage 2:** Integration of Expiration Risk	2.1. Update of the Expiration Risk Inventory Report	Inventory Planning	**Repetitive:** Weekly	Update of the input files and running the Python script
		2.2. Identification of Most Concerning Product Groups (Expiration Risk)	Inventory Planning	1 Stage of Identification	According to **AHP** and **Effort Distribution,** only applied one time in the beginning of 2nd stage. This means there will only be one stage of identification of 5 most concerning product groups
		2.3. Ranking and Prioritization of Product Groups (Expiration Risk)	Inventory Planning	5 Product Groups	The 5 most concerning product groups are **sorted by expiration risk**
		2.4. Communication with Country Teams of the Product Groups and SKUs	Inventory Planning	-	The execution takes more time that Obsolete Inventory strategy because it will be the first contact between Inventory Planning and Country Teams
		2.5. Creation of Action Plans with Responsible Stakeholders (To-Be Expired Inventory)	Inventory Planning and Country Teams	**Deadline:** 2 Weeks	**2 Weeks Deadline** to create the action plans for all the product groups
		2.6. Creation of Action Plans with Responsible Stakeholders (Expired Inventory)	Inventory Planning and Country Teams	-	No deadline defined, since this objective has the ownership of the Quality Team
		2.7. Weekly Monitoring of the Stock Cost	Inventory Planning	**Repetitive:** Weekly	-
3.	**Stage 3:** Prediction of Obsolescence	3.1. Identification of > 40 Coverage SKUs	Inventory Planning	1 Stage of Identification	This requires the update of the Excess & Obsolete Report and a follow-up analysis of the **> 40 coverage cases**
		3.2. Ranking and Prioritization of Product Groups (Stock Cost)	Inventory Planning	5 SKUs	**> 40 coverage i**s a filter of SKUs, that have cost associated. The prioritization happens according to that cost.
		3.3. Communication with DP of the Product Groups and SKUs	Inventory Planning	-	-
		3.4. Creation of Action Plans with Responsible Stakeholders	Demand Planning and Country Teams	**Deadline:** 4 Weeks	It is higly ambitious to consider the actual creation of actual plans. In the available time, it is mainly expected that the communication is established with the country teams.

Figure 73 - Detailed Description of the Strategic Planning of 3 Stages Project

Table 26 - Weekly Monitoring of the Stock Cost for Stage 1, Focus in Obsolete Inventory

SKU	W0	W1	W2	W3	W4	W5	W6	Savings
EMAHE_ATA	775 802 €	631 385 €	578 953 €	417 850 €	522 456 €	512 397 €	461 529 €	314 273 €
EMADD_MTA	158 554 €	158 498 €	158 277 €	157 806 €	157 778 €	157 779 €	157 558 €	996 €
EMAED_BTA	103 835 €	102 471 €	103 991 €	103 835 €	102 734 €	102 719 €	102 542 €	1 293 €
EMAHU_AAA	22 187 €	-	-	-	-	-	20 452€	1 735 €
EMAUH_AAA	456 131 €	444 505 €	425 908 €	357 739 €	346 638 €	326 690 €	321 666 €	134 465 €

Table 27 - Evaluation of Product Group's Behaviour according the to the evaluation criteria

Product Group	**Reduction of Costs** *(Equation 8)*	**Storage Capacity** *(Equation 9)*	**Potential of Revenue** *(Equation 10)*	**Effort and Complexity**
EMAHE_ATA	40,5%	47,0%	179,4%	5-10 stakeholders
EMADD_MTA	0,6%	0,5%	-57,1%	2-5 stakeholders
EMAED_BTA	1,2%	1,1%	-86,7%	2-5 stakeholders
EMAHU_AAA	7,8%	7,5%	0,0%	2-5 stakeholders
EMAUH_AAA	29,5%	25,2%	-30,2%	5-10 stakeholders
Weighted Avg. (*Equation 11)*	29,9%	34,1%	85,8%	3,19

Equation 8 - KPI to measure Reduction of Cost per Product Group

$$Reduction\ of\ Costs_{\ Product\ Group}(\%) = \frac{Stock\ Cost_{W0} - Stock\ Cost_{W6}}{Stock\ Cost_{\ W0}} \times 100$$

Equation 9 - KPI to measure Reduction of Stock per Product Group

$$Reduction\ of\ Stock_{\ Product\ Group}(\%) = \frac{Stock\ Units_{W0} - Stock\ Units_{W6}}{Stock\ Units_{\ W0}} \times 100$$

Equation 10 - KPI to measure Increase of Sales per Product Group

$$Increase\ of\ Outflow_{\ Product\ Group}(\%) = \frac{Sales_{\ Last\ 7\ Weeks} - (Sales_{\ Last\ 14\ Weeks} - Sales_{\ Last\ 7\ Weeks})}{Sales_{\ Last\ 14\ Weeks} - Sales_{\ Last\ 7\ Weeks}} \times 100$$

Equation 11 - KPI to measure Weighted Average for generalist criteria

$$Weighted\ Average_{\ Criteria\ X}(\%) = \frac{\sum_{i=A}^{E} (\ Score_{\ P.\ Group\ A} \times Stock\ Cost_{\ P.\ Group\ A\ [W0]})}{\sum\ Stock\ Cost_{\ P.\ Group\ A-E\ [W0]}} \times 100$$

Note 1: For the criteria related to Inventory Quantity reduction, Stock Units was used instead of Stock Cost, to calculate the weighted average.

Note 2: For the criteria related to Sales/ Outflow, Sales of First 7 Weeks was used instead of Stock Cost, to calculate the weighted average. If Sales of Last 7 Weeks were used to do the weighting, the average would be 147,9%. If no weight was used, the average would be 1,1%. Since the quantity of data is highly residual, any small changes would have a high impact. According to this, the weight for this criterion was considered as 0, so that it does not bias the analysis.

Table 28 - Comparison of the estimations with the obtained results

	Description of the Estimation	**Estimated Score** *(Table 12)*	**Description of the Obtained Results**	**Obtained Score**
Reduction of Costs	Significant reduction of stock cost, **10-20%**	4 (1,54)	High reduction of stock cost, **29,9 %**	5 (1,92)
Storage Capacity	Significant reduction of inventory, **10-20%**	4 (1,23)	High reduction of inventory, **34,1 %**	5 (1,54)
Potential of Revenue	Significant increase in outflow inventory, **10-20%**	4 (0)	Available data not significant to assign a score	0
Effort and Complexity	Involvement of **5-10** stakeholders and challenging innovation	3 (0,58)	Involvement of **5-10** stakeholders and challenging innovation	3 (0,58)
Sum	-	11 (3,35)	-	13 (4,04)
% Score	-	73,3% (67,0%)	-	**86,7%** (80,8%)

Risk and Opportunities Management Process

Table 29 - Criteria to evaluate risks according to the Severity - Likelihood Mattix

Field of Evaluation	Status	Level	KPI
Severity	Insignificant	1	< 5%
	Low	2	5 – 10%
What is the impact of the hazard if there is no doubt it is going to happen?	Moderate	3	10 – 20%
	Severe	4	20 – 30%
KPI: increase in NVA Inventory costs.	Critical	5	> 30%
Likelihood	Rare	1	< 5%
	Unlikely	2	6 – 25%
What are the chances of the most critical status of the hazard to occur?	Possible	3	26 – 75%
	Likely	4	76 – 98%
KPI: estimated probability of the event to occur	Very Likely	5	> 98%

Table 30 - Failure Mode Effect Analysis (FMEA) for the NVA Inventory Strategy

	Potential Failure Mode	**Effects**	Sev.	**Causes**	Occ.	**Control**	Det.
	What is the event?	*What is the impact?*		*Why would it happen?*		*What are the current processes to prevent it?*	
#1.1	Action plans in different stages of development	Difficulty in managing weekly evolution	1	Uncertain and variant work-method of each country	4	Attempt to establish standardized procedures in every country	4
#2.1	Lack of responsiveness from stakeholders	Delayed definition of action plans	2	Excessive workload	3	Team Barometers, Weekly Team Meetings and Big Levers	2
				Lack of commitment or motivation			
				Lack of belief in the process			
#2.2	Error in repetitive procedures that output the report	Wrong identification of concerning situations	2	Distraction or human error	2	*A posteriori* data checks to validate reliability of the report	5
				Lack of supervision			
#3.1	Erratic quantification of inventory in the warehouse	Erratic decision-making, based in unreliable numbers	5	Complex SC, with several warehouses and processes	5	OPS restructure with multiple collaborative teams	2
				Low-quality/ manual quantification systems	4	Migration to new platforms (e.g.: SO99+)	2

#3.2	Mismatch between forecast and phase-out of products (forecast = 0 when phased out)	Product is not considered as obsolete	3	Lack of communication between DP and Country Team	5	SOP Meetings: country teams + S&OP	2
#3.3	Error in quantities of real stock or assigned ratios	Misalignment in liquidation phase	2	Non-standardized system-integration procedures	3	Teams Communication Channel with multiple teams for stock file creation	1
		Legal problems due to incompliance	4	Communication of false information/ data to customers	2	Multiple communication channels when problem occurs	2
#4.1	Country team is not aware of obsolescence/ expiration condition of a product	Holding waste products in Warehouse	4	Inefficient processes of communication	4	Obsolete & Expiration Inventory Reports	4
#4.2	Unshared data from Country/ Warehouse teams	Overlapping work or misaligned decision-making	2	Uncommunication of strategy to liquidate	2	Multiple channels and meetings to promote collaboration	3

Note 1: Severity (Sev.) is measured by the intensity the intensity of the impact of the failure, with a scale from 1 to 5 where 5 represents the most severe situation. Occurrence (Occ.) is measured by the probability of the root cause that provokes the failure to happen, with a scale from 1 to 5 where 5 represents the most probable situation. Detectability (Det.) is measured by the capacity of the current processes to mitigate the negative impact of the failure event, with a scale from 1 to 5 where 5 represents the most difficult failure to detect with the current existing processes.

Note 2: The evaluation of each failure mode is calculated by the RPN number, that consists of the multiplication of Severity, Occurrence and Detectability. The highest RPN represents the most significant failure mode.

APPENDIX 5 – CONCLUSION AND OBJECTIVES

Table 31 - Evaluation of the execution of the initially proposed objectives

Objective	Location
Understanding the traditional journeys of investigation of inventory management inefficiencies from an academic framework	Section 2.2 Effective Inventory Management
Understanding the company's current replenishment processes, meaning the current definition of inventory parameters and target service levels	Section 1.2.2. Inventory Management Policy
Analysis of operational constraints, such as inbound and outbound capacities, and warehouse storage capacities	Section 3.3. Analysis of the Current Situation
Identification of the most significant causes that currently deviate the company from achieving the desired capacity and costs	Section 3.3.3. Summary of Main Conclusions and Introduction of the Improvement Measures
Development of a tool that automates the categorization of products according to their ABC Analysis, to quantitively define the service level inputted for the definition of inventory parameters	Section 3.3.2.1. Inventory Categorization through ABC Analysis
Identification and Categorization of NVA Inventory	Chapter 4. Data-Driven Tools to Support Non-Value-Adding Inventory
Definition of action plans to mitigate the impact of the highlighted root causes and to improve the operational and financial situation of inventory	Chapter 5. Non-Value-Adding Inventory Management Integrated Strategy
Implementation of a pilot-project with the designed action plans and identification of risks and opportunities for the future of the strategy	Chapter 6. Results and Discussion