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Managing inbound inventory in a complex portfolio environment

A two-echelon warehousing strategy based on root cause analysis

Master's thesis in Supply chain Management

WILMA LINDBLAD
EMIL SVENSSON

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECONOMICS
DIVISION OF SUPPLY AND OPERATIONS MANAGEMENT

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Department of Technology Management and Economics
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden
Telephone + 46 (0)31-772 1000

AI use: In this thesis AI has been used to help with grammar and wording improvements. However, all findings are based on the author's own analysis of the collected data as well as the conclusion made.

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SUMMARY

As manufacturing companies grow and supply chains become increasingly more complex. This creates greater demand on warehouse operations in inventory management, storage capacity, and material availability. These challenges are examined through a case company that has experienced rapid growth in recent years. For the case company this has led to a more complex product portfolio and created challenges related to inventory accumulation, obsolete materials, and warehouse congestion. The case company currently operates with both an internal and external warehouse, but with no clear structure for storage allocation and the replenishments between the two locations. The purpose of this thesis was therefore to identify the root causes behind the current situation and propose a differentiated two-echelon warehousing strategy.

The study was conducted as a single case study and by using a mixed method approach by combining interviews, observations, ERP data, and internal reports. The root cause analysis methods were used to identify the underlying causes, while ABC/XYZ classification, safety stock calculations, and replenishment analysis formed the basis for the proposed strategy.

The findings showed that the main causes are inaccurate demand information, unstable production planning, uniform safety stock policies, and poor coordination between the warehouses. Based on these findings, a differentiated two-echelon warehousing strategy is proposed. The strategy introduces storage allocation criteria and replenishment rules adapted to different material categories. High-frequency materials are stored internally with calculated safety stock, while intermittent materials are primarily stored externally and replenished to the internal warehouse against a confirmed production order. The proposed strategy reduces warehouse congestion, free up pallet positions, and creates a more structured replenishment process.

Keywords: Inventory management, two-echelon warehousing, ABC/XYZ classification, safety stock, warehouse congestion, replenishment strategy.

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Wilma Lindblad, Gothenburg, May 2026
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List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

BOM	Bill of Material
CIMO	Context Intervention Mechanism Outcome
CoV	Coefficient of Variation
ERP	Enterprise Resource Planning
FIFO	First-in-First-out
MOQ	Minimum Order Quantity
MRP	Material Requirements Planning
MTO	Make-to-Order
RCA	Root Cause Analysis
ROP	Reorder Point
SKU	Stock Keeping Unit

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1

Introduction

In the following chapter an introduction to the company is presented, followed by the problem formulation, purpose of the study, research questions, and finally the scope and limitations of this thesis.

1.1 About the Case Company

This case study is conducted together with Company X at their factory in Sweden. It is one of the largest manufacturers of snus and nicotine products in Scandinavia. In 2022 it was acquired by a global giant, which has further strengthened the company's global presence and resources (Deployment Lead, personal communication, January 12, 2026). Company X also operates across several diversified business areas and product categories. However, this case study will only focus on the smoke-free portfolio including the snus and nicotine products that are produced at the facility. The consumer market for snus is mainly in Scandinavia but for the nicotine pouches the main markets are Scandinavia and the U.S but are present in countries all around the world (Deployment Lead, personal communication, January 12, 2026).

The production site in Sweden employs approximately around 500 people, working both day and night. At this site, both tobacco based snus and nicotine variants are produced and packaged (Deployment Lead, personal communication, January 12, 2026). Within the facility, several production lines are dedicated specifically to different product types. Some lines are used exclusively for traditional tobacco snus, while other production lines are dedicated to nicotine snus. In addition, the tobacco packaging line is then divided into both packaging for pouches and other lines for loose snus, while the nicotine ones are only in pouch form (Deployment Lead, personal communication, January 12, 2026).

1.2 Problem formulation

The production facility is the main site for both snus and nicotine manufacturing and handles all inbound material flows required for production. The nicotine segment has grown rapidly in recent years, both in production volumes and product variety. The portfolio now has a large number of market-specific variants, each requiring its own unique packaging materials that cannot be used across markets or flavours except the cans and lids. This has increased the complexity of inbound material management compared to the more stable and predictable snus portfolio. In June 2024 the facility

went through a large organizational transition because of the integration into the large Company Y corporate structure. This transition introduced new planning standards, reporting requirements, and governance structures that changed how key functions such as purchasing, planning and warehouse management manage their activities. The transition has happened together with a period of increasing pressure on the internal warehouse, which is currently operating well beyond its originally designed capacity. The facility experiences several warehouse and planning problems, as the internal warehouse holds too much inventory than it is designed to hold. The overflow with materials are therefore stored on the floor and in aisles, which affect both the safety and prevent processes like First-in-First-out (FIFO) rotation. There is also an issue regarding obsolete materials that are still in the warehouse and take up space.

Whether these challenges are symptoms of an underlying cause or independent problems needing different solutions is not yet known. The organizational transition may have disturbed coordination mechanisms that previously prevented these issues from appearing at the same time. Furthermore, the facility operates with both an internal and an external warehouse, but no clear criteria currently exist for deciding which materials should be stored internally and which should be stored externally, or how replenishment between the two locations should work.

1.3 Purpose

The purpose of this thesis is therefore centered around two main objectives. The first is to identify and understand the factors behind the accumulation of inventory and the congestion of the warehouse at the company X facility. Lastly, to improve how the internal and external warehouses operate together.

1.3.1 Research Questions

Based on the purpose of this case study, these two research questions were formulated.

RQ1: What are the root causes and effects of inventory accumulation, obsolescence, and warehouse congestion at Company X?

RQ2: How can the identified root causes guide the design of storage allocation criteria and replenishment rules for a differentiated two-echelon warehousing strategy at Company X facility?

1.4 Scope and limitations

The scope of this thesis focuses on the inbound material flow at the facility of Company X, specifically the procurement, storage and handling of labels, cans and lids used in production. The study covers the internal warehouse and the associated

external warehouse, as well as the planning and purchasing functions that coordinate how materials move between them. The outbound flow of finished goods, production processes and distribution to customers are not included. Supplier parameters such as lead time and minimum order quantities are treated as given constraints. The larger Company Y corporate governance structure is described where relevant but is not within the scope of proposed changes.

One important limitation is that customer demand data was not available at the item level during this study. So the production frequency is used as a replacement in the safety stock calculations in Chapter 5.

2

Theory

In this chapter, relevant theories and previous research are presented. These specific theories were selected as they address the key aspects of the research problems. Supply chain dynamics and information visibility provide a basis for understanding how demand information and planning decisions can contribute to inventory accumulation and warehouse congestion. Inventory management theories were necessary to include as it provides concepts related to inventory control, safety stock, and planning stability, which is central to understanding why accumulation and obsolescence occurs.

Theories on two-echelon inventory systems and warehouse operations are included due to the fact that this thesis focuses on the interaction between an internal and external warehouse. These theories create the foundation for understanding how inventory can be allocated and managed across multiple sites and the coordination between them. Lastly, the root cause analysis methods are included because the first research question aims to identify the underlying causes of inventory accumulation, obsolescence, and warehouse congestion. These methods provide a structured approach for identifying and how to analyze the observed problems.

2.1 Supply Chain Dynamics

A supply chain is not only a linear process where products move from one step to another. Instead, it works as a connected network where different parts depend on each other, which means that a decision in one part in the supply chain can affect the whole system (Christopher, 2011). The author also mentioned that supply chain dynamics relates to how materials and information move through the whole chain and how these movements can create uncertainty over time. However, a major challenge companies face is that production and purchasing decisions are often made on forecasts and not from customer demands (Christopher, 2011). In environments where the market is always changing the forecast may become inaccurate, which can lead to higher inventory or product shortages. This creates inefficiencies and increases costs within the supply chain.

According to Christopher (2011), the uncertainty created can be reduced by going

from a forecast-driven management to a demand-driven approach. This would allow companies to reduce the amount of inventory kept to handle uncertainty while also improving efficiency, but only if correct information is shared across the entire supply chain. The issue here is if the information is not shared properly and the decisions are made independently a bullwhip effect may occur (Christopher, 2011).

What the bullwhip effect means is that it shows how demand information can become misinterpreted as it moves across the supply chain (Lee et al., 1997). This can happen even if the customer demand remains stable, because demand information may change as it moves through the supply chain. As stated by Lee et al., (1997), there are two main reasons why this can happen, the demand signal processing and order batching. For demand signal processing it means that companies will treat incoming orders as a sign of future demand and adjust production and inventory accordingly. When this occurs repeatedly, even small changes in demand can lead to higher variations in orders especially when lead times are long. The second reason for order batching is when companies place larger orders at certain times instead of ordering continuously. According to Lee et al., (1997), this often is due to lower the ordering costs or fit the production schedules. Often resulting in sudden changes in ordering patterns that do not match the real customer demand, leading to excess inventory and planning difficulties.

2.1.1 Information Asymmetry & Visibility

Information asymmetry appears when supply chain actors do not have access to the same operation information, or when shared information is incomplete or difficult to use. This can reduce decision quality in forecasting, purchasing and replenishment because choices are made based on partial signals rather than the underlying situation. Supply chain visibility is closely connected and concerns the extent to which actors have access to information they consider key or useful for their operations and mutually beneficial to share. Barratt & Oke (2007) argue that information sharing is an activity, while visibility is a potential outcome of that activity. They define supply chain visibility as the extent to which actors have access to or share information they consider useful and mutually beneficial. They also emphasize that shared information creates visibility if it is perceived as accurate, trusted, timely, useful and presented in a usable format, and then incorporated into the decision making process.

When visibility is low or information quality is poor, planning systems may trigger decisions that do not match the physical reality. DeHoratius & Raman (2008) show that accurate inventory records are critical for decision support tools that forecast demand and replenish inventory. They explain that inventory record inaccuracy can cause an automated replenishment system to place an order when it is unnecessary or fail to order when it should. This can create both overstock and stockouts even in organizations with advanced technology. They also describe how records errors can arise through selling and restocking errors, replenishment errors, database errors and poor or incomplete data synchronization.

Visibility is therefore often treated as a means to reduce uncertainty and unnecessary buffers by improving the informational bases for replenishment decisions. Christopher (2011) describes collaborative replenishment approaches where frequent information exchange about usage and inventory supports replenishment based on consumption rather than intermittent orders. In this view, better information can substitute for inventory buffers when supply chain partners coordinate planning and replenishment using shared data.

2.2 Inventory Management

Inventory management is described to be a process of planning and controlling the inventory stocks, so that the correct material and the right quantity is available when needed (Jonsson & Mattsson, 2009). The authors also mentioned that inventory management involves a trade-off between the ability to meet demand, the amount of capital that is tied-up in stock, and the costs associated with ordering, storage, and material handling. The process of inventory management includes the decisions about how much to order and when to order it. This directly influences inventory performance and forms the basis for different inventory control methods, which will be discussed in the following sections.

2.2.1 Cycle stock & Lot Sizing constraints

Cycle stock refers to inventory accumulating when materials or products are purchased and delivered in larger quantities instead of being supplied in a continuous flow that matches consumption (Jonsson & Mattsson, 2009). This means that when materials are supplied in larger quantities than current production requires, the excess inventory is stored until it is needed. According to Jonsson & Mattsson (2009), this often happens due to fixed costs related to ordering, transportation, and material handling because larger quantities are more cost-efficient.

Therefore, the size of the cycle stock is closely connected to lot sizing decisions, since the quantity ordered directly affects how much inventory needs to be stored (Jonsson & Mattsson, 2009). To estimate the amount of cycle stock held in inventory, average inventory levels under stable demand conditions are often assumed to be around half of the order quantity. This is based on the assumption that inventory levels are highest immediately after delivery and then gradually decrease until the next shipment arrives (Jonsson & Mattsson, 2009). Christopher (2011) explains this through the economic order quantity approach. Where larger order quantities can reduce ordering costs per unit but at the same time increase the amount of inventory held in storage and the capital tied up in stock.

However, in practice companies are not always able to order the quantity that is considered economically balanced, even though larger quantities can reduce ordering costs (Jonsson & Mattsson, 2009). The authors explain this by stating that suppliers often require companies to order according to their minimum order quantities. Because of this requirement, companies are forced to order larger quantities than

what is needed for short term production needs. According to Jonsson & Mattsson (2009) this can increase cycle stock levels and create a greater need for storage space.

2.2.2 Planning stability in MRP environments

Material requirements planning (MRP) systems are designed to support purchasing and production planning by creating time-based plans that are sensitive to changes in demand and other planning inputs (Jonsson & Mattsson, 2009). Because of this sensitivity, the system automatically creates planned orders that can be adjusted in both timing and quantity when planning conditions change. This gives the system flexibility to respond to demand changes, but it can also lead to frequent rescheduling and may disrupt purchasing and production activities (Jonsson & Mattsson, 2009).

To reduce these disruptions the authors explain that companies often use different control mechanisms within the planning system. One commonly used method is firm planned order, where specific orders are fixed and cannot automatically be changed by the system during a certain time period. Another method described is the use of time fences, which divide the planning horizon into different periods where separate planning rules apply. In the period closest to production, changes are usually not allowed because materials may already have been procured and production resources have already been allocated (Jonsson & Mattsson, 2009). However, further into the planning horizon some changes may still be allowed even though they are often subject to certain restrictions. Jonsson & Mattsson (2009) explain that maintaining a stable planning process requires both appropriate system settings and active planning control. This is because the forecast changes and unexpected events can trigger rescheduling throughout the system, which can disrupt the purchasing and production activities.

Since forecast changes and unexpected events can trigger rescheduling, companies may use a frozen planning period to create more stability in the master production schedule (Jonsson & Mattsson, 2009). Sridharan & Berry (1990) conducted a simulation to examine how different freezing approaches affect both lot sizing costs and schedule stability. The results showed that by having a frozen period of the master production schedule it can help decrease the instability in planning, even when customer demand is uncertain. The study also showed that frequent replanning within the planning horizon often increased both instability and total costs instead of improving responsiveness. In summary, frozen planning periods were found to be most effective when there are clear rules regarding what changes are allowed within the schedule (Sridharan & Berry, 1990).

2.2.3 Safety Stock & the Reorder Point

Safety stock refers to the additional inventory that is kept to protect against uncertainty in demand or supply (Jonsson & Mattsson, 2009). It is often used to be able to maintain product availability when actual demand or delivery times differ from what was originally planned. To determine the appropriate level of safety stock to

have, it is important to look at the cost of holding extra inventory against the risk of stock shortages (Jonsson & Mattsson, 2009). Jonsson & Mattsson (2009) also present the cycle service level as a common method for calculating the safety stock. The cycle service level measures the probability that no shortages occur within a single replenishment cycle. Based on the chosen service level, a safety factor k is taken from the standard normal distribution. For example, at a 95 percent service level, k equals 1.65. The safety stock is then calculated as:

$$SS = k \times \sigma DDLT$$

where $\sigma DDLT = \sigma_D \times \sqrt{L}$ is the standard deviation of demand during the lead time. Under the assumption that demand in each period is statistically independent, the standard deviation during a lead time of L weeks can be derived from the weekly demand standard deviation as follows:

$$\sigma DDLT = \sigma_D \times \sqrt{L}$$

Expressing the weekly standard deviation through the coefficient of variation CoV , where $CoV = \sigma_D$ divided by average weekly demand D , gives:

$$SS = k \times CoV \times D \times \sqrt{L}$$

This calculation shows how demand variability affects the amount of safety stock required to achieve a certain service level. Products with more unpredictable demand generally require larger safety stock levels in order to maintain the same service level. (Jonsson & Mattsson, 2009). The authors further explain that certain conditions must be fulfilled for this calculation method to be reliable. The normal distribution can only be used when demand during the lead time is relatively stable and evenly distributed. As a general guideline, the average demand during lead time should be more than twice as large as the standard deviation during the same period (Jonsson & Mattsson, 2009). If this condition is not met the demand is considered too irregular for the normal distribution model to be reliable. In such situations, Jonsson & Mattsson (2009) recommend using a make-to-order approach instead of having a safety stock. To know when a new order should be placed in order to avoid inventory levels falling below the safety stock level, a reorder point calculation is used. Jonsson & Mattsson (2009) define it as:

$$ROP = SS + D \times L$$

When stock falls to this level, a replenishment order is placed and materials arrive after the lead time has elapsed. The safety stock component absorbs any demand

above the average that occurs during that waiting period. In a two-echelon context where an external warehouse supplies an internal forward position, L in this formula refers to the transfer lead time between the two locations rather than the original supplier lead time, since the trigger is based on the internal stock level and fulfilled from the external warehouse (Jonsson & Mattsson, 2009).

2.2.4 ABC/XYZ Inventory Classification

In manufacturing and distribution environments, inventory items usually differ significantly in terms of demand patterns and importance. According to Jonsson & Mattsson (2009), by using a classification system that is based on factors such as demand volume and demand variability. This would mean that different inventory policies be applied based on which classification the items belong to instead of having one standard for the entire inventory portfolio.

The ABC classification ranks items by their share of total annual demand volume, dividing them into A, B, and C classes. A items account for the majority of total volume despite representing a small proportion of total item numbers, following the Pareto principle where roughly 20 percent of items account for 80 percent of total value (Jonsson & Mattsson, 2009). C items are individually low-volume and numerous. The XYZ classification adds a variability dimension, grouping items by the coefficient of variation of their demand. X items have stable and predictable demand. Z items have highly variable or intermittent demand, as illustrated in Table 2.1.

Syntetos et al., (2005), examine different demand patterns and present classification methods based on two factors, how often demand occurs and how much the demand quantity varies over time. The study explains that products with highly varying demand are more difficult to manage using traditional inventory models because the demand changes are often more unpredictable than the model assumes. As a result, the calculated safety stock levels become too low to achieve the intended service level even when inventory levels are increased. This issue becomes especially significant for items that have a coefficient of variation above approximately 0.7, since highly irregular demand makes safety stock less reliable (Syntetos et al., 2005; see Table 2.1).

In the study by Teunter et al., (2010), the effects of applying the same inventory policy across all products within the same ABC class were examined. This was done by using data from three large industrial datasets, the study showed that this approach can lead to unnecessary high inventory costs. This is because items within the same ABC class may still have very different demand variability, so having the same safety stock and service level policy may not be suitable for all items (Teunter et al., 2010). Therefore should the inventory classification not only be based on volume importance but also on demand variability. The study highlights the importance of using a more differentiated inventory management approach instead of applying one standard policy across all items within the same group (Teunter et al., 2010).

Volume class Variability class	A <i>High volume</i>	B <i>Medium volume</i>	C <i>Low volume</i>
X <i>CoV ≤ 0.49</i> <i>Stable demand</i>	AX <i>High volume, stable</i>	BX <i>Medium volume, stable</i>	CX <i>Low volume, stable</i>
Y <i>CoV 0.49–0.70</i> <i>Moderate demand</i>	AY <i>High volume, moderate variability</i>	BY <i>Medium volume, moderate variability</i>	CY <i>Low volume, moderate variability</i>
Z <i>CoV > 0.70</i> <i>Intermittent demand</i>	AZ <i>High volume, intermittent</i>	BZ <i>Medium volume, intermittent</i>	CZ <i>Low volume, intermittent</i>

Table 2.1: Illustration of ABC/XYZ classification

According to Stević & Merima (2021), the ABC/XYZ matrix provides a practical basis for applying different inventory policies depending on both demand volume and demand variability. Stević & Merima (2021) demonstrated this in a study within the construction material industry, where the combined ABC/XYZ method. The result showed that different product groups need different replenishment strategies depending on their demand characteristics.

2.2.5 Two-Echelon Inventory Systems

Multi-echelon systems refers to inventory systems where the inventory stock is stored at more than one location within the supply chain. In a two-echelon system, a central warehouse supplies another warehouse or storage location closer to the point where the material is used (Silver et al., 2017). Meaning, when an on-site warehouse next to production is combined with an external warehouse, it can be viewed as a two-echelon system. According to Silver et al., (2017) that the inventory performance can improve when replenishment decisions are coordinated using shared information across all stock locations. This further helps reduce unnecessary changes in replenishment planning and improves coordination between warehouses.

How inventory is distributed within the supply chain is another important decision

in multi-echelon inventory systems. According to Silver et al., (2017), this involves deciding whether inventory should be stored centrally or closer to production and consumer points. Centralized storage provides greater flexibility, while local storage can improve responsiveness. Products with low demand and high value are often more suitable for centralized storage and delivered when needed, while products with higher demand may instead be stored closer to production (Silver et al., 2017). In raw-material settings, the onsite warehouse can therefore be viewed as the downstream location supporting daily operations, while the external warehouse functions as an upstream buffer for larger inventory volumes.

Another important aspect of multi-echelon inventory systems is how replenishment decisions are controlled between different stock locations. As described by Diks et al., (1996) a key distinction is made between installation stock policies and echelon stock policies. Under an installation stock policy, replenishment decisions are based only on the inventory available at the local warehouse. However, for echelon stock policy the replenishment decisions consider the total inventory across all connected stock locations. This includes inventory in each warehouse and the ones in transit between them. Diks et al., (1996) further explain that the service level at the downstream location depends on the replenishment policy used between the different locations. This means that storage decisions and replenishment decisions are closely connected and should be treated as part of the same system.

2.2.6 Lean Supply Chains & Supplier Relationship Design

Christopher (2011) argues that supply uncertainty is one of the primary drivers of excess inventory in supply chains, and that uncertainty can be reduced not only through better demand forecasting but by structuring supplier relationships so that deliveries are reliable, frequent, and quantity-controlled. He distinguishes between supply chains that respond to uncertainty by building large buffer stocks and supply chains that reduce uncertainty through closer supplier collaboration and more frequent smaller deliveries. The latter approach, which he associates with lean supply chain principles, reduces the need for safety stock by shortening the effective replenishment cycle and making inbound flow more predictable. A supplier delivering daily in controlled quantities creates a fundamentally different inventory situation from a supplier delivering in large irregular batches, even if the total weekly volume is identical in both cases.

Silver et al., (2017) formalize this relationship between delivery frequency and internal inventory requirements. Under a scheduled replenishment arrangement where deliveries occur at regular times in controlled quantities, the average cycle stock held internally equals approximately half of one delivery quantity. Increasing the delivery frequency while reducing the quantity per visit therefore directly reduces the internal buffer required without changing the total volumes supplied over any given period.

2.3 Root Cause Analysis

A root cause analysis (RCA) is a structured approach for identifying and addressing underlying causes of a problem rather than repeatedly responding to its symptom (Andersen & Fagerhaug, 2006). Doggett (2005) emphasizes that when root causes are not identified, organizations tend to treat symptoms, which allows the problem to persist. It is also highlighted that RCA is not a single technique, but that different RCA tools can produce different levels of causal insights and confidence. Tool selection should therefore reflect what the problem requires, such as identifying root causes, revealing interdependencies among causes, and supporting the testing of causal logic (Doggett, 2005).

2.3.1 Fishbone Diagram and Interrelationship Diagram

A common tool used in a root cause analysis is the Ishikawa diagram, also referred to as a fishbone diagram, this is because it looks like a fish (Ishikawa, 1986). In the fishbone diagram the problem is placed at the head of the diagram, while potential causes are divided into different categories on the side and is further explained in detail (Doggett, 2005). This diagram is a great tool to support and to structure brainstorming to identify possible root causes as well as areas where additional information may be needed (Doggett, 2005).

An important characteristic of the fishbone diagram is that the main cause categories can either follow standard template or be adjusted depending on the problem being analyzed (Doggett, 2005). This flexibility is useful because the category structure can be adapted to fit different industries and situations. In a supply chain context, Ilie & Ciocoiu (2010) showed that the fishbone diagram can help with identifying how different functions are connected, which might otherwise be difficult to detect when analyzed separately. According to Doggett (2005), the diagram identifies possible causes, but further analysis is needed to determine which causes are most important.

To then show how the different causes influence each other, an interrelationship diagram can be used. According to Doggett (2005), this diagram helps identify which causes are the main drivers and which are mainly consequences of other factors. This is done by analyzing the number of outgoing and incoming links between the different causes. This becomes important when several connected causes have been identified and priorities need to be established.

2.3.2 5 Whys Analysis

The Five Whys analysis is a method used in the root cause analysis to identify the underlying causes of a problem by repeatedly asking “Why” the problem occurred. According to Serrat (2017), the method begins with the observed problem and works backwards through a series of why questions in order to move beyond the visible symptoms and identify the root cause. The number five is used as a general guide, since some problems require less and some require more, but it depends on the

situation.

This method is often considered useful due to it encourages a deeper analysis of problems instead of focusing only on the visible. Liker & Hoseus (2008) further describe the method as supporting a system-focused perspective, where the purpose is to identify weaknesses in processes and systems rather than placing blame on individuals. According to Serrat (2017), the five whys method should be used as part of a structured problem-solving process and not be applied mechanically. This is because effective use of the method depends on having a clearly defined problem, providing honest answers, and continuing the questioning process until causes that can be addressed are identified. However, the method has some limitations, since analyses may stop too early at visible symptoms and different teams may reach different conclusions (Serrat, 2017). The authors therefore highlight the importance of continuously verifying the answers throughout the analysis process.

3

Methods

In the following chapter, the methodological approach used in this case study is presented, including the research design, data collection methods, analytical approach, ethical considerations, and how trustworthiness and quality is ensured throughout the study. The methodology has been developed to address the two research questions by combining qualitative and quantitative methods within a single case study design (Bryman & Bell, 2015). Rather than focusing on isolated operational issues, the study investigates how organizational structures, planning processes, and physical warehouse operations interact within the facility.

The study follows a diagnostic-to-prescriptive research structure. Andersen & Fagerhaug (2006) describe problem solving as a process that must begin with diagnosing and understanding the root causes of a problem. This is needed before continuing to propose solutions, the authors argue that proposing solutions before identifying the underlying causes allows problems to persist. This logic is the process of this study, where RQ1 focuses on the current situation and finding the root causes of inventory accumulation, obsolete stock, and warehouse congestion. For the second part, RQ2 builds on the findings in part one to propose improvements in the form of a differentiated two-echelon warehousing strategy. With this logic it ensures that the recommendations in RQ2 are grounded in empirically verified causes and not based on generic best practice. The overall methodical structure of the study is presented in Figure 3.1.

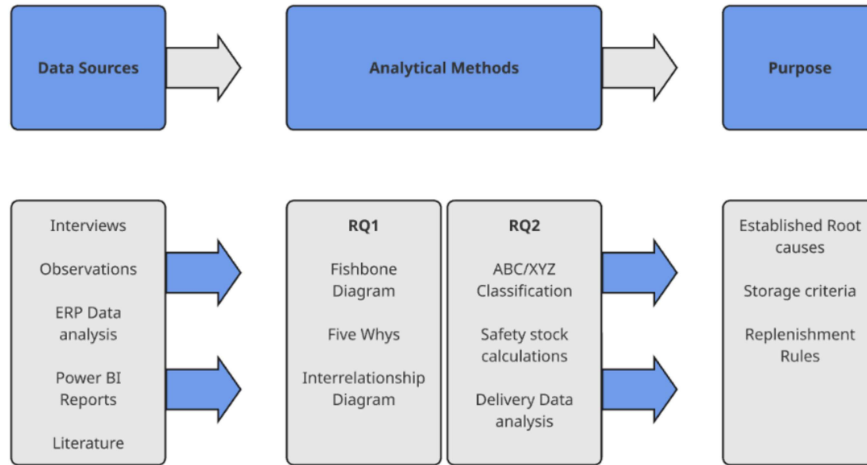


Figure 3.1: Overview of the study’s methodical structure used to address the research questions

3.1 Research Design & Approach

This study was conducted as a single case study focusing on one production facility within the organization. According to Yin (2018), a case study is particularly useful when research questions aim to answer how and why within a real organizational context. Since the purpose of this study is to understand how organizational and operational conditions contribute to warehouse congestion, a single case study was suitable as it allows for more in-depth understanding of one specific organizational setting instead of comparing multiple cases (Johansson, 2007).

The study also follows an abductive approach, which Dubois & Gadde (2002) describe as a continuous process of moving between empirical findings and theoretical understanding throughout the research process. The initial theoretical understanding was established through the literature review and continuously refined as interviews, observations, and quantitative analyses were conducted. Similarly, Bryman & Bell (2015) describe the abductive approach as a way to develop a deeper understanding of the studied situation by going back and forth between the empirical findings and theory.

Furthermore, a mixed method design was used by combining qualitative and quantitative data collection and analysis methods. By combining different methods it allows for a deeper understanding of organizational problems by allowing different forms of data to complement one another (Bryman, 2006). This approach supports methodical triangulation, by using both quantitative and qualitative methods strengthens the validity and reliability of the results as it can be cross-checked against each other (Denzin, 2017). The qualitative part of the study consists of interviews, observations, and internal documents used to understand operational routines, coordination challenges, and warehouse processes. The quantitative part consists of ERP-based inventory and production data analysis used to identify in-

ventory patterns, warehouse utilization, and demand variability.

3.2 Data Collection

The collection of data in this case study was based on a mixed method approach which includes both qualitative and quantitative data. The data collected was through interviews, observations, analysis of internal company data, and a literature review. Yin (2018) emphasizes that strong case study evidence is built on multiple sources that converge on the same findings, and the data collection in this study has been designed with this principle in mind. Each method is described below, including how it contributes to addressing the research questions.

3.2.1 Literature Review

The literature review was conducted to establish the theoretical foundation for both RQ1 and RQ2 before the empirical data collection began. The purpose of the literature review was to gain a deeper understanding of the research area, identifying relevant theories and frameworks and used as a complement to the empirical findings gathered throughout the study. According to Snyder (2019), a literature review can in its entirety be used as a research method by collecting and analyzing previous research and frameworks on the topic. However, in this case study the literature review was used to support the understanding of the empirical findings and provide a basis for the proposed improvements.

The literature review supported both the quantitative and qualitative parts of the study. For the qualitative part, it was used to identify relevant operational challenges and support the development of the interviews and observations. For the quantitative part, the literature review provided a solid foundation for understanding concepts and frameworks used in the analysis, including inventory classification and safety stock calculations.

To find the relevant literature for both the quantitative and qualitative research parts, Chalmers Library, Google Scholar, and related course material will be used to find these. During the use of Chalmers Library and Google Scholar the primary keywords used were: inventory management, warehouse operations, material planning, and storage classification.

3.2.2 Interviews

The interviews were conducted with carefully selected participants that play a key role in the different functions at the organization that are relevant to the research problems. The participants chosen for these interviews are operating at different functions across the organization due to the research questions spanning over different functions. The people that were interviewed during this case study included a capacity planner, procurement/MRP, warehouse employee, deployment lead, and the chief of warehouse as seen in Table 3.1. By interviewing different people with

different roles will capture different perspectives across multiple areas but also at different levels of the organization to get a comprehensive understanding of the problem and how it currently functions in practice today (Adeoye-Olatunde & Olenik, 2021).

Position	Duration	Topic
Capacity planner	30 min	Production
Procurement/MRP 1	45 min	Procurement
Deployment Lead	1 h	Production
Procurement/MRP 2	30 min	Procurement
Procurement/MRP 3	45 min	Procurement
Chief of warehouse	1 h	Warehouse operations
Logistic Project manager	1 h	Warehouse projects
Warehouse employee	50 min	Warehouse operations

Table 3.1: Interviews conducted at Company X

A semi-structured interview format with open ended questions were used for the interviews. The interviews started with pre-prepared core questions, after which the participant can answer freely and this format allows the researcher to ask follow-up questions. This provides flexibility from both the researcher’s side but also the participant, while also providing the interview to go more in depth of the topic (Bryman & Bell, 2015). In addition to the formal interviews, continuous communication also took place through Microsoft Teams and informal discussions with several participants. Although these interactions were not structured interviews, they contributed to additional clarification throughout the study.

3.2.3 Observations

To further gain a broader overview of the entire process, observations were used as a compliment to the interviews. Even though interviews provide valuable insights into what the warehouse employees do, it can differ from what is actually done in practice. It is described by Yin (2018) that direct observations in a case study research is very valuable due to it allows the researcher to observe the process in its natural setting and it is independent of how the participants describe it. Morgan et al., (2016) further elaborated that direct observations will reduce the limitations of interviews, such as memory gaps, selective reporting, or lack of awareness of their own routines.

In the context of this case study, which focuses on warehouse operations, the observations helped to capture the complexity of the material flow. The observations made focused specifically on import activities, storage layout, and the internal movement of goods in-house. These aspects were important to look at to understand how the

materials move through the facility, how different areas of the warehouse are used, and how operational routines are carried out in practice. Overall, the combination of the interviews and observations strengthened the base of the study by providing both practical and experiential perspectives on the warehouse operations. For RQ1, the observations were important for identifying visible signs of congestion, such as floor stacking, blocked aisles, and FIFO violations, which could not be captured through interviews or system data alone. For RQ2, observing how storage areas were utilized provided useful input when evaluating potential warehouse improvements and storage strategies.

3.2.4 Quantitative data collection & Analysis

The quantitative data collection was conducted to provide an objective foundation for analyzing the current operational situation. First the primary data were extracted, which is data collected directly from the source (Bryman & Bell, 2015). In this case it was data extracted from Company X's internal ERP system. This system contained records related to the inventory levels of the products, orders, and stock movements. According to Bryman & Bell (2015), secondary data is however data that has already been collected and used by others. In this study the secondary data were collected from different Power BI reports provided by Company X to see the production schedule a year back and upcoming to see the slow movers in stock in relation to past, current and planned production.

To analyze the collected data, Microsoft Excel was used for structuring, calculating, and visualizing the empirical material. To visualize the findings graphs, tables, and diagrams were used to identify patterns related to inventory accumulation, warehouse utilization, and product variability. For the diagnostic part in the diagnostic-to-prescriptive process which is related to RQ1, the empirical findings focused on understanding why this has happened and how it is related to each other. Three different root causes methods were used, where the first one is the fishbone diagram to organize possible causes into different categories. The second method was the Five Whys method to further see the deeper underlying causes, and lastly the interrelationship diagram was used to analyze how these causes and effects influenced each other (Doggett, 2005; Andersen & Fagerhaug, 2006).

For the second part of the diagnostic-to-prescriptive process, the analysis focused on RQ2. The focus was to take the input from the diagnostic part to find relevant improvements. ABC/XYZ classification was used to group materials based on production volume and demand variability. After the classifications, safety stock calculations were made to find suitable levels based on the different material categories (Jonsson & Mattsson, 2009). Together, these methods formed the basis for the two-echelon warehousing strategy.

3.3 Ethical Considerations

Ethical considerations are an important aspect to consider when doing a case study, especially when working with other people and conducting interviews. According to Bryman et al., (2019), there are four main principles to consider when doing a case study involving participants are, informed consent, avoidance of harm, confidentiality & anonymity, and responsible conduct. To address these principles in this case study, all interview participants were informed at the beginning of the interview about the purpose of the study. Consent was also obtained by asking the participants if it was okay if the interview was recorded, and if not, no recording was made. The interview participants were informed that they could withdraw at any moment without questioning. Furthermore, confidentiality and anonymity were ensured by not mentioning any names if not approved by the participant, and that all the information gathered was reported in a responsible manner. This aligns well with what the Ethical Review of Research on Humans emphasizes regarding these four principles to consider when a research involves human participants (Swedish Ethical Review Authority, n.d).

3.4 Trustworthiness & Research Quality

Trustworthiness and research quality are important aspects of case study research. Since this study combines both qualitative and quantitative methods, several criteria were used to ensure quality of the research. According to Lincoln & Guba (1985), research quality can be assessed through four criteria, credibility, transferability, dependability, and confirmability.

In this study the credibility was strengthened through triangulation described by Denzin (2017) by combining interviews, observations, ERP data, and internal reports to compare the findings from multiple sources. To assess the transferability criteria, detailed description of the operational setting, warehouse processes, and analytical methods were provided to help the reader whether the findings may be relevant in similar contexts. The dependability was supported by documenting the research process and analytical methods throughout the study to maintain a clear and structured process. Lastly, the confirmability was addressed by grounding the analysis in empirical data and then applying structured analytical methods to reduce the influence of subjective interpretation and personal bias (Lincoln & Guba, 1985).

4

Empirical Findings

The empirical findings presented in this chapter are based on interviews with key people at the facility, direct observations conducted during site visits, and analysis of internal data extracted from the ERP system and production planning tools. The findings are organized around four operational functions that together create the material flow from demand signal to production output: Marketing and Planning, Material Requirements Planning, the Warehouse function, and the Production function. Figure 4.1 illustrates the relationships between these functions and the information flows that connect them.

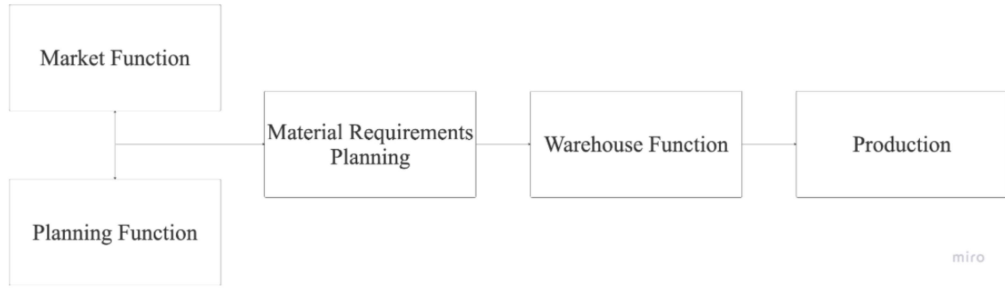


Figure 4.1: Overview of the four operational functions examined in this chapter and the information flows connecting them.

Each function is presented separately in this chapter. The findings are structured into three parts: current state, which describes how the function currently operates; causes, which identify the factors contributing to the current situation; and effects, which describe the resulting consequences for the organization.

4.1 Marketing and planning

4.1.1 Current State

The market function at Company X is responsible for driving demand signals, managing new product launches, and communicating each market's material requirements. As seen in figure X, the market function operated alongside the planning

function. The role of the planning function is to determine how much is possible to produce at the facility, as well as on which lines and when. Together these two functions create the first initial material demand, which is then transferred downstream to the MRP team, warehousing, and production.

The information flow between market, planning, and the MRP team operates through three consecutive planning systems. First, the demand forecast is created in one system, where the market team enters volume requirements for each product and market. These forecasts are then translated into another system used by the planning team, where production volumes are allocated to specific production lines. Lastly, the data is transferred to the ERP system, where the production planners generate the actual production schedule, which determines the material requirements for purchasing. Instead of being developed as a single system, this structure has evolved by connecting multiple planning platforms over time, which has led to dependencies between systems that were not initially intended to be linked.

Following the organizational restructuring in June 2024, both market and planning functions were integrated into a broader Company Y reporting structure. This transition introduced new reporting requirements, planning standards and compliance obligations that changed how demand information is communicated between market, planning and purchasing without resolving the underlying system translation incompatibilities.

4.1.2 Cause

The key issue identified from the interviews with the MRP team was the decline in accuracy as demand information is passed through the three consecutive planning systems. From the interview with MRP planner 2, it was explained that the errors can occur at each stage of the translation, resulting in demand figures that do not accurately reflect actual production needs. This issue is further affected by a structural limitation, as some materials are not included in the bill of material (BOM) and are therefore not visible to purchasing until production begins. As explained by MRP planner 2, this means that the procurement for these materials are based solely on forecast data, without visibility of confirmed production orders.

Furthermore, the MRP planners are no longer involved in new product launches. In the past, the MRP planners were included early on in the process, which made it possible to assess materials and place orders in time. Today, the process relies on a request-based system where project managers submit volume estimates, often without the required lead time or confirmed production quantities. In addition, minimum order quantity (MOQ) set by suppliers with a fixed order quantity further limits the purchasing flexibility by ordering larger volumes than required. MRP planner 1 mentioned that the forecasts for new launches are often unavailable when the materials are needed, and the quantities are often incorrect due to optimistic market projections or incomplete system setup. MRP planner 1 further elaborated that the project managers on new launches do not always update the shared planning

documentation in time. As a result, purchasing becomes aware of the new launch too late and cannot place orders within normal lead times.

4.1.3 Effects

The consequences of these issues can be clearly linked to the upstream information flow as described above. From the interview with MRP planner 2, it was mentioned a situation where the planning system showed a requirement of 250,000 labels for a new product launch but the actual requirement was 1.6 million units. This clearly shows the extent of inaccuracies that can happen when demand information is not correctly transferred through the different planning systems. MRP planner 1 further highlighted that up to 30% of the actual demand is not visible in the planning system, requiring purchasing to act on demand signals received through emails and shared documents instead of the system. This creates a higher workload, where about three hours per week are spent on purchasing snus labels, while around 20 hours are spent on purchasing nicotine labels. This shows how much more complex the nicotine segment has become.

The information issues are reflected in consistent over-purchasing of market specific materials, particularly for new launches in the nicotine segment where forecasts are less accurate. Furthermore, due to new launches the demand becomes unpredictable, while some markets are relatively small. In combination with the MOQ leading to purchasing larger volumes than what is required. As a result of the over purchasing, the inventory levels increase and also the congestion in the warehouse.

4.2 Material Requirement Planner

4.2.1 Current State

The MRP function is responsible for procuring all materials that are needed for production at the facility. This includes materials such as labels, cans, print paper, and other materials needed for production. The function is structured around three planners, each assigned to a specific material category. MRP planner 1 procures labels for both snus and nicotine, MRP planner 2 procures print paper, cartoons, and additives, lastly MRP planner 3 procures cans and lids.

For the nicotine segment, all SKUs use the same can and lid, except for the Norwegian market where both must have a specific colour due to regulation. The three labels needed (top, side, and bottom), however, vary depending on market and flavour. This results in a total annual demand of 38,705,791 cans, corresponding to an average of 744,342 units per week. During the observed period, 2,412 production batches were made, with an average of 46.4 batches per week. The average batch size is 16,047 units, while the median batch size is significantly lower at 8,640 units, indicating a distorted distribution where a small number of larger batches increase the average. The batch sizes range from as low as 720 units to as high as 374,800 units, reflecting the variation between high volume global products and

smaller markets.

For the snus segment, cans and lids differ by product format (e.g., pouch, loose, size, weight, and market). For example, in the Swedish market loose snus is packed in paper cans, while in other markets it is packed in plastic cans. Overall, sixteen different can and lid types are identified across the snus portfolio. As for the nicotine segment the labels for snus also vary depending on the specific market. In comparison to the nicotine segment, snus has an annual demand of 127,793,152 units, corresponding to a weekly demand of 2,457,560 units. The average batch size is 38,796 units, with a median of 30,000 units. This shows that snus has approximately 3.3 times higher annual demand than the nicotine segment. The snus segment reflects as more mature and stable, where the higher demand and larger batch sizes result in more predictable production patterns compared to the more variable nicotine segment.

Looking at the purchasing process, it is based on two main approaches. The first one is ordering materials based on a fixed production plan that covers the two week frozen horizon and is used for stable and high volume materials. The second approach is based on the Master Plan in the ERP system, where confirmed production orders are combined with forecast data and are used for the majority of materials. The safety stock levels differ between the material categories, all depending on the lead time from the supplier and supply conditions. MRP planner 1 explained that labels usually have approximately four weeks of safety stock, depending on the supplier. For materials such as additives or other formula based materials the safety stock is about three months due to lead times up to 12 weeks according to MRP planner 2. Furthermore, MRP planner 3 mentioned that cans and lids carry a directive of approximately six to eight weeks, these are calculated manually and can vary depending on the planner's judgment.

4.2.2 Cause

A central issue mentioned in the interviews were the directives from Company Y to have a safety stock of six months for all nicotine related materials. According to the Chief of Warehouse, this decision was made at the corporate level without considering the storage capacity of the facility. By having a six month safety stock for a segment with many variations, frequent design changes, and market-specific packaging creates a misalignment between corporate inventory policy and warehouse capacity.

Safety stock for materials related to the snus production is set locally but has no clear method, as it depends on the individual material planner but is usually around six weeks. MRP planner 3 explained that safety stock levels are based on judgment and general guidelines rather than calculations. Additionally, there is no process to regularly review whether safety stock levels are still appropriate as production volumes, demand patterns, or the product portfolio change. As a result, parameters are not updated and continue to reflect earlier conditions rather than current ones.

As mentioned in 4.2.2 the minimum order quantity is another issue as many of the nicotine products have a relatively low production volume. MRP planner 1 stated that the suppliers set these minimum order quantities based on their own production needs, often requiring a full production run to justify their setup costs. The MOQ for printed labels for the nicotine products is approximately 60,000 units. However, the actual production could be as low as 40,000 units or less for a new launch. A similar situation is for cartons, where the demand for a new launch can be 500 cartons, while the MOQ is 2,500, as explained by MRP planner 2. There is currently no defined process for managing the surplus materials or whether they will be used again. Another issue identified regarding the lack of system support for tracking when materials expire. Some of the materials have limited shelf lives, but the ERP system does not provide automatic alerts when expiry dates are approaching. As a result, the MRP planners need to monitor this manually, which is not done systematically and increases the risk of materials expiring before use.

Lastly, a related governance gap concerns the phase-out of discontinued materials. A formal lifecycle status flow exists within the ERP planning system, where direct materials progress through defined statuses and each status change is assigned to the Masterdata team. The Phase Out status is intended to be set when the market function designates a material as superseded, after which a manual check and market approval are required before physical disposal can be initiated. In practice this flow has broken down at its initiating step: following the June 2024 organizational transition, the market function is not consistently initiating the Phase Out designation, meaning discontinued materials remain in Active status indefinitely and MRP continues generating procurement signals for them. A further barrier is that previous scrapping decisions resulted in materials being disposed of that were subsequently needed again, creating emergency reorders and direct attributable responsibility for the individual who initiated the decision. This has produced a bias toward inaction where the personal cost of a wrong scrapping decision is immediate and visible, while the cost of retaining inactive stock is absorbed by the organization rather than attributed to any individual.

4.2.3 Effects

The impact of these consequences becomes evident in practice, especially in how safety stock levels are set and managed. As MRP planner 3 highlighted, the safety stock for high volume snus products are often too high, as an example where one product had 1.5 million labels in safety stock. This amount is hard to justify based on the current lead times and production capacity. The Chief of Warehouse described a similar situation for lids and cans, where the facility at one point held much more stock than needed for the coming weeks. This issue was resolved through informal actions rather than a formal review process. At the moment the MOQ constraints lead to repeated over-purchasing when orders are placed. The carton example described by MRP planner 2, where 2,000 surplus cartons have remained in storage since the initial launch with no confirmed future use shows how this issue occurs in practice. These examples reflect a broader pattern and are not limited to

individual cases.

The data used to create figure 4 and figure 5 was obtained from multiple sources. A Power BI report provided by the Chief of Warehouse identified SKUs that had not moved for more than six months. This dataset was complemented with internal data extracted from the ERP system, as well as the production schedule, to verify that no production orders had been executed for these items during the same period. To further validate whether the identified SKUs were truly inactive, a review of the BOM was conducted, particularly for components related to the labelling process. Inventory transaction data was also analyzed to confirm that the SKUs had not been used under different production numbers.

Based on this combined dataset, all items that have not been used for more than six months were gathered and categorized as inactive inventory. These items are assumed to have low likelihood of future use, potentially due to product design changes or obsolescence. As shown in figure 4.2, the majority of inactive inventory is associated with nicotine products, accounting for 84% of the total inactive materials, while snus products represent 16%.

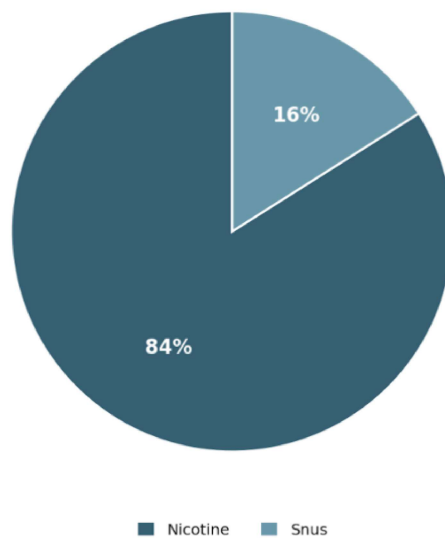


Figure 4.2: % of inactive labels

As shown in figure 4.3, the total volume of inactive inventory is presented by product category, distinguishing between nicotine and snus labels. The data indicates that nicotine products account for the majority of inactive inventory, with a volume exceeding 10,5 million units that have not been used for more than six months. In contrast, snus products represent approximately 3,4 million units of inactive inventory during the same period.

In addition to the difference in volume, figure 4.3 also shows the associated cost of this inactive inventory (the cost for each product not the inventory cost). The total

cost of inactive nicotine inventory amounts to approximately 2.3 million SEK, while the corresponding cost for snus products is approximately 0.41 million SEK. Overall, the results show that a substantial share of inactive inventory is concentrated within the nicotine category, both in terms of volume and cost.

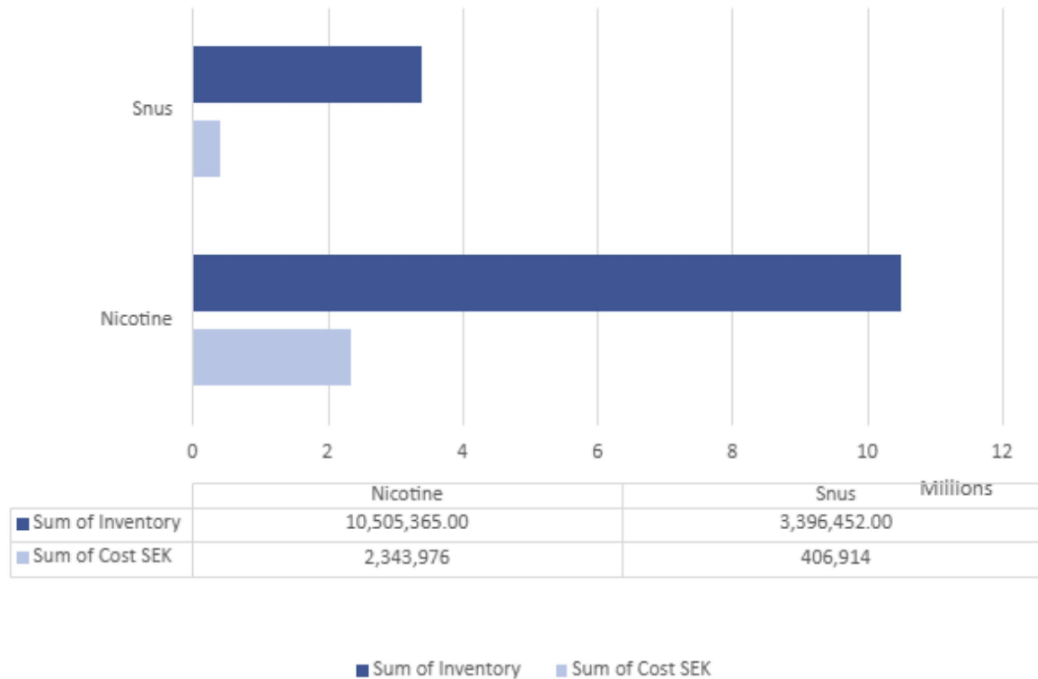


Figure 4.3: How much inventory of labels that are inactive of the two categories snus and nicotine and the total cost for the products of each category

4.3 Warehouse function

4.3.1 Current state

The warehouse function at the facility is responsible for receiving and processing all inbound material deliveries, placing materials into designated storage locations, and preparing and supplying materials to production when needed. From observations, incoming deliveries are scanned and registered in the ERP system and then placed in available storage locations, either in racks or on the floor. The materials in the warehouses are intended to follow the FIFO principle, where older materials are used before new ones to minimize the risk of any expiration dates. When production orders are released, materials are picked and placed near the production in the correct quantity one day prior to production.

The internal warehouse is located close to the production and spans over several floors, it was designed to hold approximately 800 pallets. The facility has currently four loading docks shared between all inbound and outbound deliveries. In addition to this, an external warehouse is used to store materials and is located approximately

15 minutes from the facility. According to the Chief of Warehouse the external warehouse operates on a pallet basis, meaning that the whole pallet will be shipped to the internal warehouse instead of the required amount. This is also applied to mixed pallets, where the entire pallet must be moved even if only parts of it are needed. The current lead time from placing a transfer order to receiving the materials from the external warehouse is around 24 hours, although it can be shorter if necessary. The decision regarding if the materials should be placed internally or externally are currently depending on available space rather than on usage, demand, or importance for production.

4.3.2 Causes

From the interviews, an issue was identified regarding the lack of a clear process for managing discontinued and obsolete materials. According to MRP planner 2, there was previously a process for handling these materials, where the market function formally communicated discontinuation decisions which enabled the articles status in the ERP system to be inactive. Once the status of the article is changed, purchasing would no longer receive signals to order the material, and the warehouse could scrap any remaining physical stock. However, this process has not functioned effectively for several years. The primary reason why this process is no longer used is a disagreement over cost ownership. From the interviews with the MRP planners, it was mentioned that the market function should stand for the costs for the scraping materials due to it being them that initiate the purchase. On the other hand the market function has not accepted this responsibility, resulting in a situation where neither party takes responsibility for initiating the phase-out process. The Chief of warehouse described this situation as being caught in a trap, where materials that could be removed remain in storage because the responsibility for the cost has not been resolved at the corporate level.

Through observations and interviews with warehouse employees it was mentioned that there is no clear structured delivery scheduling system. The suppliers deliver and pick up according to their own schedules, without coordination with the facility, which leads to several trucks arriving at the same time and causing congestion at the warehouse. In some cases the same supplier makes multiple deliveries on the same day, even though the shipments could have been combined into a single delivery. This further contributes to unnecessary congestion at the warehouse and the loading docks. From analyzing the inventory transaction data over a twelve month period showed that most deliveries are on Thursdays and stand for approximately 30% of all inbound deliveries. Since this pattern is consistent throughout the whole period, it can be considered a structural feature of the current schedule rather than an isolated occurrence.

Highlighting another issue related to how the inbound goods are handled upon arrival. MRP planner 1 noted that there are some cases where the ERP system shows that an article has not been delivered and the supplier confirms that the delivery has taken place. This is due to delays in registration as the warehouse employees may

not have sufficient time to register it during the day shift and the night shift does not receive the necessary information. This often leads to a new purchase order being made when the warehouse employees can't find the articles, although the articles are often found later on, resulting in excess stock. Consequently, materials are physically present in the facility but not visible in the planning system. Furthermore, the decision regarding whether a material should be stored internally or at the external warehouse is primarily based on available space rather than a defined criteria. As a result of this, the internal warehouse has currently tried to be redesigned to place slow moving items in a certain location. Whereas the external warehouse is primarily used for overflow rather than as a planned second storage location. According to the Chief of Warehouse a previous internal proposal was made to have a dedicated external warehouse with its own staff but it was not approved at the corporate level. As a result, the current approach remains reactive with no structured system in place to manage the allocations between the internal and external warehouse.

Lastly, the facility has become an unintended distribution hub for materials supplied to other facilities. According to the Chief of Warehouse, this role was not formally planned but has developed over time as the facility holds the largest and most diverse inventory. Acting as distribution hub leads to additional handling for the warehouse employees, increased use of warehouse space, while also contributing to congestion at the loading docks.

4.3.3 Effects

As mentioned previously, The internal warehouse was designed to hold approximately 800 pallet positions. Of these, 473 are allocated to label materials and 164 are the preferred allocation for cans and lids, meaning these two material categories alone account for 637 positions, or 80 % of the designed capacity. As confirmed by the Chief of Warehouse, 126 of the 473 label positions are informally designated as a slow-mover area for low-frequency materials, and 58 positions are currently occupied by obsolete stock valued at 2.71 million SEK with no functioning removal pathway, leaving only 415 label positions effectively available for active materials. The rapid expansion of the nicotine portfolio has further intensified this pressure. As documented in Section 4.2, the nicotine segment now comprises 461 active item numbers across multiple markets, each requiring its own set of market-specific labels. This proliferation forces the warehouse to hold far more label varieties than the designed capacity was intended to accommodate, consuming space beyond what the production volumes alone would justify. The excess is managed by storing pallets on the floor in front of the racking systems and in the aisles. Data collected from the ERP system showed that the facility handles approximately 50 to 60 transport movements per day including inbound and outbound deliveries and internal transfers. During observations at the facility, several forklifts were operating at the same time in a small dock area, handling both incoming and outgoing goods, which created safety risks and slowed down the work due to waiting. Figure 4.4 illustrates the pallet allocation across the designed capacity, label positions, and can and lid positions.

4. Empirical Findings

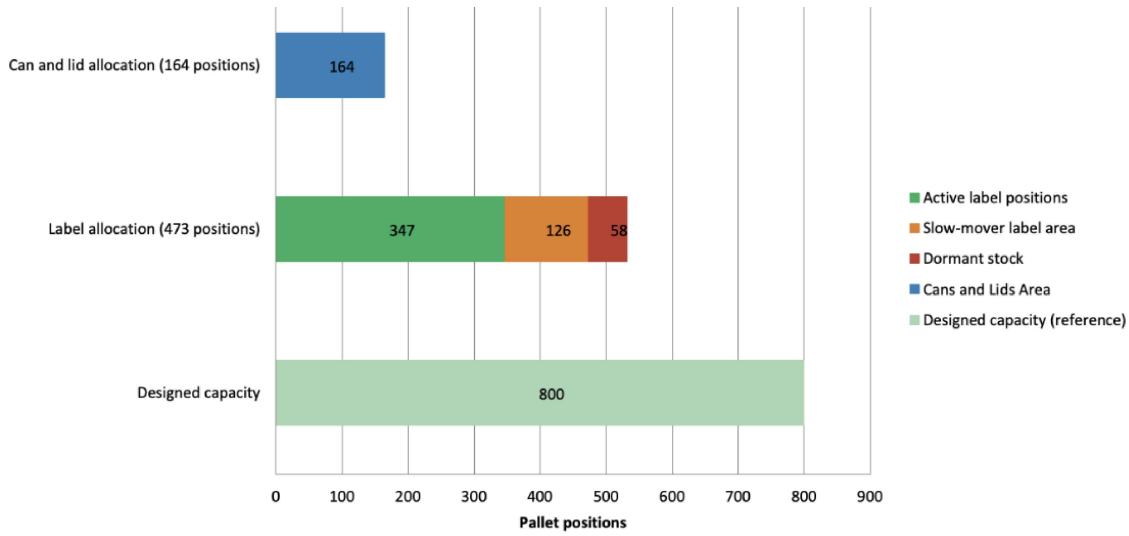


Figure 4.4: Illustration of the overcapacity in the internal facility

Due to the current capacity constraints, the FIFO principle is not operationally feasible. Incoming deliveries are placed wherever space is available, often blocking access to older stock. Resulting in older materials often becomes hard to retrieve without additional handling, increasing risk of expiry or obsolescence. From interviewing the warehouse employees, it was mentioned that some items stored in the upper rack positions had not been moved for extended periods. To estimate how much space the inactive label inventory occupies from figure 4.3, a standard EU pallet was used with the dimensions of 800 mm x 1200 mm x 144 mm. The average storage height per pallet position in the warehouse was estimated at 48 cm above the pallet. Each pallet holds approximately 240,000 labels (average value, as quantities vary by label type) The number of pallets required is calculated as:

$$\text{Number of pallets} = \frac{13\,901\,817}{240\,000}$$

Based on the total inventory shown in figure 4.3, this results in 58 pallets for inactive labels.

From looking at the inventory transactions on every transport that has been made from and to the facility to the external warehouse from 17/3/2026 and back to 4/6/2025, this is when the external warehouse was first used. It showed that there have been 14 trips from the internal facility to the external warehouse, and 54 trips from the external warehouse to the internal facility, as seen in figure 4.5. The data for this is based on that every item that has the same reference number was on the same truck so it equals one trip. This imbalance with nearly three times as many inbound as outbound movements reflects the reactive nature of the current external storage operation, where materials are called in from external storage as immediate production needs arise rather than being managed through a planned

replenishment cycle. The pallet in pallet out constraint of the external warehouse means that each inbound trip frequently brings more material than is immediately required, contributing to further accumulation in the internal warehouse. The MRP planners also purchase materials that are shipped directly to the external warehouse because of the high safety stock requirements at the moment.

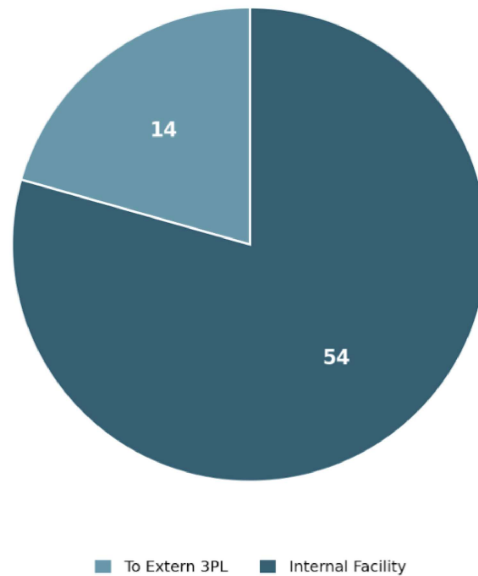


Figure 4.5: Amount of trips to and from the internal facility and External warehouse

4.4 Production function

4.4.1 Current state

The facility currently has several production lines for both snus and for nicotine products. Nicotine products has at the moment two production lines, and snus has two lines dedicated for production of loose snus and the others for pouches. Production planning for both segment types is handled by planning teams located outside the facility that create and manage the production schedule in the ERP system based on demand from the market and planning functions. The production plan is intended to follow a frozen period of two weeks, where confirmed production orders are expected to remain stable and unchanged. This frozen period allows purchasing, warehouse, and production to communicate and coordinate their activities. Where purchasing places orders, the warehouse prepares storage and materials, and production plans its resources. When a production order is released within this period, the warehouse employees receive picking information and prepare the required materials to the production line a day in advance of the production.

4.4.2 Causes

The central issue identified through the interview with Deploy Lead is the instability of the frozen production plan in practice of the nicotine products. Analysis of production data showed that the frozen plan changes an average of 28.08 times per week across the nicotine production, as illustrated in table 4.1. This table represents the average number of modifications made to confirmed production orders within the two-week frozen horizon. When compared to 110 planned production batches per week, this corresponds to a planning instability ratio of 32,94%, indicating a high level of deviation within what is intended to be a frozen period. The Capacity Planner confirmed during the interview that planning instability is a known issue and that efforts to improve planning discipline are ongoing.

KPI	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	Avg	Instability ratio
STP Changes Supply Planning (0+1)	6	29	32	24	44	25	39	31	21	27	35	24	28.08	32.94%

Table 4.1: Average number of production plan changes per week within the two-week frozen horizon of the nicotine portfolio

A further issue is the absence of a formal process for governing changes within the frozen period, including what types of changes are permitted, who must authorize them, and how their downstream impact on purchasing commitments and warehouse operations is assessed. According to the Chief of Warehouse, planning decisions are made by teams outside the facility who are not fully aware of the operational consequences that changes create for purchasing and warehouse operations. Changes that appear justified from a scheduling perspective may therefore generate significant operational disruptions without the planning teams being aware of the consequences.

Given that label lead times are approximately four weeks and formula material lead times range from six to twelve weeks, purchasing must commit to orders well before the production plan enters the frozen horizon. When the plan changes after these commitments have been placed, a mismatch arises between ordered materials and revised production requirements, generating excess inventory or material shortages depending on the direction of the change.

4.4.3 Effects

The instability of the production plan directly affects daily warehouse operations. As described in Section 4.4.2, warehouse employees pick materials one day prior to production. When the production plan changes, employees must return materials to storage or adjust picked quantities. Given the frequency of changes, materials are not always returned to their correct storage locations, creating further confusion about stock positions. Items may subsequently appear missing in the system, triggering new purchase orders even when the materials are physically present in the warehouse.

Across the twelve-month observation period from February 2025 to February 2026, the 5,706 production batches recorded in the dataset represent 564 unique item num-

bers: 103 belonging to the snus portfolio and 461 to the nicotine pouch portfolio. Figure 4.6 presents the distribution of these item numbers by production frequency and total production volume over the observation period. Each point in the figure represents one item number, with snus items and nicotine items shown in separate colours. The figure reveals a structural divide between the two portfolios: snus item numbers cluster toward the upper right of the chart, indicating high production frequency and high volume, while nicotine item numbers are concentrated toward the lower left, indicating low and irregular production with substantially smaller batch volumes. A large proportion of nicotine item numbers appear at the very bottom of the frequency axis, reflecting the pattern of one or two production events per year that characterizes the market-launch driven nature of the portfolio. This distributional pattern provides the empirical foundation for the portfolio classification conducted in Chapter 5.

An analysis of production data over the twelve-month period from February 2025 to February 2026 provides context for the scale of production affected by this instability. As shown in Figure 4.6, a total of 5,706 production batches were executed during this period, averaging approximately 110 batches per week. Of these, 3,294 batches were snus, averaging approximately 63 per week, and 2,412 batches were nicotine pouches, averaging approximately 46 per week. With an average of 28,08 plan changes per week, approximately 32,94% of all planned production batches are affected by changes within the frozen period, roughly one in every four production events.

The contrast between the two product lines also highlights the complexity of the planning environment. The average batch size for snus is approximately 38,796 units, while for nicotine items the average batch size is approximately 16,047 units. Despite this size difference, snus represents 58% of total production batches and nicotine 42%. The nicotine segment involves 461 active item numbers compared to 103 for snus, creating a substantially more complex planning and material management environment relative to its production volume.

As shown in figure 4.7 and 4.8, the production frequency distribution across the 564 active item numbers illustrates the extent of the long tail of infrequent production that characterizes the nicotine portfolio. A substantial proportion of item numbers were produced only once or twice during the twelve-month observation period, reflecting the market launch driven nature of nicotine variant spread and the limited repeat production that follows initial market entry.

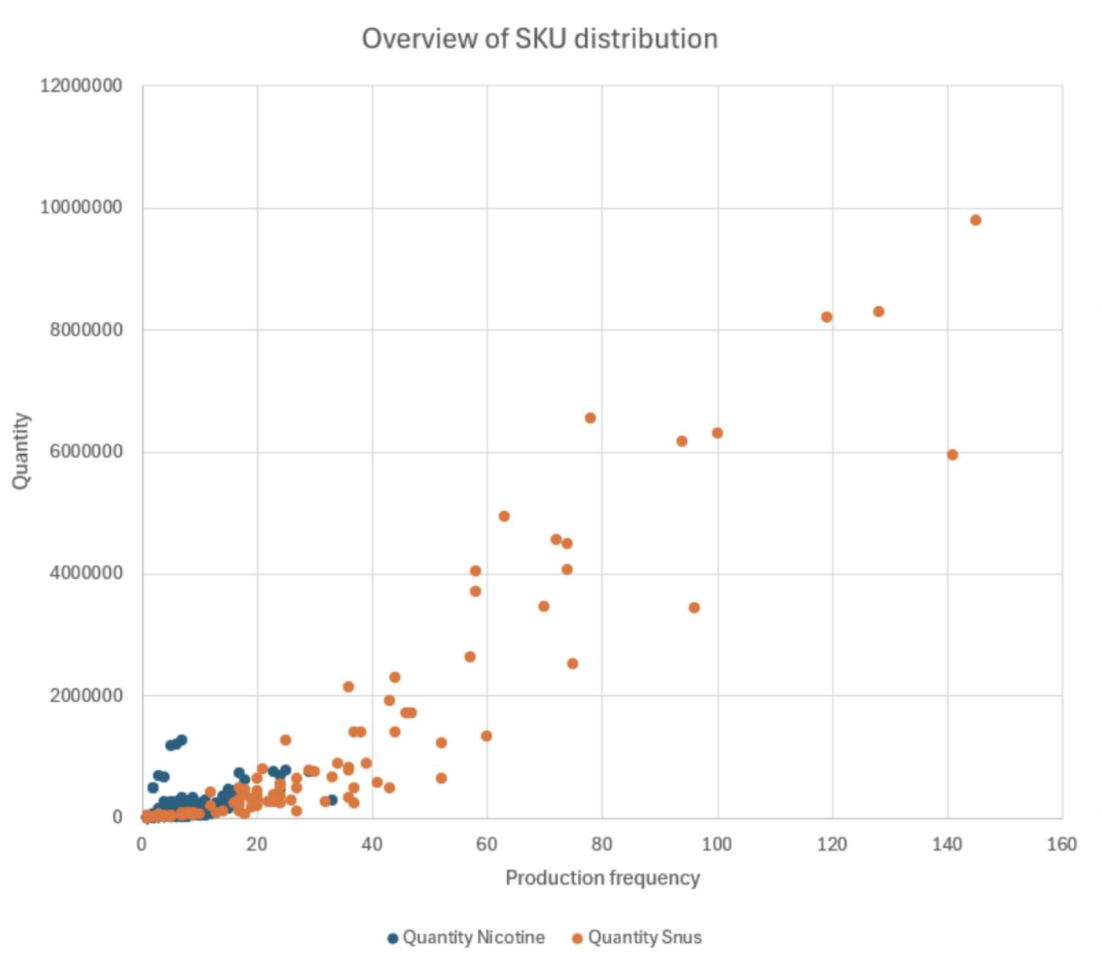


Figure 4.6: Distribution of all 564 active item numbers by production frequency and total production volume over the twelve-month observation period from February 2025 to January 2026.

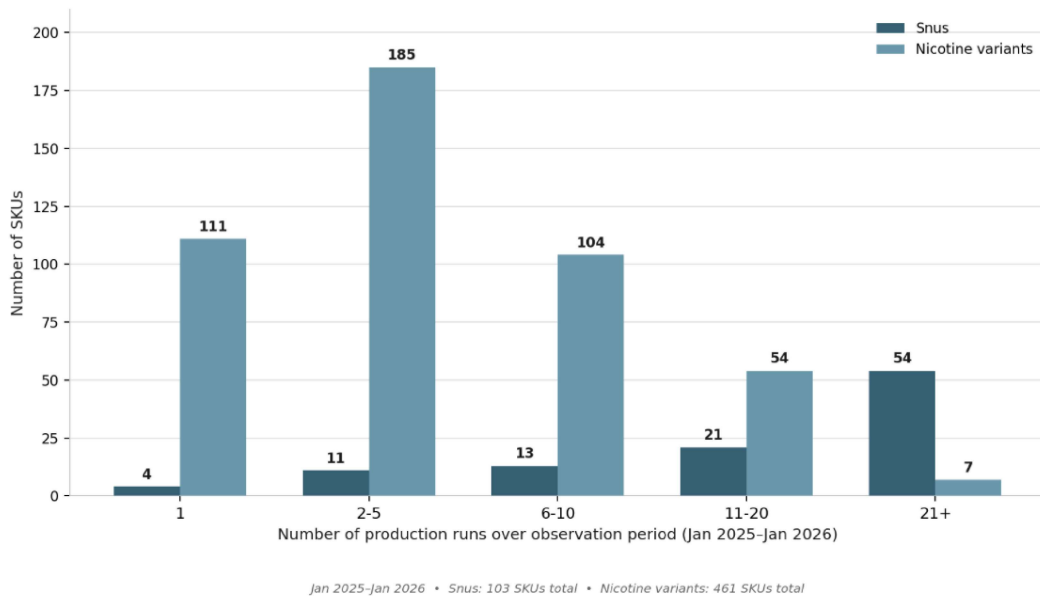


Figure 4.7: Number of production runs from January 2025 to January 2026

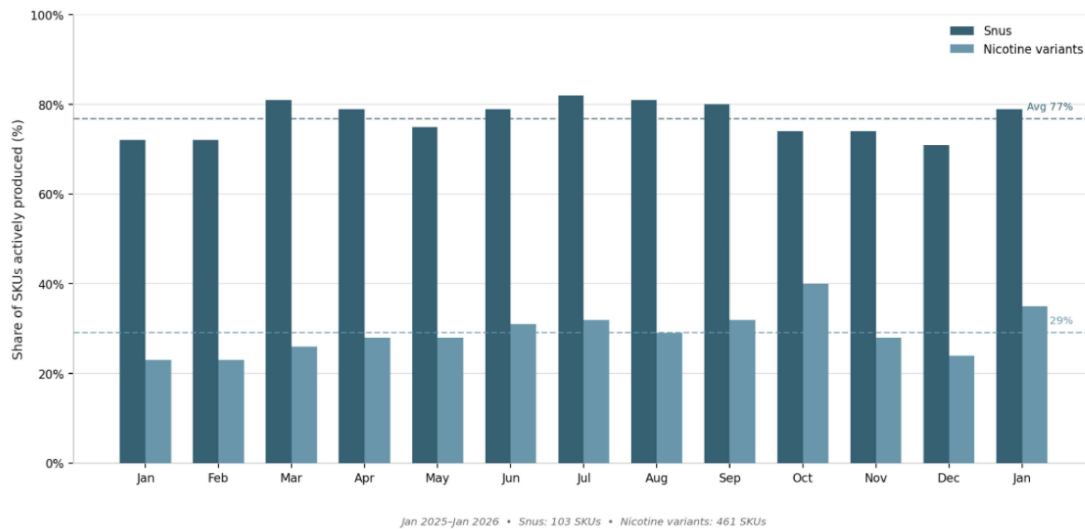


Figure 4.8: Distribution of item numbers by production frequency over the twelve-month observation period from January 2025 to January 2026

4.5 Summary table

Table 4.2 summarizes the empirical findings from Sections 4.2 to 4.5. The table and the findings from this chapter is intended to serve as a reference for the root cause analysis in Chapter 5.

4. Empirical Findings

Function	Current State	Cause	Effects
Marketing & Planning	Demand passes through three planning systems before reaching MRP	Number lose accuracy at each step; MRP is left out of new launches and the forecasts arrive too late and are often too optimistic	One case showed 250k labels planned when 1.6M were actually needed. Around 30% of real demand is not seen
MRP	Planners manage material categories using fixed plans and ERP signals	Company wide rule requires 6 months of safety stock for nicotine. Old materials are not closed so the system keeps ordering them	13.9M label units with 2.75M SEK has not been used for 6 months with no clear way to remove them
Warehouse function	Internal warehouse designed for 800 pallets; external site used as overflow	No one takes responsibility for the cost of scrapping old materials. Incoming materials are stored on the floor, FIFO can't be used	Around 58 pallet positions are blocked by unused stock.
Production function	A two week frozen plan is meant to keep orders stable so purchasing and warehousing can prepare	In practice the nicotine plan changes an average of 28 times per week. There is no rules for who can make changes or how	The nicotine segment has 461 active item # vs. 103 snus, but produces smaller and less predictable batches, making it harder to plan and manage materials

Table 4.2: Summary of findings

5

Analysis

This chapter presents the root cause analysis and answers RQ1 by identifying the underlying causes of inventory accumulation, obsolescence, and warehouse congestion at the facility. And also how RQ1 sets the foundation for the analysis of RQ2.

5.1 Root cause analysis

From the empirical findings presented in Chapter 4, it clearly showed that the identified issues are closely connected across the four functional areas. When considering the problems individually, each problem reflects a specific issue, such as poor information flow in planning, phase-out process, undifferentiated safety stock policy, or instability in the production plan. Taken together, these issues point to a broader systemic problem, where the facility receives far more incoming materials than its space and processes can handle. This chapter uses structured root cause analysis to understand why this is happening and to formally answer RQ1.

Failures are rarely the result of a single factor, but rather a chain of underlying causes. RCA provides a structured approach to identifying and understanding why failures occur and evolve over time. As outlined by Doggett (2005), the RCA is focusing on looking beyond the surface level by working backward to find the conditions or decisions that caused them. Doggett (2005) also describes several tools that support this process, each helping to view the causes from a different angle. In this analysis three tools were applied, where the first tool used was a cause-and-effect diagram often referred to as the fishbone or Ishikawa diagram. This diagram provides a visual overview of all identified causes grouped into different categories (Ishikawa, 1986). The fishbone diagram works as a way to organize the analysis, ensuring that all major categories of causes are included and offering a clear overview before going into more detail. The diagram is a useful tool in a supply chain context according to Ilie & Ciocoiu (2010), as it helps uncover connections between different functions that may not be visible when analyzed separately.

The second tool that was used is the Five whys method, where the question “why” is asked repeatedly to find the root cause of a problem (Doggett, 2005). This method was applied to three different chains of causes, each showing a different

path leading to inventory build-up and warehouse congestion. The third tool is an interrelationship diagram, which illustrates how identified causes influence one another rather than linking causes to a single effect. By looking at how many links each factor has, the interrelationship diagram shows which causes have a strong influence on others and which are mainly influenced themselves. The chapter ends by answering RQ1, combining the results from all three tools to explain the root causes and their impact.

5.1.1 Fishbone diagram

Figure 5.1 presents the fishbone diagram for the observed issues of inventory accumulation, obsolescence, and warehouse congestion at the facility. In line with Doggett (2005), the identified causes are organized into categorical grouping, each representing a specific area of organizational activity. From the empirical findings six such groups were identified and further elaborated as seen in figure 5.1.

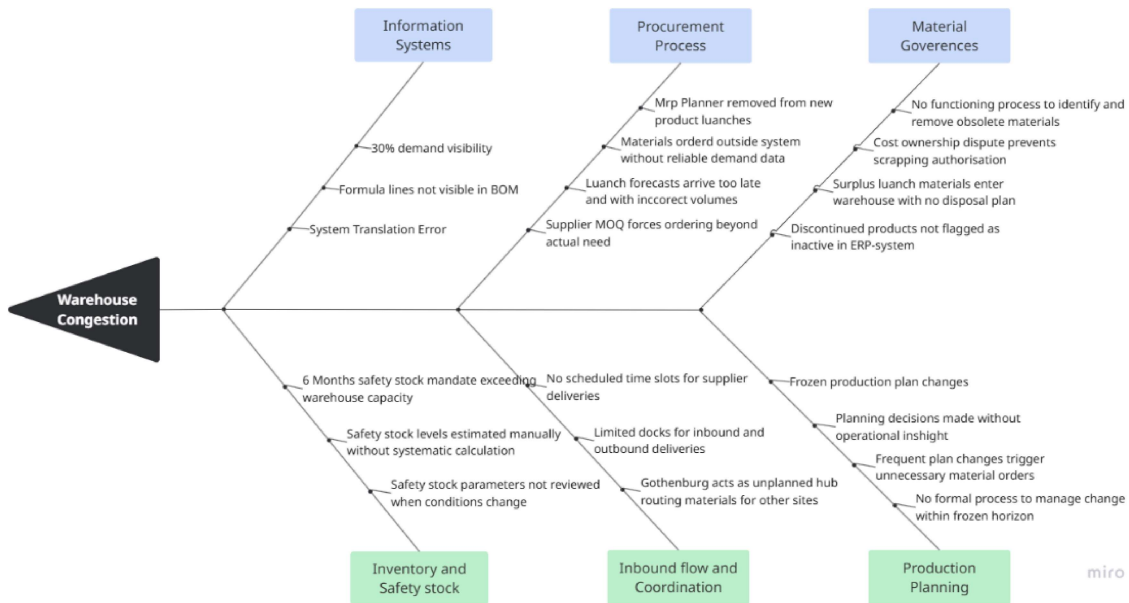


Figure 5.1: Fishbone diagram for inventory accumulation, obsolescence, and warehouse congestion at the facility

Information systems: The main structural driver within this category relates to the decline in demand signal accuracy as it moves through the three different planning systems, along with the limited visibility of specific materials that is not seen in the BOM. As identified in Chapter 4, translation errors occur at each system interface, resulting in significant deviations between planned and actual requirements. As mentioned previously when the system indicated a requirement of 250 000 units compared to the actual market demand of 1.6 million units. This reflects a clear case of information asymmetry, where different parts of the organization operate based on incomplete or distorted information, which reduces the decision quality. Fur-

thermore, it also highlights limited supply chain visibility when critical demand and material requirements are not fully accessible or usable within the system (Baratt & Oke, 2007).

The lack of accurate and complete data contributes to instability in the MRP system, as planning outputs are directly dependent on the quality of input data. As described by Jonsson & Mattsson (2009), MRP systems are highly sensitive to changes in demand data, meaning that inaccuracies can result in frequent rescheduling and unstable planning outcomes. This indicates that the observed instability is not caused by the system itself, but by the quality of the information it relies on. These inaccuracies in demand information also reflect the bullwhip effect described by Lee et al., (1997), where even minor errors in demand increase as information moves through the supply chain.

Procurement and ordering: Under this category the main causes originate from that the MRP team are no longer included in new product launches. As a result, material requirements are being communicated outside formal channels, this limits the ability to place orders within appropriate lead times and the correct quantities. Resulting in that the MRP team is often required to make decisions based on incomplete or delayed information. This means that the team cannot rely on confirmed production requirements, and orders are instead based on forecasts, which further highlights the lack of coordination and communication between the different functions. As Christopher (2011) argued that effective supply chain performance depends on timely and accurate information sharing, allowing decisions to be based on actual demand rather than assumptions.

Beyond the issues related to information flow, the MRP team is also constrained by the suppliers minimum order quantities (MOQs), which limit the ability to adjust order volumes to actual needs. This issue is described by Jonsson & Mattsson (2009) as a lot-sizing constraint, where order quantities are determined by external requirements rather than internal demand. This creates a gap between the quantity required and the quantity that must be purchased, particularly in the case of new product launches with low initial volumes. With the high MOQs the MRP team is required to order more than needed in production, resulting in a consistent excess of materials in stock. This excess of materials is driven by both inaccurate demand information and MOQs set by the suppliers, directly contributing to the build-up of inventory and warehouse congestion.

Material lifecycle governance: For this category, the findings showed that the facility lacks a functioning process for managing discontinued and obsolete materials. Although a formal phase-out process exists in the ERP system, the process is not followed in practice. Resulting in that materials that are no longer in use remain in an active status and occupy space in the warehouse. The market function is responsible for identifying and communicating discontinued materials, but this is not done after the organizational transition in 2024. This means that the materials will remain in an active status in the ERP system, and the purchasing and

planning function will continue to treat this as usable inventory. At the same time, responsibility for scrapping costs is unclear between functions, creating reluctance to formally remove materials from stock.

The findings made in Chapter 4 also indicate that previous cases where scrapped materials later become needed in production have created hesitation toward future scrapping decisions. The risk of removing materials too early is seen as more serious than the long term cost of keeping them in inventory. This reflects the visibility and governance problems discussed by DeHoratius & Raman (2008), who argue that inaccurate inventory records and weak inventory control processes can lead to both excess stock and operational inefficiencies. Christopher (2011) similarly highlights that insufficient coordination and poor information sharing across the supply chain increase the risk of unnecessary inventory accumulation. The result of this is that the inactive materials will continue occupying pallet positions within both the internal and external warehouse, reducing available storage capacity for active production materials and directly contributing to warehouse congestion.

Inventory and safety stock policy: When looking within this category the issue originates from a misalignment between the corporate safety stock policy and the actual demand characteristics of the product portfolio. At the moment the corporate policy is to have six months of safety stock for all materials in the nicotine segment, without considering local capacity constraints or the variability within the portfolio. This policy creates a fundamental mismatch between policy and demand behavior. A large share of the nicotine portfolio is characterized by highly irregular and unpredictable demand patterns, where traditional safety stock logic is less applicable.

According to inventory management theory, safety stock levels should be determined based on demand variability and lead time uncertainty in order to balance service levels and inventory costs (Jonsson & Mattsson, 2009). By applying a fixed time safety stock across all materials, regardless of their demand characteristics will lead to excessive inventory levels rather than improved service performance. However, for the snus materials, safety stock is not being calculated systematically but is based on employee experiences. This indicates a lack of statistical grounding, as effective safety stock calculations require quantitative inputs such as demand variability and lead times (Silver et al., 2017). Without such data-driven approaches, safety stock levels risk being either too high or too low, reducing overall planning accuracy.

At the moment the safety stocks are not regularly reviewed or adjusted, which creates a problem due to the demand patterns and portfolios evolve over time. The corporate directives stay unchanged, and the manual parameters will be unchanged for a long time before acting on it. This reinforces the misalignment over time, as inventory policies do not adapt to actual operating conditions. As Jonsson & Mattsson (2009) describes, inventory control requires continuous monitoring and adjustment of parameters to reflect the actual demand of the products, and by not doing this there is a risk of safety stock being outdated which is the case for

Company X's facility.

Inbound flow & delivery coordination: Operational inefficiencies in the handling of inbound material flows form the main causes within this category. There is no structured delivery scheduling system, resulting in that suppliers deliver according to their own timetables rather than aligned with the facility's capacity. What has been seen is that the inbound deliveries tend to be at the same time, creating uneven workload distribution at goods reception.

As Christopher (2011) argues, supply uncertainty and operational disruption can be reduced by structuring inbound flows so that deliveries are reliable and coordinated with the facility's capacity rather than driven by supplier schedules. This is not the case at the facility. Empirical observations showed that the majority of inbound deliveries are concentrated on specific days, indicating systematic scheduling behaviour driven by suppliers rather than by the facility's capacity. With limited dock capacity and personnel this creates congestion and reduced operational efficiency.

A further issue that contributes to this is the registration of inbound goods. As described in chapter 4, some of the materials are physically received but are not registered in the system, which creates a mismatch between the physical inventory and system data. This issue can be linked to inventory record inaccuracy, this increases the risk of incorrect planning decisions, including duplicate or unnecessary orders (DeHoratius & Raman, 2008). In addition, the facility operates beyond its intended scope by functioning as a distribution point for other locations. This introduces additional handling activities and increases pressure on already constrained dock capacity. The situation is further exacerbated by the full-pallet transfer requirement from the external warehouse, where entire pallets must be moved regardless of actual demand. This reflects a lack of flexibility in material handling processes and can be related to lot-sizing constraints, where operational rules lead to the transfer of quantities that exceed immediate needs (Jonsson & Mattsson, 2009).

Production planning and change governance: The findings from this category are linked to the instability of the production plan and the absence of a structured governance framework for managing changes within the frozen planning horizon. The frequent modifications in the production plan indicates that intended stability of the frozen plan is not maintained in practice, reducing its effectiveness as a planning control method. The purpose of having a frozen planning horizon is to create stability in production schedules, allowing upstream functions such as purchasing to operate with predictable demand signals (Jonsson & Mattsson, 2009). When changes occur in this period both the reliability and coordination across the supply chain is reduced.

In this case, changes in the production plan are made without properly considering their downstream impact. As a result, purchasing decisions are based on a plan that is often revised. The key materials often have long lead times, so orders must be placed well before the frozen horizon begins. When the production plan is sub-

sequently changed, whether in time or quantities, a mismatch arises between the materials already ordered and what is actually needed for production. As highlighted by Jonsson & Mattsson (2009), frequent adjustments to planning inputs create instability in the production plan, especially in environments with long lead times. Without a structured process to manage these changes the issues will continue over time. As demonstrated by Sridharan & Berry (1990), a frozen horizon without formal change governance is functionally equivalent to no freeze at all. This leads to materials being procured based on outdated requirements, arriving at the warehouse without a confirmed consumption plan and adding to inventory accumulation and increased operational complexity.

5.1.2 5 Whys Analysis

The fishbone diagram provides an overview of the contributing causes but does not differentiate between root causes and resulting outcomes. While these diagrams are useful for structuring causes it does not indicate their importance or depth (Ishikawa, 1986). To go further in depth the five whys method is applied to identify the underlying root causes of each problem. The five whys is a method to further explore the cause-and-effect relationships by asking the question why over and over (Serrat, 2017). This method helps to go beyond the surface level symptoms and to identify underlying causes. Liker & Hoseus (2008) describes this method to focus on the real causes of the problems instead of individual actions. In this case, the method has been applied to a set of key operational problems identified in Chapter 4. Each problem has been analyzed by repeatedly asking the question why until a structural root cause is uncovered.

The fishbone diagram identified causes across six functional categories, providing a broad overview of the contributing factors. However, not all identified causes operate at the same level of depth, some represent operational symptoms while others reflect more fundamental structural failures. To differentiate between them, the Five Whys method is applied to four selected cause chains and are selected based on three criterias, see Appendix B for all four chains. First, each chain is grounded in empirical findings from Chapter 4, supported by quantitative data, interview evidence, or a combination of both. Second, each chain has a direct and traceable connection to the observed outcomes of inventory accumulation, obsolescence, and warehouse congestion rather than being an indirect or secondary contributor. Third, each chain corresponds to a distinct functional area, ensuring that the analysis covers the width of the problem rather than concentrating on one part of the organization. The four chains examine why inactive inventory accumulates, why purchasing systematically over-orders, why the frozen production plan is not frozen in practice, and why the safety stock policy is misaligned with portfolio demand characteristics. The Five Whys analysis shows that the identified operational problems are connected to broader structural issues rather than isolated operational mistakes. Many of the root causes are linked to governance gaps, weak planning coordination, and the lack of differentiated inventory control principles following the organizational transition.

5.1.3 Interrelationship Diagram

While the fishbone diagram organizes causes around a single effect and the five whys trace individual cause chains, the interrelationship diagram focuses on how these causes are connected to each other. Doggett (2005) notes that different RCA tools serve different analytical objectives and that revealing interdependencies among causes requires a tool specifically designed for that purpose. By mapping directional links between causes, the interrelationship diagram identifies which factors drive others and which are mainly influenced, making it possible to separate key drivers from resulting effects. This difference is not visible in either the fishbone diagram or the five whys and is essential for prioritizing which root causes to address.

As shown in Figure 5.2, warehouse congestion, inventory accumulation, and operational disruption appear as downstream effects characterized mainly by incoming connections. These represent outcomes rather than root causes, meaning that addressing them individually would not resolve the underlying problem. The relationships between the drivers show how the problem is sustained over time. Reduced demand visibility contributes to planning instability, while frequent plan changes further weaken the reliability of purchasing inputs. At the same time, accumulated inactive materials remain in the system because there is no functioning removal process, reinforcing inventory build-up. These connections mean that the four root causes do not operate independently but form a pattern in which each increases the conditions that sustain the others. Doggett (2005) notes that this type of interdependency is precisely what the interrelationship diagram is designed to reveal, and why it is necessary alongside the fishbone and five whys rather than as a replacement for them.



Figure 5.2: Interrelationship diagram showing the identified root causes and their effects on warehouse congestion at Company X.

The diagram also indicates that certain factors influencing the system lie outside the scope of direct intervention, particularly the organizational transition and the expansion of the nicotine portfolio. These act as external conditions that have intensified the root causes but cannot be addressed through operational changes at the facility level.

5.2 Answer to RQ1

Based on the three tools applied in this chapter, the first research question can be answered.

RQ1: What are the root causes and effects of inventory accumulation, obsolescence, and warehouse congestion at the Company X facility?

In the analysis, four root causes were identified, all of which are linked to the same underlying condition. As seen in Figure 5.2, all root causes are connected to the June 2024 organizational transition. This transition introduced new structures but did not fully replace the informal ways of working that previously supported key operations at the facility. The root causes should therefore not be viewed as separate issues but rather as connected outcomes of the same organizational change. The transition disrupted several key processes at the same time without clearly replacing them. The fact that all four root causes are connected to the same organizational change has two important outcomes. As it explains why the operational problems have gradually worsened since the organizational transition, it also clarifies to which problems can be addressed at the facility level.

With the four main root causes identified from the Five Whys, analysis showed that the inventory accumulation and warehouse congestion at the facility are not caused by individual issues but by several structural problems. With the incomplete demand information it will lead to continuing over purchasing meaning more materials will arrive than what the production needs. The weak and not used lifecycle governance, results in that materials will still be in inventory and not have any purpose of use in the future. Also, the unstable production plan causes materials to arrive and then the production plan changes or cancels. Lastly, the directive of having a certain amount of safety stock regardless of their demand frequency. Furthermore, all these issues reinforce each other and contribute to increasing warehouse congestion and inventory accumulation at the facility.

5.3 From root causes to warehousing strategy

This section presents a differentiated two-echelon warehousing strategy for Company X. The strategy is developed based on the root causes identified in the previous sections and consists of storage allocation criteria and replenishment rules for managing materials between the internal and external warehouse. The word guide is important because the root causes do not describe a specific warehousing solution. Instead,

they identify the conditions that the strategy must address. A root cause showing that purchasing cannot access accurate demand information does not automatically point to a specific warehousing solution. Instead, it shows that replenishment decisions based on demand forecasts are unlikely to work at Company X. The design decisions presented in this chapter are therefore a direct response to the problems identified in the analysis. This is what guide means throughout the chapter: each design decision is based on a specific empirical finding and developed to address the identified problem.

The later section is divided into two parts, where the first is a set of storage allocation criteria that determine whether a material is held at the internal warehouse or at the external warehouse. The second is a set of replenishment rules that decide how and when materials move between the two locations. Both parts are presented separately for label materials and for cans and lids since these two material categories have different structures that make a single approach impossible. Labels are SKU-specific where each of the 461 nicotine variant item numbers requires its own unique set of labels that cannot be substituted across variants. Cans and lids are shared components, where a single nicotine can type serves all 461 variants. This structural difference means the root causes guide the design differently for each category.

5.4 How the Root Causes Guide the Strategy

Each of the four root causes identified leads to one or more design decisions that guide the warehousing strategy.

Root Cause 3 (undifferentiated safety stock policy) tells us that the same inventory policy is currently applied to materials with very different demand patterns. As a result, demand characteristics must be considered when deciding whether a material should be stored in the internal or external warehouse.

Root Cause 2 (absent lifecycle governance) shows that materials with no recent production activity remain in the internal warehouse for long periods. To address this issue, materials that have not been used for an extended period are moved to external storage, freeing up space for materials that are still needed in production.

Root Causes 1 and 4 (structural information asymmetry and production planning instability) show that forecasts and production plans are not reliable enough to be used as replenishment triggers for externally stored nicotine label materials. Demand information is incomplete and production plans change frequently, making it difficult to know when materials are actually needed. For this reason, replenishment should be triggered by confirmed production orders rather than forecasts or planned production. The analysis also shows that changes within the frozen horizon must be controlled for this approach to work effectively.

5.5 Storage allocation

The root cause analysis identified two factors that determine where materials should be stored. The first is demand class, meaning materials with different demand patterns should not be managed in the same way. Resulting in that the storage decisions need to reflect how often and how predictably materials are used (Teunter et al., 2010). The second is recent production activity, space in the internal warehouse should be used for materials that are still needed in production, while materials that have not been used for the past six months should be stored externally regardless of demand class (Diks et al., 1996). Both factors must fit within the physical limits of the facility. Of the 473 internal label positions, 58 are currently occupied by inactive materials, leaving 415 positions available for active materials. For cans and lids, the preferred allocation is 164 positions.

5.5.1 Portfolio classification

The ABC/XYZ matrix is used here as it provides a systematic basis for creating differentiated warehouse policies by combining volume classification with variability classification. Stévic & Merima (2021) demonstrate this in a real warehouse setting that the matrix translates directly into class-specific storage and replenishment decisions. This study applies the same principle to the Company X portfolio, extending it to a two-echelon context where the classification determines not only the inventory policy for each class but the physical storage location.

All 564 active item numbers are classified in two dimensions, where the volume class is determined by each item's share of total annual production volume, dividing items into A, B and C. The variability class is determined by the coefficient of variation of production frequency, dividing items into X, Y and Z. Syntetos et al., (2005) identify a coefficient of variation above 0.7 as the point at which demand becomes intermittent. This value is used to define the limit between the Y and Z categories in the variability classification.

The classification produces different profiles for snus and nicotine materials where the snus portfolio of 103 items is mainly AX and AY. 47 AX items and 29 AY items account for the vast majority of snus production volume and these are high-volume materials produced consistently and predictably. The nicotine variant portfolio of 461 items is dominated by low-frequency high-variability categories. 2 AX items, 37 AY items, 28 AZ items, 119 BZ items and 262 CZ items, where the 262 CZ items represent 57% of the nicotine portfolio. As mentioned by Teunter et al., (2010), applying the same policy across items with such different demand patterns is far from cost-optimal, which confirms that the classification must drive differentiated decisions.

5.5.2 From demand class to storage location

After deciding which demand class an item belongs to, the next step is to determine where each item should be stored. To do this two frameworks will be used, where the first one is the two-echelon model of Diks et al. (1996), where it is shown that the forward position in a two-echelon system should only hold stock that will be consumed before the next replenishment. When looking at the context of Company X, the internal warehouse represents this forward position. Meaning that the internal warehouse should hold materials that are used frequently enough for the inventory to be consumed before excess stock builds up. The second framework is the demand categorization approach mentioned by Syntetos et al., (2005). The framework highlights that materials with highly irregular demand, a standing buffer is not suitable. This is due to the fact that traditional safety stock calculations do not accurately capture the variability and therefore should these materials have a make-to-order replenishment. Applied to Company X, this means that BZ and CZ items should not hold a standing buffer at any level.

Combining these two frameworks with the portfolio classification results in the storage allocation decisions presented below and summarized in Table 5.1. AX and AY items belong in the internal warehouse with a calculated safety stock since their demand is frequent and stable enough for inventory to be consumed before excess stock accumulates. Holding these materials internally is consistent with the principle proposed by Diks et al. (1996). BZ and CZ items, however, belong in the external warehouse with no standing buffer. Their demand patterns are too irregular for a standing buffer to be effective, and materials should therefore only be transferred to the internal warehouse when a confirmed production order is released (Syntetos et al., 2005). For AZ and BY items it is different due to the fact that they fall in between these two groups. It is because their demand is frequent enough that some inventory can be held internally, but variable enough that having all inventory internally would create excess stock. For this reason, a small buffer is kept in the internal warehouse, while the majority of the inventory is stored externally and transferred when needed.

ABC/XYZ class	Material	Storage location	Replenishment trigger	Safety stock
AX / AY	Snus labels	Internal: fixed positions	Reorder point (ROP = $SS + D \times L$)	Calculated: 1 to 3 weeks
AX / AY	Nicotine labels	Internal: flexible positions	Reorder point (ROP = $SS + D \times L$)	Calculated: 2 to 3 weeks
AZ / BY	Nicotine labels	Split echelon: small internal buffer, bulk external	Internal buffer triggers transfer from external	Small internal buffer only
BZ / CZ	Nicotine labels	External only	Confirmed production order within frozen horizon	No standing buffer: make-to-order
Inactive (6 months)	All label materials	External: managed dormant position	Confirmed production order only	No buffer
All types	Snus and Nicotine cans and lids	Internal: all types	Consumption-matched daily delivery agreement	Cycle stock only: 107 positions total

Table 5.1: Storage allocation framework by ABC/XYZ demand class. MTO = make-to-order. ROP = reorder point. Full safety stock policy is presented in Appendix C.

With this proposed allocation, it was checked against the available warehouse capacity which showed that it is feasible. By moving low-frequency BZ and CZ materials to the external warehouse, the 126 positions currently occupied by these materials become available. The remaining 415 positions are sufficient to store the AX, AY, AZ, and BY materials internally. In addition, applying the recency criteria allows the 58 positions currently occupied by inactive stock to be recovered. This makes all 473 label positions available for active materials and their required safety stocks, creating additional warehouse capacity that is not available under the current inventory policy.

5.5.3 Normality condition: confirming the allocation

The storage allocation decisions presented in Section 5.5.2 assume that a standing buffer is appropriate for AX and AY materials but not for BZ and CZ materials. To verify this assumption, the normality condition proposed by Jonsson & Mattsson (2009) and Silver et al., (2017) was used. According to the authors, the normality condition states that the mean demand during lead time must exceed twice the standard deviation of demand during lead time for a safety stock calculation to be reliable. When this condition is not met, safety stock is unlikely to be effective, making make-to-order replenishment a more fitting solution.

The condition was applied to four representative items using production frequency

as a demand proxy, since customer demand data is not available at the item level, see detailed calculations in Appendix B. The results confirm that the line between AY and BZ corresponds to the point at which a standing buffer is no longer statistically justified. Based on these findings, the recommended safety stock policies for each storage category are presented in Table 5.2.

Category	Storage	SS approach	Trigger	Justified SS	Current
Snus AX	Internal fixed	Calculated formula valid	Continuous review ROP	1 week	6 weeks
Snus AY	Internal flexible	Calculated formula valid	Fixed cycle biweekly	1 to 3 weeks	6 weeks
Nicotine AY	Internal flexible	Calculated: higher CoV	Biweekly vs Master Plan	2 to 3 weeks	26 weeks
Nicotine AZ / BY	Split echelon	Small internal buffer	Order release triggers transfer	1 to 2 wks internal	26 weeks
Nicotine BZ	External only	No buffer: MTO	Confirmed production order	0	26 weeks
Nicotine CZ	External: dormant zone	No buffer: MTO plus inactivity flag	Confirmed order; flag if inactive 6 months	0	26 weeks

Table 5.2: Proposed storage locations, replenishment triggers, and safety stock policies by demand category.

5.5.4 Recency of production activity

A second factor used to determine storage location is recent production activity. This means that materials that have not been used in production for over six months are moved to the external warehouse regardless of their ABC/XYZ class. By applying this rule to the current portfolio has a direct impact on warehouse space. As shown in Section 4.3, inactive materials currently occupy 58 pallet positions in the internal warehouse. So when moving these materials to the external warehouse it frees these pallets up for those materials that are still actively used in production. It will increase the available capacity from 415 to 473 positions. This rule complements the demand-class allocation described previously. The demand-class allocation frees 126 positions by moving BZ and CZ materials to external storage, while the six-month rule frees an additional 58 positions. Together, these changes ensure that internal warehouse space is used for active materials rather than slow-moving or inactive inventory.

5.5.5 Storage allocation for cans and lids

The storage allocation decision for cans and lids differs from the decision for labels. This is because the question for labels is what materials should be stored internally

and what should be stored externally. But for cans and lids the question is how much space each component type requires.

This difference is due to the structure of the materials, labels are specific to individual product variants, while cans and lids are shared across many variants. For example, a single nicotine can type is used across all 461 nicotine variants. As a result, demand is combined across many products, making it more stable than the demand for individual label items. Silver et al., (2017) explain that combining demand across multiple products reduces variability compared with managing individual items separately. This means that safety stock can be used for all can and lid types and that they should be stored in the internal warehouse. Holding these materials internally is also consistent with the two-echelon principle proposed by Diks et al. (1996), which states that the forward position should hold materials that are regularly consumed.

The amount of space required depends on two factors. The first is the average daily consumption of each component type. The second is the delivery frequency from the supplier, which determines how much inventory must be kept between deliveries. As seen in chapter 4, cans and lids are already delivered on most days of the year. Under a consumption-matched daily delivery schedule the required inventory consists of cycle stock and safety stock at a 95% service level. The full calculations are presented in Appendix C. The calculations show that all 18 can and lid component types require a total of 107 pallet positions. This is below the preferred allocation of 164 positions identified by the Chief of Warehouse and leaves 57 positions available as additional space. The analysis identified two implementation paths. Five component types already receive near-daily deliveries and therefore only require formal agreements with suppliers. The remaining component types would require an increase in delivery frequency. As these five component types represent 79 of the 107 pallet positions, most of the expected benefits can be achieved without major operational changes.

5.6 Replenishment Rules

The storage allocation decisions establish where each material is stored. This section will look at how the materials should be replenished based on their category, but also what happens after production is complete. Three distinct rules apply, one for nicotine BZ and CZ label materials held externally, one for AX and AY label materials and snus materials held internally, and one for cans and lids. Each rule is presented with the specific finding that makes it necessary and the operational mechanism that implements it.

5.6.1 Frozen horizon

The replenishment rules that will be presented in this section depends on one condition that is outside the control of the facility. This condition is that confirmed production orders must be available early enough for purchasing to order and receive the required materials before production starts. As mentioned in Section 4.3, label lead times are four weeks. Confirmed production orders must therefore be available at least four weeks before the production date. The current two-week frozen horizon does not provide enough time for this. Jonsson & Mattsson (2009) state that a frozen horizon should cover the lead time of the most critical materials. Sridharan & Berry (1990) also show that a frozen horizon loses much of its value if changes can still be made freely within the period. The frozen horizon should therefore be extended from two weeks to four weeks to match the label lead time. In addition, a formal process should be introduced to control changes within the frozen period, including who can approve changes and what information is needed before a change is accepted. This decision must be made above the facility level and cannot be implemented by Company X alone. It is therefore treated as a prerequisite for the replenishment rules presented in the following sections. All other parts of the proposed replenishment design can be implemented within the facility's existing authority.

5.6.2 Replenishment rule for nicotine BZ and CZ label materials

The analysis showed that forecast-based replenishment is not suitable for externally stored nicotine BZ and CZ label materials. Two findings explain why, first is that purchasing is no longer involved in new product launches at an early stage after the transition. So the material requirements often arrive late and through informal channels rather than through the planning system. Second, up to 30% of actual demand is not visible in the planning system due to translation errors between the three planning systems. According to Syntetos et al., (2005), items with intermittent demand should be replenished based on actual demand events rather than forecasts. When demand information is incomplete, forecast-based replenishment increases the risk of transferring materials too early which creates unnecessary inventory, or too late which creates shortages when production takes place.

Root Cause 4 adds a second problem for nicotine label materials with the production plan changes an average of 28.08 times per week within the two-week frozen horizon, meaning that roughly one in three planned production events is changed. This creates a direct problem for label materials because each nicotine label is specific to one market variant and cannot be used for another. A transfer ordered for one variant cannot be redirected if that production event is later rescheduled or cancelled. The materials simply arrive in the internal warehouse and remain there without a production order to consume them. Sridharan & Berry (1990) show that a frozen horizon without formal control of changes provides little protection against this type of instability, as changes can still be made without considering their impact on purchasing and warehouse operations. Together these findings lead to one replenishment rule. For nicotine BZ and CZ label materials, transfers from the external warehouse are only triggered by a confirmed production order within the frozen planning horizon. A confirmed production order with a committed date provides a clear signal of what is needed and when it is needed, without relying on either a demand forecast or a production plan that may change.

One practical issue also affects how this rule works is that the external warehouse only transfers materials in full pallet quantities, regardless of how much a production order actually requires. For BZ and CZ label materials, this creates a recurring problem. Production order quantities are often only a small fraction of a full pallet. For example, a nicotine CZ item with an average batch size of 5,280 units requires less than 0.03 pallets at a label density of approximately 240,000 labels per pallet. This means that when a full pallet is transferred to the internal warehouse, approximately 234,720 labels remain after production is complete. This situation occurs every time a BZ or CZ material is transferred. If the remaining materials are not returned to the external warehouse, they will gradually accumulate in the internal warehouse and recreate the congestion that the strategy is designed to prevent. A return flow is therefore required.

The transfer and return should therefore be treated as one process rather than two separate activities. The transfer is initiated one working day before the confirmed production date, in line with the 24-hour transfer lead time confirmed by the Chief of Warehouse. Materials are consumed during production and any remaining quantity is returned to the external warehouse within two working days after batch closure. The two-day window gives warehouse staff enough time to close the batch and prepare the return without creating a backlog. Company X should coordinate return transfers with the existing dock schedule to avoid additional congestion, ideally using the same truck movements that deliver the next transfer to collect the remaining materials from the previous production run.

5.6.3 Replenishment rule for AX and AY label materials and snus materials

For AX and AY label materials that are stored internally with calculated safety stock, a reorder point trigger is used. According to Jonsson & Mattsson (2009), the

reorder point is calculated as $ROP = SS + D \times L$, where D is the average weekly demand, SS is the calculated safety stock from Section 5.5.3, and L is the transfer lead time from the external warehouse. It is important to note that L refers to the one day transfer lead time confirmed by the Chief of Warehouse, not the four week supplier lead time used in the safety stock calculations. When the inventory level reaches the reorder point, a transfer from the external warehouse is triggered and the materials arrive the next working day.

The full-pallet transfer rule also applies to these materials, but the effect is much smaller than for BZ and CZ items. AX and AY materials are used frequently, meaning that a full pallet is consumed across several production runs within a short period of time. As a result, large amounts of leftover material do not accumulate in the internal warehouse. For this reason, the reorder point trigger does not require the same return process that is needed for BZ and CZ materials. Snus label materials follow the same reorder point approach. As described previously, snus production is based on a stable production plan, and the planning instability identified in Root Cause 4 applies specifically to nicotine products. Snus AX and AY materials are therefore stored internally with calculated safety stock and replenished using a reorder point trigger rather than a confirmed production order.

5.6.4 Replenishment rule for cans and lids

The replenishment rule for cans and lids is different based on the inbound delivery patterns identified in Chapter 4 rather than the root cause analysis. As shown in Section 5.5.5, all can and lid types are stored internally, and the target allocation is 107 pallet positions compared with the preferred allocation of 164 positions. Reaching this target depends on controlling delivery quantities. The proposed replenishment rule is therefore a delivery scheduling agreement that matches deliveries to production consumption. Christopher (2011) argues that supply uncertainty can be reduced through reliable, frequent, and controlled deliveries. Silver et al., (2017) describe this as scheduled daily replenishment, where cycle stock covers inventory between deliveries and safety stock covers normal variation in demand. The inbound delivery data shows that near-daily deliveries already exist, with deliveries taking place on 253 of 365 days. This means that the main change required is not more frequent deliveries, but better control of delivery quantities. The delivery scheduling agreement should include three elements for each of the 18 component types. First, a maximum delivery quantity that matches daily production consumption. Second, fixed delivery days that fit the facility's dock schedule. Third, delivery time windows that avoid the Thursday delivery peaks identified in Section 4.4.

5.7 Expected Effects of the Proposed Strategy

Based on the issues identified in Chapter 4 and the warehousing strategy developed in Sections 5.5 and 5.6, the proposed strategy is expected to produce several improvements. However, the proposed strategy has not been implemented or tested by Company X. The outcomes presented in this section should therefore be interpreted

as expected effects based on the analysis conducted in this thesis rather than verified operational results. Some improvements are supported by quantitative calculations, such as reduced safety stock levels and increased warehouse capacity, while others are based on the expected consequences of the proposed design. Table 5.3 compares the current situation with the expected outcomes of the proposed strategy.

Metric	Current state	Proposed state	Improvement
Internal label positions occupied by BZ/CZ materials	Up to 262 item numbers in slow-mover area consuming up to 126 positions	Zero: all BZ and CZ materials move to external storage	126 positions freed
Internal label positions occupied by dormant stock	58 positions occupied by 2.71 million SEK inactive inventory	Zero: recency criteria moves inactive materials externally	58 positions recovered
Effective internal label positions available	415 (473 minus 58 dormant)	473: full allocation available for active materials with justified buffers	+58 positions
Safety stock for snus AX materials	Approximately six weeks: 1,130,774 units (Item 1)	Approximately one week: 197,772 units	5.7 times reduction
Safety stock for nicotine AY materials	26 weeks: 393,360 units (Item 2)	Approximately 2.5 weeks: 37,495 units	10.5 times reduction
Safety stock for nicotine BZ and CZ materials	26 weeks of standing buffer regardless of demand pattern	Zero standing buffer: make-to-order on confirmed production order	Full elimination of speculative buffer
Internal can and lid positions under peak delivery	Periodically exceeds 164: peak single-day nicotine lid receipt requires more than 250 positions for one component type	Maximum 107 positions across all 18 component types under controlled deliveries	57-position buffer within preferred 164 allocation
Replenishment trigger for nicotine BZ and CZ	Forecast-based or plan-based: wrong by up to 30 percent by design; generates orders for cancelled events	Confirmed production order: fires only when specific committed date exists	Eliminates speculative ordering for 381 item numbers

Table 5.3: Before and after comparison of the proposed two-echelon warehousing strategy against the current state at the facility

Table 5.3 shows that the proposed strategy is expected to improve warehouse capacity utilization, reduce inventory levels, and align replenishment decisions more closely with actual production requirements. The biggest improvements come from relocating slow-moving and inactive materials to the external warehouse and starting using a production driven replenishment instead of forecast. Furthermore, coordinated deliveries through a scheduling agreement for cans and lids is expected to reduce delivery peaks and improve material handling efficiency. As mentioned

previously, it is important to know that the calculations made here are based on production frequency and not the actual customer demand data. The results should therefore be interpreted as estimates rather than exact values and may change if detailed demand data becomes available.

5.8 Answer to RQ2

The second research question will be answered here.

RQ2: how the identified root causes guide the design of storage allocation criteria and replenishment rules for a differentiated two-echelon warehousing strategy at the Company X facility?

RQ2 builds upon the findings of RQ1. While the answer to RQ1 identified the root causes contributing to inventory accumulation and warehouse congestion, it did not provide a specific warehousing solution. Instead, the identified root causes provided insights into the operational challenges that a future warehousing strategy must address. These insights were used to guide the design of the proposed two-echelon warehousing strategy and the development of its storage allocation criteria and replenishment rules. More specifically, the findings showed that applying the same inventory policy to materials with very different demand patterns contributes to excess inventory, particularly for low-frequency items. This makes demand class the primary criteria for determining whether materials should be stored internally or externally. In addition, the accumulation of inactive inventory highlights the need to consider recent production activity as a secondary allocation criteria, ensuring that internal warehouse capacity is reserved for materials that actively support production.

The replenishment rules were also developed based on the findings from RQ1. It showed that demand information is often incomplete and that the production plan for nicotine products changes frequently, even within the frozen planning horizon. This makes forecast-based replenishment unreliable for low-frequency nicotine materials, as materials may be ordered for production that are later changed or cancelled. Therefore, replenishment for externally stored nicotine label materials is triggered only when a confirmed production order exists. For materials with more stable demand, such as AX and AY labels and snus materials, traditional reorder points remain suitable. For cans and lids, replenishment is supported by a delivery scheduling agreement that aligns deliveries with production requirements. To conclude it the two-echelon strategy allocates the materials based on their actual demand patterns and how recent it was in production. Resulting in the slow-moving and inactive materials will not be held internally, and the high frequency items will remain internally. How the replenishment will work is also based on the item's characteristics, as low frequency items will only be replenished against a production order while the high frequency items through reorder points. All of the identified root causes guide both the criteria for the storage allocation and how the replenishment should work in the facility.

6

Conclusion

The aim of this study was to examine why inventory accumulates and causes congestion at the internal facility of Company X and to propose a differentiated two-echelon warehousing strategy to address the underlying causes. In the study four main root causes were identified, all of them were connected to the organizational; transition that happened in June 2024. The root causes were poor information sharing between functions, insufficient control over material lifecycle, unstable production planning, and safety stock policies. These causes are not only individual problems, but also reinforce one another and all contribute to the warehouse operating beyond its intended capacity.

The proposed strategy focused on two main areas. The first one is the storage allocation method ABC/XYZ demand classification. Where materials with demand patterns that meet the normality condition will be stored internally together with a calculated safety stock. There were 381 materials out of 461 nicotine products that did not meet this condition and therefore will be stored externally without a safety stock. For the materials that have not been used for over six months will also be moved to external storage. This will free up pallet positions that are currently occupied by inactive inventory. However, all cans and lids will continue to be stored internally within the target limit of 164 pallet positions and managed through a daily delivery schedule.

For the second area, it concerns the rules for the replenishment. For the nicotine materials that are stored externally and classified as BZ and CZ, replenishment should be triggered by confirmed production orders. For AX and AY label materials and snus materials, a reorder point system should instead be used. For cans and lids, the current uncoordinated inbound deliveries should be replaced with a supplier delivery schedule that matches the actual consumption.

By applying the proposed strategy, the safety stock levels for snus AX materials and nicotine AY materials are reduced. At the same time, storage positions occupied by slow-moving labels and inactive inventory are released, making the full allocation of 473 label pallet positions available again.

6. Conclusion

7

Future research

Potential future research regarding the topic of this study could be by looking further into these additional directions. Where the first one would be by looking closer at the safety stock calculation, that now currently uses production frequency as replacement for demand since customer data was not available during the study. For the second one, the classification calculations could be repeated by using actual demand data and see if the same boundaries and results hold. By redoing this it would give Company X a more precise objective before any implementation is made.

Another direction regards the implementation, a follow up study tracking warehouse capacity before and after the implementation could show whether the improvements actually would happen in practice. The third direction is regarding the frozen planning horizon, where this thesis extends the horizon to four weeks for the replenishment rules to work. However, it does not examine what a formal process for managing changes within this horizon should be like or how other materials beyond labels would be affected by such a change. A fourth direction follows the cost ownership dispute from one of the root causes, where this thesis could not resolve since it requires decisions about the facility level. Future research could look into how the organizations should divide the responsibility for decisions about how materials that are no longer in use should be handled.

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A

Appendix 1

Interview questions

1. Could you briefly describe your role and your main responsibilities at Company X facility?
2. How would you describe the current situation in the warehouse in terms of space and material flow?
3. What do you see as the main challenges in managing inbound materials at the facility today?
4. How are decisions currently made about where to store materials internally or at the external warehouse?
5. How does the demand and planning information you receive support your daily work?
6. Are there situations where the information you receive is incomplete or arrives too late to act on? How are safety stock levels currently set and how often are they reviewed?
7. How has coordination between functions changed since the organizational transition in 2024?
8. How does the facility currently handle materials that are discontinued or no longer needed for production?
9. Are there any barriers that prevent inactive or obsolete materials from being removed from the warehouse?
10. In your view, what is the most important change that would improve the current situation at the facility?
11. Is there anything else you think is important for us that we have not covered?

B

Appendix 2

Here are the four chains for the 5 Whys analysis.

Why	Question	Answer
1	Why is inactive inventory accumulating?	Materials that are no longer needed are not being removed from the warehouse.
2	Why are these materials not removed?	They cannot be scrapped because the phase-out process is not functioning properly.
3	Why is the phase-out process not functioning?	There is a cost ownership dispute between planning and the market function, meaning neither party initiates or approves scrapping.
4	Why has the cost dispute not been resolved?	There is no clear governance structure with responsibility for deciding cost allocation for discontinued materials.
5	Why does no such governance structure exist?	The organizational changes in June 2024 removed the previous way of handling these materials without establishing a new process.
Root cause	→	There is no defined process or responsibility for removing discontinued materials from the warehouse.

Table B.1: Chain 1, Why is dead stock accumulating in the warehouse?

B. Appendix 2

Why	Question	Answer
1	Why does purchasing systematically over-order?	Purchasing commits to quantities that exceed actual production requirements, particularly for nicotine launches.
2	Why do ordered quantities exceed actual requirements?	Purchasing acts on demand signals that are inaccurate or incomplete at the point of ordering due to system translation errors and late forecasts.
3	Why are demand signals inaccurate or incomplete?	Two issues occur, error in translating data across multiple planning systems reduces accuracy, and purchasing is not included in new launches. Meaning information is received late and outside formal processes.
4	Why is purchasing excluded from new launches?	The organizational changes in June 2024 restructured cross-functional teams without ensuring that purchasing remained involved in demand planning activities.
5	Why has this exclusion not been addressed?	There is no formal process to assess how decisions about team structure affect procurement and inventory outcomes. As a result, the link between purchasing exclusion and over-ordering has not been formally recognised.
Root cause	→	Structural information asymmetry between market and purchasing: the organizational changes disrupted the flow of demand information to purchasing, making it difficult to base ordering decisions on accurate and timely data.

Table B.2: Chain 2, Why does purchasing systematically over-order inbound materials?

Why	Question	Answer
1	Why is the frozen plan not frozen in practice?	The plan changes an average of 28.08 times per week within a supposed two-week freeze, corresponding to a planning stability ratio of 32.94 percent.
2	Why does the plan change so frequently within the frozen period?	There is no clear process to control what changes can be made, who approved them, or how their impact should be assessed.
3	Why does no change control process exist?	Planning decisions are made by teams remote from the facility who lack visibility of the downstream operational consequences; there is no governance mechanism that connects planning changes to purchasing commitments or warehouse impacts.
4	Why do planning teams lack visibility of operational consequences?	The current two-week frozen horizon is shorter than the lead times for critical materials: labels require four weeks, formula materials six to twelve weeks. Purchasing must therefore commit before the plan is stable, and plan changes after commitment are treated as routine rather than exceptions.
5	Why has the frozen horizon not been extended to match lead times?	No systematic analysis has been conducted of the relationship between frozen horizon length, material lead times, and inventory accumulation. By extending the horizon would require change governance that does not currently exist.
Root cause	→	Production planning instability without change governance: The frozen period is shorter than material lead times, and there is no process to control changes, leading to frequent plan changes and mismatches between orders and actual production needs.

Table B.3: Chain 3, Why is the frozen production plan effectively not frozen?

Why	Question	Answer
1	Why is safety stock policy misaligned with portfolio demand characteristics?	The same six month safety stock level is applied to all nicotine items, regardless of difference in demand or production frequency.
2	Why is the directive applied uniformly across all item numbers?	There is no process at the facility level to adjust safety stock based on actual demand patterns.
3	Why is there no adjustment process at the facility level?	The safety stock policy is set at the corporate level, and the facility does not have the authority to change it.
4	Why was the policy set without considering local conditions?	The directive was set during the June 2024 transition as a standard rule across all facilities, without analysing differences in demand or storage capacity.
5	Why was no facility-level adaptation mechanism established alongside the directive?	The transition focused on standardization and compliance, without establishing a process to adapt the policy to local conditions.
Root cause	→	Undifferentiated safety stock policy misaligned with portfolio reality: A standard corporate policy is applied without adjustment to local demand patterns, leading to safety stock levels that do not reflect actual needs.

Table B.4: Chain 4, Why is the safety stock policy misaligned with portfolio demand characteristics?

C

Appendix 3

The following calculations apply the normality condition to four representative materials selected from the relevant ABC/XYZ demand classes. Since item-level customer demand data was unavailable during the study period, production frequency was used as a proxy for demand. The summarized results are presented in Table X in Section X.

The safety stock calculation used throughout the analysis is:

$$SS = k \times CoV \times D \times \sqrt{L}$$

where $k=1.65$ represents a 95 percent cycle service level, CoV is the coefficient of variation of production frequency, D is the average weekly demand in units, and L is the replenishment lead time in weeks. The lead time was set to four weeks based on the supplier agreements described in Section 4.3.

The normality condition is defined as:

$$D \times L > 2 \times \sigma DDLT$$

where $\sigma DDLT$ is the standard deviation of demand during the lead time, derived as:

$$\sigma DDLT = \sigma D \times \sqrt{L}$$

When condition in normality condition is satisfied the safety stock formula produces a statistically reliable result. When it is not satisfied the demand pattern is too irregular for the normal distribution to apply and make-to-order replenishment is the appropriate response.

Step	Calculation
<i>Annual production</i>	9,800,040 units
<i>Average weekly demand (D)</i>	$9,800,040 \div 52 = 188,462$ units/week
<i>σD (weekly std. dev.)</i>	59,931 units
<i>$\sigma DDLT = \sigma D \times \sqrt{L}$</i>	$59,931 \times \sqrt{4} = 119,862$ units
<i>Mean demand during lead time</i>	$188,462 \times 4 = 753,849$ units
<i>Normality check</i>	$753,849 > 2 \times 119,862 = 239,724$
Condition	SATISFIED
<i>Justified SS = $1.65 \times \sigma DDLT$</i>	$1.65 \times 119,862 = 197,772$ units (≈ 1 week)
Current directive (6 weeks)	1,130,774 units — 5.7$\times$ justified level

Table C.1: Item 1: Snus AX

Step	Calculation
<i>Annual production</i>	786,720 units
<i>Average weekly demand (D)</i>	$786,720 \div 52 = 15,129$ units/week
<i>σD (weekly std. dev.)</i>	11,362 units
<i>$\sigma DDLT = \sigma D \times \sqrt{L}$</i>	$11,362 \times \sqrt{4} = 22,724$ units
<i>Mean demand during lead time</i>	$15,129 \times 4 = 60,517$ units
<i>Normality check</i>	$60,517 > 2 \times 22,724 = 45,448$
Condition	SATISFIED
<i>Justified SS = $1.65 \times \sigma DDLT$</i>	$1.65 \times 22,724 = 37,495$ units (≈ 2.5 weeks)
Company Y directive (26 weeks)	393,360 units — 10.5$\times$ justified level

Table C.2: Item 2: Nicotine AY

Step	Calculation
<i>Annual production</i>	319,560 units
<i>Average weekly demand (D)</i>	$319,560 \div 52 = 6,145$ units/week
<i>σD (weekly std. dev.)</i>	11,117 units
<i>$\sigma DDLT = \sigma D \times \sqrt{L}$</i>	$11,117 \times \sqrt{4} = 22,234$ units
<i>Mean demand during lead time</i>	$6,145 \times 4 = 24,582$ units
<i>Normality check</i>	$24,582 < 2 \times 22,234 = 44,468$
Condition	NOT SATISFIED
Response	Make-to-order, no standing buffer appropriate
Company Y directive (26 weeks)	159,780 units of statistically unreliable buffer stock

Table C.3: Item 3: Nicotine BZ

Step	Calculation
<i>Annual production</i>	52,800 units
<i>Average weekly demand (D)</i>	$52,800 \div 52 = 1,015$ units/week
<i>σD (weekly std. dev.)</i>	1,984 units
<i>$\sigma DDLT = \sigma D \times \sqrt{L}$</i>	$1,984 \times \sqrt{4} = 3,968$ units
<i>Mean demand during lead time</i>	$1,015 \times 4 = 4,062$ units
<i>Normality check</i>	$4,062 < 2 \times 3,968 = 7,936$
Condition	NOT SATISFIED
Response	Make-to-order, produced ~4 times per year
Company Y directive (26 weeks)	26,400 units = 2 full production runs as standing buffer

Table C.4: Item 4: Nicotine CZ

Item	Class	D/week	CoV	Normality check	Justified SS	Current directive	Excess
Snus Item 1	Snus AX	188,462	0.318	PASSES: $753,849 > 239,724$	197,772 (1 wk)	1,130,774 (6 wks)	5.7x
Nicotine Item 1	Nicotine AY	15,129	0.751	PASSES: $60,517 > 45,448$	37,495 (2.5 wks)	393,360 (26 wks)	10.5x
Nicotine item 2	Nicotine BZ	6,145	1.809	FAILS: $24,582 < 44,468$	MTO recommended	159,780 (26 wks)	MTO
Nicotine Item 3	Nicotine CZ	1,015	1.954	FAILS: $4,062 < 7,936$	MTO recommended	26,400 (26 wks)	MTO

Table C.5: Normality condition results and justified safety stock levels for representative ABC/XYZ materials.

Component	Type	Avg daily cons.	Std dev.	SS (units)	Cycle stock	Target pal.	Schedule status
Nicotine	Can	148,860	69,550	114,757	74,430	21	Formalise existing
Nicotine	Lid	148,860	69,550	114,757	74,430	10	Formalise existing
Snus Item 1	Can	132,042	61,704	101,812	66,021	25	Formalise existing
Snus Item 1	Lid	132,042	61,704	101,812	66,021	10	Formalise existing
Snus Item 2	Can	128,964	56,956	93,978	64,482	24	Formalise existing
Snus Item 2	Lid	128,964	56,956	93,978	64,482	9	Supplier agreement
Snus Item 3	Can	42,799	23,748	39,184	21,399	9	Supplier agreement
Item 3	Lid	42,799	23,748	39,184	21,399	4	Supplier agreement
Item 4	Lid	38,031	22,320	36,827	19,015	3	Supplier agreement
Item 5	Lid	34,175	18,833	31,075	17,088	3	Supplier agreement
Item 6	Lid	32,839	23,177	38,241	16,420	3	Supplier agreement
Item 7	Can	29,982	16,942	27,955	14,991	7	Supplier agreement
Item 7	Lid	29,982	16,942	27,955	14,991	3	Supplier agreement
Item 8	Can	11,454	9,123	15,053	5,727	3	Supplier agreement
Item 8	Lid	11,454	9,123	15,053	5,727	1	Supplier agreement
Item 9	Lid	19,903	12,655	20,881	9,952	2	Supplier agreement
Item 10	Lid	6,245	5,317	8,773	3,122	1	Supplier agreement
Item 11	Lid	2,611	3,195	5,271	1,306	0	Supplier agreement
TOTAL						107	vs. 164 preferred

Table C.6: Target internal pallet positions per can and lid component type under a consumption-matched daily delivery scheduling model. SS at 95 percent service level ($z = 1.65$). Cycle stock equals half of one day of average production consumption.

