Pull Planning in the Value Chain: a Case Study on the Automotive Electronics Sector

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Abstract

This dissertation focuses on operational improvements within an anonymous automotive electronics firm, referred to as Company Alfa. The central goals are to optimize raw material inventory management.

Company Alfa operates in the automotive electronics sector, supplying electronic components to high-end car manufacturers globally. In this dynamic industry, quick adaptation to fluctuating demands and minimizing excess raw material stocks is crucial for competitiveness.

The study begins by outlining the context of the automotive electronics industry, underlining the growing significance of electronics in vehicles and the operational challenges associated with it. The main objective of this dissertation is to optimize raw material procurement for inventory cost reduction. The methodology involves using Value Stream Mapping to analyze material and information flows, identifying areas for improvement. The project progresses through stages of solution development, stakeholder engagement, and action implementation.

The research aimed to identify the key factors affecting optimal raw material stock levels in the electronic automotive industry, concluding that these factors fall into five dimensions: Master Data Parameterization, Supplier Negotiations, SAP Formula, Forecast and Production Planning, and Vendor-Managed Inventory.

The study further examined how these dimensions should be integrated into stock level definition. Master Data Parameterization, for example, includes elements like Safety Time, Goods Receipt Processing Time, Incoterms, and Minimum Order Quantity, necessitating regular reviews for accuracy. Supplier Negotiations involve considerations like the Evolution of Non-Cancelable Non-Returnable items and Minimum Order Quantities, emphasizing the importance of periodic parameter reviews.

Effective production planning, striking a balance between meeting customer demand and preventing overproduction, was explored, considering absenteeism and its link to variable salary. Lastly, Vendor-Managed Inventory (VMI) was found to be the most advantageous approach, particularly in this sector, as it reduces inventory costs and improves process responsiveness.

Revising ERP parameterization, including Incoterms and Transit Times Revision, yielded a freed cash flow of €89,887.6€, with substantial savings in obsoletes and spare parts raw material, reducing the total Raw Material inventory valuation by €66,000 and estimating yearly savings of €13,600. Negotiation with suppliers, particularly in terms of MOQs, resulted in €738,460 in free cash flow and improved material flow, along with annual labor cost reduction of €2,400. Addressing high absenteeism levels in production planning is expected to reach a target rate of 6.5%, potentially freeing up to 14 employees to counter production planning issues.

In conclusion, this dissertation aims to provide practical solutions for enhancing Company Alfa's production flexibility and inventory management, addressing the unique challenges faced by the automotive electronics sector.

Resumo

Esta dissertação concentra-se em melhorias operacionais dentro de uma empresa anónima de eletrónica automóvel, designada como Empresa Alfa. Os objetivos centrais são otimizar a gestão de inventário de matérias-primas.

A Empresa Alfa atua no setor de eletrónica automóvel, fornecendo componentes eletrónicos a fabricantes de automóveis de gama alta a nível global. Nesta indústria dinâmica, a adaptação rápida às flutuações da procura e a minimização dos stocks em excesso de matérias-primas são cruciais para a competitividade.

O estudo começa por contextualizar a indústria de eletrónica automóvel, destacando a crescente importância da eletrónica nos veículos e os desafios operacionais associados. O objetivo principal desta dissertação é otimizar a aquisição de matérias-primas para redução dos custos de inventário. A metodologia envolve a utilização de Mapeamento do Fluxo de Valor para analisar os fluxos de material e informação, identificando áreas de melhoria. O projeto avança por etapas de desenvolvimento de soluções, envolvimento das partes interessadas e implementação de ações.

A pesquisa teve como objetivo identificar os principais fatores que afetam os níveis ideais de stocks de matérias-primas na indústria de eletrónica automóvel, concluindo que esses fatores se enquadram em cinco dimensões: Parametrização de Dados Mestres, Negociações com Fornecedores, Fórmula SAP, Previsão e Planeamento de Produção e Inventário Gerido pelo Fornecedor.

O estudo examinou ainda como essas dimensões devem ser integradas na definição dos níveis de stock. A Parametrização de Dados Mestres, por exemplo, inclui elementos como Tempo de Segurança, Tempo de Processamento do Recebimento de Mercadorias, Incoterms e Quantidade Mínima de Encomenda, exigindo revisões regulares para manter a precisão. As Negociações com Fornecedores envolvem considerações como a Evolução de Itens Não Canceláveis Não Retornáveis e Quantidades Mínimas de Encomenda, destacando a importância de revisões periódicas de parâmetros.

O planeamento de produção eficaz, equilibrando a procura do cliente e a prevenção de sobprodução, foi explorado, tendo em conta o absentismo e a sua ligação a remuneração variável. Por fim, concluiu-se que o VMI é a abordagem mais vantajosa, especialmente neste setor, uma vez que reduz os custos de inventário e melhora a capacidade de resposta do processo.

A revisão da parametrização do ERP, incluindo a revisão de Incoterms e Tempos de Trânsito, resultou num fluxo de caixa libertado de 89.887,6€, com poupanças substanciais em materiais obsoletos e peças de reposição, reduzindo a avaliação total do inventário de matérias-primas em 66.000€ e estimando poupanças anuais de 13.600€. A negociação com fornecedores, especialmente no que diz respeito às Quantidades Mínimas de Encomenda, resultou num fluxo de caixa livre de 738.460€ e melhorias no fluxo de materiais, juntamente com uma redução nos custos de mão-de-obra de 2.400€ anuais. A abordagem dos níveis elevados de absentismo no planeamento de produção pretende atingir uma taxa alvo de 6,5%, potencialmente libertando até 14 funcionários para enfrentar os problemas de planeamento de produção.

Em conclusão, esta dissertação visa fornecer soluções práticas para melhorar a gestão de inventário da Empresa Alfa, enfrentando os desafios únicos enfrentados pelo setor de eletrónica automóvel.

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Five years. Half a decade replenished with effort, everlasting work sessions and, most importantly, great memories, all condensed into this one project.

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"One finger cannot lift a pebble."

Anonymous

Contents

Acronyms and Symbols

ADAS	Advanced Driver Assistance System
BOM	Bill of Materials
CMI	Customer-Managed Inventory
COT	Change Over Time
CPT	Carriage Paid To
DDP	Delivered Duty Paid
DDU	Delivered Duty Unpaid
EDI	Electronic Data Interchange
ERP	Enterprise Resource Planning
FA	Final Assembly
FG	Finished Good
Incoterm	International Commercial Terms
JIT	Just in Time
KPI	Key Performance Indicator
MOQ	Minimum Order Quantity
MRP	Material Requirements Planning
NCNR	Non Cancelable Non Returnable
OEE	Overall Equipment Effectiveness
PCB	Printed Circuit Board
PCBA	Printed Circuit Board Assembly
RM	Raw Material
SMT	Surface-mount Technology
SKU	Stock Keeping Unit
VMI	Vendor-Managed Inventories
WIP	Work in Progress

List of Figures

List of Tables

Chapter 1

Introduction

The following dissertation project emerges from an improvement proposal on an operational scope within an enterprise performing in the electronic components industry for the automotive sector. The project was developed in the scope of the Master's Degree in Industrial Engineering and Management at the Faculty of Engineering of the University of Porto. The project was developed in a consultancy enterprise, Kaizen Institute Consulting Group, and emerged from the intervention in an industrial unit of the automotive electronics sector in Portugal. For confidentiality reasons, the company's name will be kept in secrecy and henceforth referred to as Company Alfa. In this chapter, the project is presented and contextualized, and the goals and adopted methodology to reach their completion are described.

1.1 Project context

Being agile is crucial in the automotive industry, and the electronics sector that supplies this industry is no exception. The variability in the supply of raw materials amplifies the need for flexibility. In the case of the enterprise in question, the non-compliance from the clients to the order regulations aggravates the inherent variability, namely in terms of the allowance period to place new orders or to change previous ones. This impacts the whole supply chain, from production to sourcing of materials, and urges for the agility of both the suppliers and the production lines.

Company Alfa is inserted within the automotive industry by offering electronic components, comprising the manufacture of the electronic parts (PCB) and assembly to the final mechanical structure, making it ready to be installed in the vehicle. Located in Portugal, this tier 1 automotive industry supplier operates in internal and external markets, selling electronics developed together with and to high-end carmakers and reaching around 100M€ in sales in 2022.

Therefore analysing how Company Alfa can strive in the automotive electronics sector became relevant, by reducing the level of stock that the high variability of demand and supply has led to. When solved, enables freed cash flow from the investment in raw materials that can then be invested in other sources of growth.

The partnership between the Kaizen Institute Consultancy Group and Company Alfa emerges at this stage to help Company Alfa strive within this challenging market. First, the focus is on finding the root causes of what hinders Company Alfa from reacting fast to the varying and unexpected demands and the accumulation of raw material stock and, secondly, on acting accordingly. Thus, a detailed analysis of planning and sourcing processes are made, and a methodology to avoid firefighting and to adjust stocks to the necessities is defined.

1.2 Automotive Electronics Sector in Portugal

The automotive electronics industry comprehends a vast group of devices that aid car movements, chemical, mechanical, and electrical processes and ensure safety, communication, and entertainment. Sangiovanni-Vincentelli (2003) defends automotive electronics may be divided into three domains: power train management, body electronic and information processing, communication, and entertainment, often referred to as infotainment. Chen (2019) adds advanced safety assistance system (ADAS), safety, Electronic Vehicles/Hybrid Electronic Vehicles (EV/HEV), instrument cluster, aftermarket, and chassis to the factory-installed electronics list.

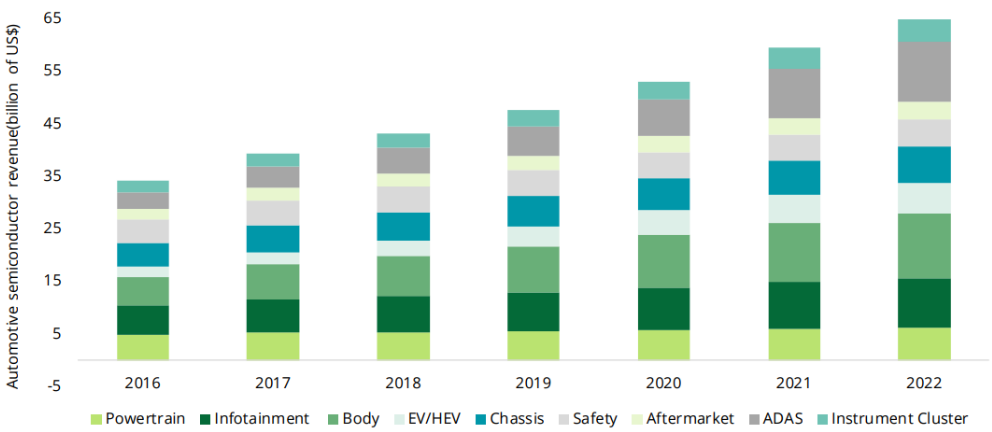

Figure 1.1: Electronic systems as % of total car cost (Chen, 2019)

The electronic components supply chain in the automotive sector is clearly divided into two tiers. Specifications are provided by automobile manufacturers (OEMs) to first-tier suppliers that design software and hardware subsystems. Likewise, second-tier suppliers may be semiconductor vendors and offer integrated circuits (IC) and intellectual property. As previously mentioned, company Alfa is considered a first-tier supplier. According to Chen (2019), in 2019, first-tear suppliers of electronic systems worldwide are valued at 120B$ and responsible for a compound annual growth rate (CAGR) of 5.5%.

Electronics in car manufacturing account for a rising percentage of the cost. Currently, it represents up to 40% of the cost, but it is expected to grow to 50% by 2023, according to Chen (2019). The evolution in the last 50 years is evident, represented in Figure 1.2, and justified by electronics being the area which has most innovated the automobile industry, alongside the need for sustainable solutions (Ferràs-Hernández et al., 2017). Therefore, an effort to seize value on the subsystem vendors is being made to increase internal electronics expertise.

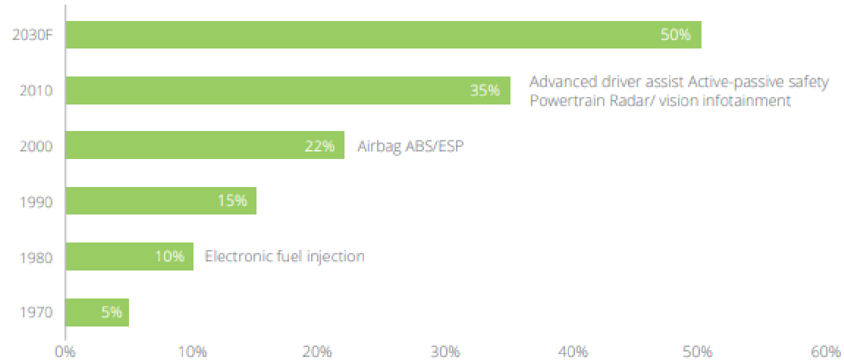

Figure 1.2: Electronic systems as % of total car cost (Chen, 2019)

Furthermore, the Cambrian moment that Ferràs-Hernández et al. (2017) uses to describe the industry is disrupting the stable and oligopolistic automotive industry into a new era of mechanical incumbents, digital giants, and emerging startups.

It is essential to explore both the automotive industry and the electronics one, more generally and individually, to understand the new trends directly impacting the automotive electronics sector.

As far as the automotive industry is concerned, the trends reshaping the sector are connectivity, autonomous cars, electric vehicles, energy storage, shared mobility, data analytics, AI, and cyber security, which also contribute to the new technological paradigm. This led to reduced entry barriers in the market, escalating competition due to the current importance of IT and EMS enterprises. In addition, the US and China are now prevailing in the development of new technologies for vehicles due to their financial power (Ferràs-Hernández et al. (2017); Flickenschild (2021)).

In the European Union (UE-27), four of the five main sold products belong to the automotive industry and related accessories. Correspondingly, in Portugal, one of the five most sold products belongs to this category and corresponds to 4.1% of the UE-27 production, Germany on top of the 52 thousand of million Euros sold products of "other parts and accessories".

Although the sector represented in the graphs of Figure 1.3 also comprehends the electric equipment besides the electronic, it was possible to depict the Portuguese panorama in 2020. This subsector within the Portuguese landscape has a modest contribution to the Gross value added and keeps growing. Employment has the lowest impact but has suffered significant rises between 2016 and 2019, with a slight reduction in 2020 (the pandemic period). Exportation accounted for 90.5% of the production in 2020 and for a visible growth trend. Interestingly, this sector has had symmetrical behavior compared to the subsector of vehicle production from 2010 to 2020, indicating these products' complementarity. Production has, on the other hand, declined 6.1% in 2020 (Lima, 2020).

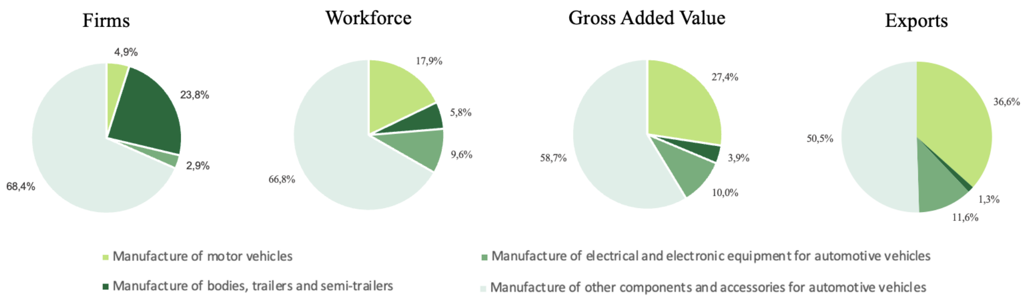

Figure 1.3: Distribution of the number of firms, workforce, gross value added and exports (adapted from Lima (2020))

1.3 Objectives and Research Questions

The main objective of the current dissertation is to minimize the level of raw material stock within the electronic automotive industry while ensuring the required service level, with the objective of reducing the invested capital. As a result, the present thesis intends to conduct a comprehensive review and optimization of the procurement strategy in the sector, particularly in regard to raw material stock management practices.

In line with the thesis's objectives, the investigation intends to address the following research question:

Research Question 1. What is the optimal stock management strategy within the electronic automotive industry?

In order to more adequately answer the main research question, two sub-questions were derived and examined:

Research Question 1.1. What are the dimensions that impact the optimal raw material stock level in the electronic automotive industry?

Research Question 1.2. How should the impacting dimensions be incorporated into the stock definition?

In order to address Research Question 1.1, a thorough analysis and respective identification of the dimensions affecting company Alpha was performed, using the Ishikawa Diagram. Furthermore, an exploration of the most significant themes according to the Company Alfa's historical data and qualitative details was conducted, allowing to answer Research Question 1.2.

1.4 Project Methodology

In the project's first phase, the Value Stream Mapping tool was used to map the value chain and analyze the material and information flows. The mapping identified a list of opportunities for improvement, of which only a part was selected to integrate the dissertation.

Subsequently, the project was split into steps, as shown in Figure 1.4. It was also divided into three macro stages: the development of the solution outline, the characterization of the proposed methodology and the implemented initiatives, and the follow-up of the actions to be implemented. The first phase includes studying all the elements that impact the processes being changed and developing the chosen methodology with substantiated solution proposals. The second comprehends the sessions with all the stakeholders who know it from different angles and have decision power. The group dynamics enhance brainstorming, enabling the sketched solution to be thoughtfully drawn with the concepts of raw material stock definition. The third phase, which may only occur partially within the time frame of development of this dissertation, comprises the implementation of new actions and identified improvement practices.

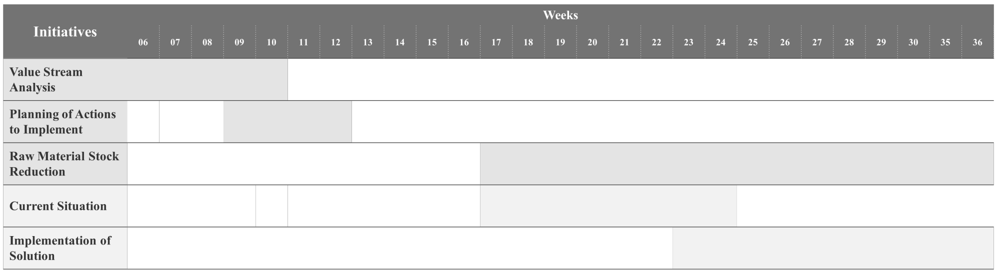

Figure 1.4: Timeline of the project

1.5 Document Structure

This dissertation is divided into six chapters. The first frames the project and presents the objectives of the project and the methodology to be followed. The second chapter reviews the existing literature on the topics that are the foundations of the project, namely the pull concept applied to sourcing raw materials. The third chapter focuses on the initial situation of the enterprise, contextualizing the production process, management policies, and information flows and identifying the root causes of the pinpointed problems. The fourth chapter explores the solutions to the found issues, outlining the methodology of implementation in detail, and depicts the obtained results until the delivery date of this dissertation and the expected results according to the implementation plan. Lastly, the sixth reflects on the main conclusions to be taken, the challenges, and potential actions to preserve and improve the developed project.

Chapter 2

Literature Review

This chapter presents concepts, methodologies and case studies relevant to the theme explored in this dissertation, published by the academic community.

2.1 Value Stream Mapping

Value stream analysis is a lean manufacturing framework used to analyze, design and manage the flow of materials and information, identifying non-value-adding activities. It encompasses all the necessary actions to bring a product from raw materials to the customer and design the flow from concept to launch. Taking a value stream perspective means focusing on the broader picture and striving to improve the entire value stream rather than optimizing isolated parts(Murugananthan, 2014).

Value stream mapping is crucial for surviving a competitive era by reducing manufacturing lead times and removing production waste to improve productivity (Azizi, 2015). Value stream mapping, a key component of value stream analysis, captures detailed information at individual stations, including station cycle time, resource utilization or uptime, setup time, work-in-progress (WIP) inventory, workforce requirements, and the flow of information from raw materials to finished goods (Murugananthan, 2014).

However, traditional value stream mapping has a limitation as it does not consider the inherent variability of processes, which may hinder achieving goals. To address this, Luz (2021) suggests integrating stochastic methods into the value stream mapping model. Although the application of these methods is still immature, it highlights a gap in the literature regarding evaluating the effect of variability sources between themselves.

On the other hand, Azizi (2015) states that the Future Value Stream Map effectively identifies wastes in activities and production processes, emphasizing its value in continuous improvement initiatives.

2.2 Pull vs Push in managing the supply chain

Supply chain management utilizes two primary policies: push and pull. The push policy involves processes originating from the company and flowing towards the market. It is characterized by the company driving production and distribution activities based on internal forecasts and decisions. On the other hand, the pull policy involves processes that flow from the market to the enterprise. Here, the market demand dictates production and distribution activities, and the company responds accordingly to customer orders.

However, these policies differ in terms of costs and their adaptability to competitive dynamics. For example, the push policy may increase costs and inventory levels as it relies on forecasts and assumptions. Conversely, the pull policy minimizes costs and inventory by aligning production with customer demand (Corniani, 2008).

The push strategy is more suitable for situations where customer service level and throughput are more valued; on the other hand, the pull strategy is more compatible with strategies that seek to minimize total inventory. In fact, pull supply strategies lead to more consumption from stock buffers, due to it being part of the replenishment mechanism. Regardless of the combination of inventory buffer level and forecast error, the pull supply network leads to lower total inventories, compared to push strategies.

Push strategies are more sensitive to forecast errors compared to pull supply chains, because the latter only react to forecasted demand for the current period, whereas the first contemplates several periods in the future. Hence, if there are low to medium conditions of forecast error, push supply networks will remain stable; on the contrary, pull strategies are advantageous in case of high forecast error levels. Inventory buffer level-wise, pull networks are more sensitive, because higher levels are required to answer to immediate needs; on the other hand, push ones only use the buffer to react to variability in the demand and errors on the forecast (Masuchun et al., 2004).

A hybrid approach can also be employed, combining elements of both push and pull systems. This approach typically utilizes standard kanban/pull arrangements, allowing direct transmission of demand information to facilitate a responsive production process.

The push/pull system offers several advantages compared to a pure pull system. It allows for lower inventory levels and better responsiveness to changes in demand. By leveraging MRP approaches' strengths while maintaining kanbans' simplicity, companies can balance efficient production planning and flexibility (Deleersnyder, 1992).

The bullwhip effect, also known as the Forrester effect, refers to the phenomenon in supply chain management where orders placed with suppliers exhibit more significant fluctuations compared to the actual sales experienced by the buyer. This creates amplified distortions that propagate upstream in the supply chain (Disney and Towill, 2003). Understanding and effectively managing the bullwhip effect and choosing the appropriate push or pull policy enables companies to mitigate distortions in their supply chains and enhance overall efficiency and customer satisfaction.

Both push and pull policies encompass a range of activities, including design, production, distribution, and communication flows within the supply chain. The focus will be given on the sourcing of material and relationship with suppliers and on the plan of production.

Focusing first on the sourcing of material, a comparison reveals important insights regarding their performance under different market disruption scenarios.

Push contracts are found to be less effective in supply chains facing significant market disruptions. On the other hand, pull contracts exhibit superior performance in such situations. In contrast, when potential market disruptions are mild, the push contract becomes more attractive for supply chains (Wang, 2017).

In a push system, the number of alliances formed influences the inefficiency resulting from suppliers' horizontal decentralization. In cases with more than two suppliers and a power demand distribution, independent actions by myopic suppliers lead to the least efficient channel. This negatively impacts all channel members and end consumers. However, suppliers can easily coordinate their production quantities in a pull system. This coordination effectively eliminates the inefficiency caused by decentralization (Granot, 2008).

Understanding the dynamics of push and pull systems and their suitability in different market disruption scenarios is crucial for supply chain management, as it can significantly impact efficiency, performance, and customer satisfaction.

Production and planning-wise, the push system is often implemented through methods like Materials Requirements Planning (MRP) and involves a proactive approach where production is initiated based on forecasts and plans. On the other hand, the pull system relies on kanban systems, where actual demand from downstream processes or customers drives production.

It is crucial to effectively shape production to maximize the benefits of the pull system. For example, leveling can be employed to efficiently schedule production lines and machines while mitigating the bullwhip effect that can cause supply chain inefficiencies.

Pull-based planning encompasses two key aspects: production pull planning and logistics pull planning. Production pull planning involves calculating orders based on consumer pull rules, ensuring production aligns with actual demand. Similarly, logistics pull planning focuses on determining picking orders according to consumer pull rules, optimizing the supply chain to fulfill customer demands effectively (Coimbra, 2013).

By implementing pull-based strategies and optimizing production and logistics planning, companies can achieve improved operational efficiency, reduced inventory levels, and enhanced alignment with customer demand (Li, 2003).

2.3 Stocks and Stock Types

Stock is the presence of any item a company keeps, be it a physical product or a service, to be used in the company's output (Ahmed and Sultana, 2014). Its existence requires variability in the production process, usually represented by fluctuating demand or irregular supply. In order to smoothen the production process and achieve higher service levels, inventory is stored and consumed periodically, thus covering said variability spikes. With the growth of unitary flow and Lean Six Sigma implementations (Laureani and Antony, 2017), which seek minimal inventory levels, businesses perceive it as harmful. Although usually assigned this negative connotation (Kim and Kim, 2016; Chikán, 2007), it becomes a necessity for easily achieving economies of scale, avoiding stockouts, and improving customer service. Nonetheless, its seemingly passive and non-lucrative standpoints require substantial capital for storage, management, and tracking. Moreover, overwhelming inventory levels potentiate low inventory turnover, risk of obsolescence, and lower flexibility to cover demand.

Inventory can reveal itself in numerous formats. The following table summarizes the most common inventory types witnessed in businesses.

Table 2.1: Types of Inventory

Type	***Description***
Merchandise	Items acquired for resale without undergoing any transformation.
Raw Materials	Items acquired for integration into the transformation process that yields the final product.
Subsidiary Materials	Supplementary items accompanying raw materials throughout the transformation process.
Work-in-Progress	The antecedent phase preceding the completed product, mandating additional transformative stages for enabling viable commercial transactions.
Semi-Finished Product	Product not yet undergone the entirety of the transformation procedures requisite for finalization but remains amenable to sale.
Finished Product	The result of the production process that combines raw materials and subsidiary materials, creating a product ready for transaction.

Larger economies, such as the automotive industry, usually associated with a wider customer spectrum and, thus, more demand variability. Given its common restriction to new implementations due to the substantial cost associated, raw material inventory is heavily present. Saranga et al. (2009) examines inventory trends within the Indian automotive industry and reveals a consistent decline in average inventory levels. This downward trend was attributed to the effective management of working capital and dedicated efforts towards enhancing product quality.

Rizkya et al. (2018) delved into a comparative analysis of inventory systems prevalent in the automotive sector. The study concluded that Continuous Review Policy (reorder points, order quantities, and lead times) tends to yield lower total inventory costs, making it a favorable choice within this industry.

Cachon and Olivares (2010) and Cachon and Olivares (2009) centered on the U.S. automobile industry, with a particular emphasis on the marked disparities in finished goods inventory levels observed among various manufacturers. These studies underscored the multifaceted influence of factors such as product diversity, demand volatility, dealership network size, and production flexibility on inventory management strategies.

Furthermore, it was noted that Toyota consistently maintained a shorter span of days of supply compared to its industry peers. This observation pointed to Toyota's distinct advantage in terms of manufacturing efficiency and proficiency in supply chain management.

2.4 Material Planning Methods

Effective material planning is a cornerstone of efficient supply chain management and plays a pivotal role in ensuring the seamless flow of materials within organizations. This subchapter delves into two prominent material planning methods, Material Requirements Planning (MRP) and Vendor-Managed Inventory (VMI), each offering unique strategies for optimizing inventory control and production processes.

2.4.1 Material Requirements Management (MRP) systems

The MRP system operates on the principle of converting demand forecasts into detailed plans for acquiring the necessary raw materials, components, and subassemblies required for the production of finished goods. At its core, MRP relies on the Bill of Materials (BOM), which is a structured list detailing the components and their quantities needed to manufacture a specific product. By combining this information with lead times for procurement and production processes, the MRP system can calculate when and how much of each item should be ordered or produced to synchronize with the production schedule. This calculation is done with the aim of preventing shortages or excess inventory of components during the production process, all based on a forward-looking perspective of finished product needs (Ptak and Smith, 2011).

In the realm of manufacturing and supply chain management, MRP has historically served as a cornerstone for effective inventory management and production planning. However, as industries have evolved, the demand for a more comprehensive and integrated approach has grown. To address this need, Manufacturing Resource Planning (MRP II) has emerged as an advanced system.

As elucidated by S. Lawrence and Martin (2019), MRP II represents an evolutionary progression from MRP, with an emphasis on the holistic orchestration of the entire production continuum, encompassing aspects ranging from materials to financial considerations and human resource management. According to Miclo et al. (2016) and Miclo et al. (2015), MRP II is juxtaposed with Demand-Driven MRP (DDMRP), and the findings suggest that DDMRP exhibits a potential capacity for superior uncertainty management when contrasted with conventional MRP methodologies. Conversely, Salimi et al. (2015)'s study delves into the distinctions between MRP and ERP (Enterprise Resource Planning) systems, offering a comprehensive exploration of their implementation dynamics.

Scientific literature underscores the merits of MRP II as a favorable option for effective manufacturing management. In particular, Liang Xing (1998) contends that MRP II represents a more contemporary approach to management. Meanwhile, M. Jacobi (1994) and Jacobi Ma (1994) accentuate MRP II's capacity to delineate a structured methodology for the comprehensive planning and control of organizational resources, with a pronounced emphasis on processes that augment the value of end products for customers. Furthermore, they assert that MRP II serves as the linchpin in the framework of total quality management. Pan Xing-qiang (2005) delves into the capacity of MRP II to address issues related to customer service, capital investments in stock, and the enhancement of production efficiency. In collective consensus, these scholarly contributions substantiate the proposition that MRP II stands as the preeminent choice for adept manufacturing management.

2.4.2 Inventory Management Strategies

Inventory Management Strategies encompass two primary paradigms, namely Customer-Managed Inventory (CMI) and Vendor-Managed Inventory (VMI). These strategies serve as fundamental approaches in the domain of inventory control to enhance supply chain coordination, where CMI involves the customer actively overseeing their inventory held at the supplier's premises, while VMI entails the supplier taking on the responsibility for maintaining inventory levels at the customer's location.

More specifically, VMI represents an approach to supply chain management characterized by the upstream supplier or vendor taking on the role of actively managing inventory levels at the downstream customer's site. This strategic collaboration is founded upon a predefined agreement between the two parties. Under the VMI model, a designated decision-maker, often the supplier, assumes responsibility for making inventory-related decisions on behalf of the customer (Govindan, 2013). Marques et al. (2012) argues that VMI strategy is perceived as part of a short-term replenishment pull system.

The core principle of VMI revolves around achieving optimal inventory levels throughout the supply chain, which translates into reduced holding costs, minimized stockouts, and enhanced overall supply chain efficiency. This approach rests on the premise that the entity closest to the production process, typically the supplier, is best positioned to forecast and respond to customer demand accurately.

The VMI methodology helps fight the bullwhip effect by promoting real-time data sharing, smoothing demand fluctuations, reducing order batching, encouraging collaboration, and lowering the reliance on safety stock. By addressing these key factors contributing to the bullwhip effect, VMI helps create a more stable and efficient supply chain, minimizing the disruptive ripple effects of demand variability (Ma et al., 2013).

In addition, VMI is associated with distinct advantages to vendors, which encompass heightened accessibility to inventory data and the establishment of more direct communication channels with their clients (Taleizadeh et al., 2020). Likewise, buyers derive substantial benefits from VMI, including the equitable distribution of risk within the upper echelons of the supply chain and a concomitant reduction in the financial burdens associated with inventory holding costs (Taleizadeh et al., 2020).

On the other hand, CMI represents an active engagement by the customer in the oversight of their inventory held at the supplier's facilities. This collaborative approach is designed to yield mutual benefits, enhancing expected profits for both parties compared to independent actions (Chen et al., 2022). CMI enables the customer to exercise greater control over critical suppliers, fostering supply chain optimization. This strategy is particularly advantageous in circumstances marked by high demand variability, extended lead times, and where the supplier's concerns about customer shortages are relatively low (Chen et al., 2022). To fully realize the potential advantages of CMI, effective incentive mechanisms are essential, necessitating bilateral negotiations within the customer-supplier relationship (Chen et al., 2022). These mechanisms may encompass schemes for sharing inventory costs and adjustments to wholesale pricing.

However, it is important to note that CMI is not without its drawbacks. Customers adopting CMI may face the need to invest in costly finished goods inventory or incur significant expenses in expediting orders to mitigate potential delays (Chen et al., 2022).

Pornphattra Aussawasuteerakul (2012) posits that the adoption of Vendor-Managed Inventory (VMI) in lieu of Customer-Managed Inventory (CMI) can yield a notable reduction in inventory carrying costs. Fry (2011) underscores the potential for VMI programs to generate cost savings within the supply chain, primarily attributable to the consolidation of shipments and the alignment of incentives. Mishra and Raghunathan (2004) further amplifies the merits of VMI by emphasizing its capacity to intensify brand competition, thereby affording retailers the advantage of reduced sales risk stemming from brand substitution. Collectively, these scholarly contributions substantiate the proposition that VMI presents a compelling array of advantages, encompassing cost reduction and heightened competition when juxtaposed with the CMI approach. However, the choice between these strategies is contingent upon the specific operational needs and objectives of the entities involved, offering versatile options for optimizing inventory management within the supply chain.

2.5 Safety stock management

Safety stock, often called buffer stock, is an extra inventory reserve held by a company beyond its regular stock levels. Its primary purpose is to prevent stockouts when faced with unexpected demand spikes, supply chain disruptions, or variations in customer demand. Safety stock helps ensure uninterrupted customer service, maintains production efficiency, and improves service reliability. It acts as a buffer against uncertainties in demand and supplier lead times, contributing to customer satisfaction and loyalty. While it increases inventory carrying costs, the benefits of preventing stockouts and disruptions often outweigh these expenses, making it a crucial component of effective inventory management. Therefore, the most relevant factors influencing safety stock are the standard deviation of demand (σ_d), the standard deviation of supplier delivery times (σ_l), and the desired level of service to be provided to customers (Piasecki, 2009). Its global formula can be obtained through the equation 2.1

$$SS = Z \cdot \sqrt{(\sigma_d^2 \cdot LT) + (\sigma_l^2 \cdot Avg.Demand)} \tag{2.1}$$

, where:
SS: Safety stock
Z: Desired service level
σ_d: Standard deviation of demand
σ_l: Standard deviation of supplier delivery times
LT: Lead time.

Although safety stock strengthens the provided service level, excessive inventory levels may not be the ideal approach with more uncertain delivery or production lead times. That said, safety time becomes an alternative to these scenarios. Safety time involves adding extra time to the lead time of components or products to ensure consistent production and to accommodate potential delays. In the context of the automotive components industry, the choice between safety stock and safety time hinges on various factors. Kampen (2010) argues that the choice between safety stock and safety lead time depends on the specific uncertainties in demand and supply. In situations with variable supply, safety lead time is more effective in improving delivery performance, while safety stock is more effective in unreliable demand situations.

Graves and Willems (2003) delve into two distinct approaches for determining the placement of safety stock, namely the "stochastic-service model" and the "guaranteed-service model."

In the stochastic service model, each segment within the supply chain maintains a specific amount of safety stock to achieve its predefined service level goal. When dealing with stages that rely on upstream suppliers, considerations include the probability of these suppliers fulfilling replenishment requests from their existing stock.

Conversely, the guaranteed-service model focuses on each stage providing a consistent level of service to its downstream customers. In this scenario, a supplying stage establishes a service time commitment and keeps enough inventory to consistently meet this commitment. A critical assumption here is that demand remains within specified limits to maintain the service-time guarantee. However, Romero (2017) proposes a new model that considers lead time volatility without assuming a specific distribution, providing a robust approach to managing uncertain lead times, further proving the extensive literature on the topic.

2.6 Dimensions that impact decisions of stock

Numerous factors play a significant role in the decisions made about stock levels and replenishment procedures in the field of inventory management. Davis (2016) listed these parameters, which span supplier-related elements like lead time and variability to internal aspects, such as management costs:

- **Lead Time of the Supplier**: The lead time of a supplier is a critical dimension that significantly influences stock decisions within supply chain management. A longer lead time can necessitate higher safety stock levels to mitigate the risk of stockouts during this extended waiting period. In contrast, a shorter lead time allows for a leaner inventory strategy, as stock can be replenished more quickly (Ramzi Hammami and Bahli, 2017).

- **Variability of Lead Time of the Supplier**: The variability of the lead time of the supplier can introduce uncertainty into stock management, leading to the need for increased safety stock to buffer against unexpected delays. Chopra et al. (2004) highlights that reducing lead time variability has a greater impact on inventory reduction than reducing lead times. Therefore, understanding and effectively managing supplier lead times is pivotal in optimizing inventory levels, ensuring product availability, and minimizing carrying costs, ultimately impacting the overall financial performance of a business.

- **Frequency of Deliveries by the Supplier**: When suppliers provide frequent deliveries, businesses have the flexibility to maintain lower inventory levels, as they can rely on more frequent restocking to meet demand. This approach can help reduce carrying costs and minimize the risk of overstocking. Contrarily, less frequent deliveries may necessitate larger safety stock levels to bridge the gaps between deliveries, which can lead to higher carrying costs and increased capital tied up in inventory. In fact, Chen and He (2017) explores the advantage of delivery flexibility in a multi-period inventory system, concluding that it can improve total profit and mitigate supply risk.

- **Quality of Suppliers' Products**: High-quality products from reliable suppliers tend to have a lower likelihood of defects or issues that can disrupt operations. When product quality is variable or uncertain, companies may maintain higher safety stock levels to mitigate the risk of stockouts caused by defective or subpar items. In this context, Torres et al. (2010) introduced a novel supplier selection model aimed at determining appropriate safety stock levels based on supplier delivery reliability. This underscores the critical role of supplier selection and demand allocation for organizations.

- **Incoterms**: Incoterms, or International Commercial Terms, outline the obligations and rights of buyers and sellers in cross-border transactions (Kim, 2021). Within this framework, DDP (Delivered Duty Paid) is a turnkey solution that lays the onus on the seller to deliver products to the buyer's location, including facilitating customs clearance and paying import duties. On the other hand, DDU (Delivered Duty Unpaid) implies that the seller must deliver the items to the buyer's location; nevertheless, the buyer has the responsibility of clearing customs and paying the duty. Carriage Paid To, or CPT, requires the seller to deliver the goods to a designated location and to pay for the carriage thereof. The buyer then assumes the risk and any additional costs once the carrier takes control of the items, frequently used for freight transportation by air and water.

Incoterms are equally instrumental in determining cost allocations. They explicitly delineate which party is accountable for various transportation costs, encompassing expenses such as freight charges, insurance premiums, and customs duties. They exert a substantial influence on the estimation of lead times, providing guidance for the establishment of delivery schedules, a factor that directly impacts decisions regarding inventory reorder points and the forecasting of lead time demand.

- **Consumption of References**: The reference consumption rate is a vital dimension that significantly influences stock decisions in inventory management. It represents the historical or forecasted rate at which products or materials are consumed or used within a specific time frame. Accurate reference consumption data is crucial for determining optimal reorder points and reorder quantities. When consumption rates are higher or more variable, businesses may need to maintain higher safety stock levels to prevent stockouts and ensure consistent customer service. Rasku and Koivisto (2005) contributes to this field by discussing the use of model reference control and Value-at-Risk analysis to determine safety stock levels and buffer uncertainties in inventory. These analytical approaches provide valuable insights into how businesses can effectively manage their inventory, particularly when dealing with fluctuating demand patterns and consumption rates.

- **Consumption Frequency of References**: Understanding consumption frequency is essential in determining reorder points and replenishment strategies. Items with frequent consumption may necessitate more frequent stock replenishments to maintain adequate availability and prevent stockouts. Conversely, items with infrequent consumption might be managed with larger batch orders or periodic restocking to optimize efficiency and reduce holding costs. Matta and Guerrero (1990) conducted research in this area and found that a strategy of setting reorder points at equal intervals between the zero level (point of stock depletion) and the high level (point at which replenishment occurs) maximizes the frequency of service and the number of days without shortages.

- **Criticality of Stockouts**: The criticality of stockouts reflects the potential consequences and impact of running out of a particular item or product. Items with a high criticality level, such as essential components in a manufacturing process, demand a proactive approach to stock management. In such cases, businesses may maintain higher safety stock levels to minimize the risk of stockouts, even at the expense of increased carrying costs. This proactive stance is essential as stockouts of critical items can lead to production stoppages, delayed deliveries, and significant disruptions that can have far-reaching effects on a company's operations and reputation. On the other hand, for items with lower criticality, a more conservative approach to inventory management may be acceptable, as the consequences of occasional stockouts are less severe. SHIH (1980) delves into the topic of inventory systems and highlights the significant disruption caused by the presence of defective items within inventory. These defects can lead to higher operating costs and inefficiencies, making it imperative to not only ensure the quality of items in stock but also manage inventory levels and mitigate the potential negative impacts of stockouts.

- **Management Costs of Stock**: The management costs of stock encompass various expenses associated with holding and handling inventory, including warehousing, insurance, labor, and the cost of capital tied up in inventory. High management costs incentivize businesses to minimize their stock levels, employing strategies such as just-in-time inventory or lean inventory practices. Conversely, when management costs are lower, companies may opt for larger inventory levels to ensure product availability and meet customer demand. Brînză Georgiana and Iosep Ciprian (2009) highlights the importance of effective stock management, which not only lowers expenses but also makes operations more efficient and meets customer demand. Reducing costs while ensuring product availability is key to staying competitive. Ewa Kempa (2011) stresses the need for efficient transport and inventory handling to avoid high operating costs. By optimizing these areas, businesses can save money and run more efficiently.

- **Price Fluctuation**: The variations in the cost of goods over time can impact the carrying costs and the economic order quantities of inventory. When prices are volatile, businesses face a trade-off between taking advantage of lower prices through larger orders and the risk of holding excess inventory if prices drop further. Conversely, during periods of stable prices, organizations may employ leaner inventory strategies to reduce carrying costs. Sharma (2017) delves into the factors that influence carrying costs, highlighting that the variation in total cost is often more pronounced than the variation in lot size. This underscores the complexity of inventory management, where changes in carrying costs can have a substantial impact on the overall cost structure, influencing the decisions businesses make regarding their order quantities and inventory levels.

- **Service Level**: Service level, in inventory management, signifies how often a business intends to fulfill customer demand. This choice significantly influences inventory decisions. Opting for a higher service level demands maintaining more safety stock to reduce the risk of stockouts. While this approach ensures product availability, it does increase carrying costs. Conversely, selecting a lower service level may cut costs but elevate the likelihood of stockouts, potentially leading to customer dissatisfaction. The essence of stock management is to strike a balance between customer satisfaction and inventory expenses. This relationship can be quantified using the formula 2.2

$$SL = 1 - \frac{p_s \cdot t}{T} \tag{2.2}$$

, where:
SL: Service level, accepted probability of shortage occurrence
p_s: Number of period stock-out
t: Length of a given period, cycle length

T: Length of the complete examined period.

A higher service level indicates a lower chance of stockouts, necessitating greater safety stock. For instance, a 96% service level means meeting demand in roughly 96% of cases. Conversely, a 2% probability of shortages implies a 98% service level. This fundamental metric guides inventory management strategies in achieving the right equilibrium between customer service and inventory holding costs (Korponai et al., 2017).

- **Minimum Order Quantity**: The minimum order quantity (MOQ), which suppliers set as the smallest order they will accept, can significantly impact inventory management. MOQs, as discussed by Zhou et al. (2007), are employed in various industries but can present challenges in supply chain management. High MOQs can lead to reduced customer flexibility and increased inventory costs. On the other hand, Schwarz (2008) explains the Economic Order Quantity (EOQ) model, which helps businesses strike a balance between ordering and storage costs. EOQ calculates the optimal order quantity to minimize overall expenses, enabling companies to manage their internal orders efficiently. In summary, understanding MOQs and employing the EOQ model are both crucial in balancing cost savings and effective inventory management.

- **Obsolescence Rate**: The obsolescence rate represents the likelihood that a product or material will become obsolete or outdated before it is sold or used. When the obsolescence rate is high, businesses face the risk of holding inventory that loses value or relevance, leading to potential financial losses. In response, they may opt for smaller order quantities and shorter stock replenishment cycles to minimize the risk of holding obsolete stock.

Chapter 3

Analysis of the current situation

This chapter reflects the analysis performed before the implementation phase. At this stage, data was gathered either from observation of the shopfloor or from the information system of the company and the current processes were mapped, in terms of material and information. Thereafter, waste and opportunities are identified, as well as the indicators to be followed.

The tool used was the Value Stream Analysis, thus the analysis performed was towards the identification of opportunities for improvement of the current situation of the Company Alfa. The analysis was performed by a multidisciplinary team from the company, allowing to map each process, in detail, and to classify each activity as value-adding or waste. Having acknowledged the value chain and the points of interest to be evaluated further in Company Alfa, a future vision is proposed, using tools described in Chapter 2.

The chapter identifies the main challenges faced by the company, including the lack of flexibility in the production process, the high levels of raw material stock, and the lack of synchronization between the production planning and procurement processes. The chapter concludes with a discussion of the results from the value stream mapping in optimizing procurement processes and enhancing production flexibility, as well as the main challenges faced by the company.

3.1 Company Alfa

Company Alfa is focused on the manufacture of automotive electronics and has an installed capacity for more than 17 million devices, that are then mostly exported. This capacity is achieved by the team that is composed of 500 people, divided into three shifts of work. It offers more than 500 references, which are unique and developed together with the carmaker. When the electronic device is to be placed outside the vehicle, the product is customized to the color the client demands.

Company Alfa is divided into three distinct areas of production: one is solely dedicated to surface-mount technology (SMT), and produces printed circuit boards (PCB), that are then pretested. The second area, the Pre-Assembly, is responsible for soldering, lacquering, and milling to PCBs, transforming them into assembled PCBs to PCBAs. The third area is dedicated to Final

Assembly, being responsible for the joint of the mechanical parts to the in-house produced PCBAs. This productive process is summarized in Figure 3.1.

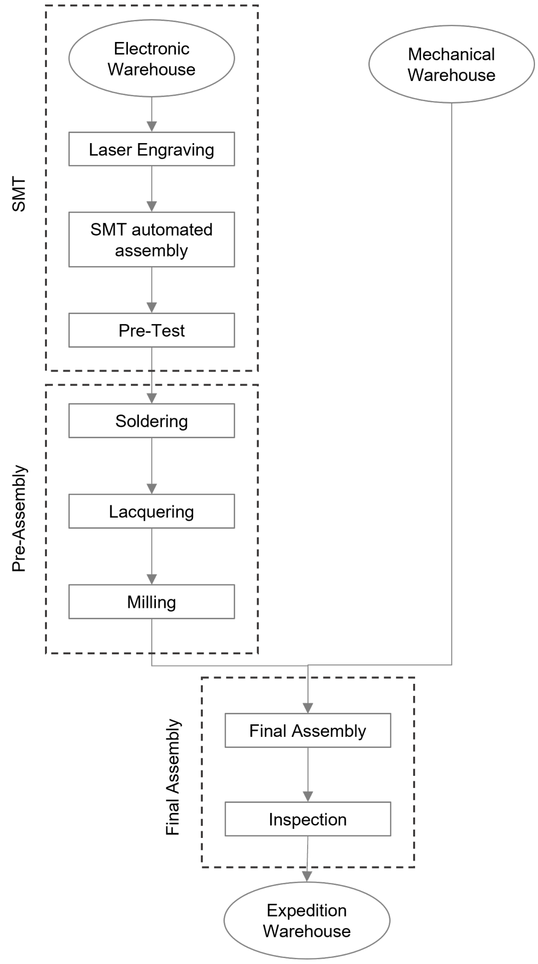

Figure 3.1: Summarized process map of production

As explained in Figure 3.1, SMT is composed of four lines of production (Electronic Warehouse, Laser Engraving, SMT automated assembly, and Pre-Test), whereas pre-assembly comprises a pool of machinery that enables the completion of the needed tasks. Finally, the Final Assembly is composed of more than 50 lines.

Physically, the production plant is divided into five areas: one for each area of production and two additional areas. These five areas can be summarized into Reception of Raw Material (which can be either Electronic or Mechanical Warehouses), SMT (its final product the finished PCBs), Pre-Assembly (which delivers the finished PCBAs), Final Assembly, and Expedition Warehouse.

3.2 Value Stream Mapping

Multiple visits were made to Company Alfa to gather the information that is being presented hereafter. All the functional departments of Company Alfa were analysed, with a deeper focus on the production and the areas that influence it directly, namely the planning and logistics. All the responsible for each area of analysis were present to clarify minutely the reality and pains of each process.

The map represented in Figure 3.2 contemplates both the material and information flow. The selection of the product is to be followed from the beginning of the process.

From what material flow is concerned, the flow starts with the raw materials being delivered in Company Alfa's facilities, stored in its warehouse. After the first stage of production, the electronic raw material (RM) is transformed into printed circuit board assembly (PCBA), which will then be assembled with other components and the origin of the finished goods (FG).

The information flow depicts the transmission of information between the areas of action, from the client's order and forecast of order to the moment the product leaves Company Alfa's facilities.

3.2.1 Material Flow Mapping

To draw the material flow map, the whole process was divided into different operational areas: three warehouses and three different stages of production. To better comprehend the material flow, the drawn map is followed by an explanation of each process.

Electronic Components Warehouse: The electronic raw materials have an area designated exclusively for their storage. After arrival in the company's facilities, these raw materials are directed to the warehouse of electronic components, where they remain until allocated to the production system. The electronic components used are printed circuit boards (PCBs), connectors, resistors, various electronic micro-components, and cables. Due to the proximity between the warehouse and the surface assembly lines (SMT), where these components are used, employees transport directly to the lines, thus eliminating logistical intervention in this process.

Mechanical Components warehouse: Mechanical components are allocated a dedicated area within the warehouse, where they are stored until they are incorporated into the production system. These essential components encompass various items such as plastic, fibrous, and metallic structures, screws, rubbers, solder pastes, springs, clips, and other related elements. The responsibility for the distribution of these components lies within the logistics department, which employs a well-defined logistic train system (mizusumashi) with predetermined routes to ensure the controlled and timely delivery of materials to the production lines.

Laser engraving: During this phase, a 2D code is etched onto each *nutzen* product as a means of identification. This QR code enables comprehensive traceability throughout the entire process, facilitating the identification of any specific task in which a defect may have occurred. In addition, the encoded information within this code includes the product reference, batch number, and the date of code generation, thus providing crucial details for effective monitoring and analysis.

SMT automatic assembly: In this section, the automated insertion of electronic components into printed circuit boards (PCBs) is carried out. The Surface Mount Technology (SMT) process comprises six sub-processes: Printer (Solder Paste Printing), Solder Paste Inspection, Pick & Place (places components in PCB), Furnace, Automatic Optical Inspection, and Pre-test. This process is performed sequentially and automatically, encompassing the assembly of electronic components onto the PCBs and the inter-machine operations. The SMT process requires PCBs derived from laser engraving bearing the corresponding identification code and the electronic components that come in reels and are sourced from the electrical warehouse. The factory currently operates four SMT lines, employing 24 individuals in three distinct shifts.

Soldering: Subsequently, larger components are manually inserted into the assembly and soldered to ensure secure placement onto the board. Finally, the output is automatedly and visually inspected to verify the integrity and accuracy of the assembly.

Lacquering: Certain products within the manufacturing process require lacquering. During this procedure, a fluid is applied as a protective coating, safeguarding the components against adverse environmental conditions, including humidity, dust, temperature fluctuations, and potential turbulence encountered by the electronic device. Meticulous programming of the lacquering process is essential to ensure it is exclusively administered to the predetermined areas, effectively mitigating undesired contact with specific components that must be shielded from direct contact with the lacquer.

Milling: Upon the completion of the preceding procedures, a thinning process is conducted on the PCB to facilitate detachment from the

nutzen. This allows for the separation of the PCB without causing damage. Specific product references are also extracted and packaged individually, ensuring their independent storage.

Final Assembly: The assembly procedure primarily involves manual operations, varying the level of automation depending on the product. In the production lines, various tasks are executed, such as cable insertion, component screwing, and the integration of the electronic module with the plastic or fibrous structure of the finished good. The logistical train (misuzumashi) fills up the supermarkets and border of lines to supply production lines every 45 minutes.

Inspection: After final assembly, the devices proceed to final inspection, where visual and functional checks are necessary to ensure all the quality requirements. The inspection is performed either manually or automatically. In case of positive evaluation, the batch is validated.

Dispatch warehouse: After inspection, the logistic train responsible for transporting finished goods stores the electronic devices in this area until they are shipped to their respective customer.

It is worth noting that besides these listed warehouses that imply operational functions of management, there are two sets of shelves of a considerable dimension to store WIP. The first is located before the machinery pool and supplies all the soldering, lacquering, and milling processes with PCBs. The WIP in this section goes back and forth to the storage shelves because each electronic device has a defined sequence of procedures, which hinders the process from being held in flow. The second WIP storage is located just after the machinery pool and keeps the assembled PCBs (PCBAs) to supply the final assembly process.

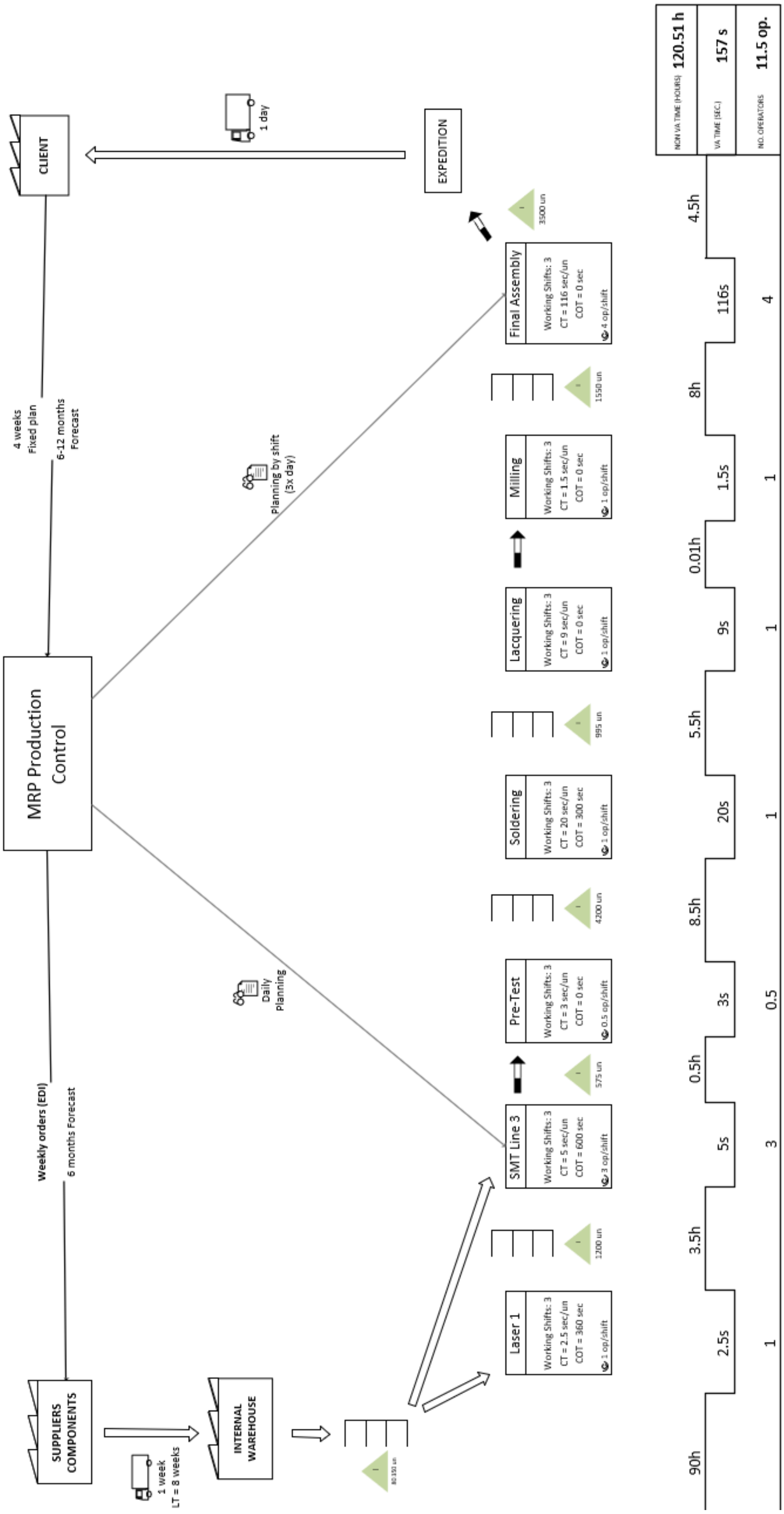

Figure 3.2: Value Stream Map of a complex product produced in Company Alfa

3.2.2 Information Flow Mapping

The information flow delineates the progression of information across diverse operational phases, commencing with the client's order and order forecast and culminating at the juncture when Company Alfa's products are prepared for dispatch from its facilities. The various stakeholders within this information flow are explicated accordingly.

Customers: Customers are the primary external stakeholders who inform the sales department through a VMI tool incorporated into their management system's software. Orders should be fixed in a four-week frozen time frame, however, suppliers do usually not comply with this order regulation.

Sales: Sales forecasting and order processing decisions are made in this division. Each order is connected to its respective EDI (Electronic Data Interchange). Decisions are then made regarding the customer's delivery date while taking into account the desired quantities, customer negotiating power and raw material stock levels. The order request is input into the management system for registration and further confirmation.

Planning: This department centralizes information from all areas involved and is responsible for issuing production orders. Through the order book delivered by the Commercial department, this department makes the production planning in a horizon of one month. This plan is changeable and adapted throughout the month, based on capacity, finished goods stocks, and available raw material, and is therefore reviewed once a week. Daily the plan is issued for the two areas of production. The planning is first idealized for the final assembly production section, and then deployed for the SMT sector.

Purchases: This department establishes the connection between the company and its suppliers. According to the long-term production plan, suppliers are updated weekly on the production needs for short and long-term production spans. According to their production capacity, suppliers inform the company of the achievable service level for that period, followed by a negotiation between the two parties.

Production: This area receives the production orders from Planning via the enterprise resource planning system (ERP) and the urgencies to be included in the plan via email. These orders are transmitted to each line and the target hourly productions are posted. The realized productions are recorded manually on the less automated lines and recorded automatically on the more developed lines. Scraping and rework are recorded manually in the ERP. All stoppages are recorded manually with the associated cause assigned to it (for example: equipment and maintenance failure, supply failure, etc.).

Logistics: This sector is dedicated to maintaining the warehouse, both for raw materials and finished products. Firstly, it receives the raw materials and stores them, and secondly, it is responsible for supplying the RMs necessary for production, through predefined routes (two) and predefined quantities to be carried by the logistics train. Finally, there is another route of the logistics train dedicated to the collection of finished products, ready to be shipped. The storage and dispatch of the finished product in the warehouse are also part of the department's duties.

3.3 Production Planning

Effective production planning is a vital aspect of modern manufacturing operations. The responsibility for this crucial task rests with the production planning team. The company employs SAP as its ERP software to manage raw material (RM) and finished goods (FG) stocks, plan orders and forecasts, and establish production schedules. A customer order creates a purchase order in SAP, and items are allocated from the warehouse inventory or production orders are created if stock is insufficient. However, the lack of automated work-in-progress (WIP) tracking poses a challenge, necessitating manual intervention to assess WIP inventory accurately.

Customer orders are expected to remain stable over a four-week period, yet frequent changes in order quantities and new order additions create a dynamic environment fraught with uncertainty. This unpredictability leads to operational urgencies that demand efficient strategies for adaptation and resource allocation. The Planning Team plays a pivotal role by evaluating the factory's current status, projecting capacity, and aligning resources to formulate a monthly production plan. However, a lack of communication between the Production and Planning teams hampers adjustments and plan fulfillment tracking.

These challenges collectively affect customer satisfaction. The absence of comprehensive WIP visibility, coupled with sub-optimal stock management, results in a planning approach that prioritizes older or urgent orders at the expense of customer requirements.

As described through Figure 3.3, 82.5% of the capital applied in stock corresponds to raw material (11.2 M€), which means that the solution may target a management model for raw materials stock levels.

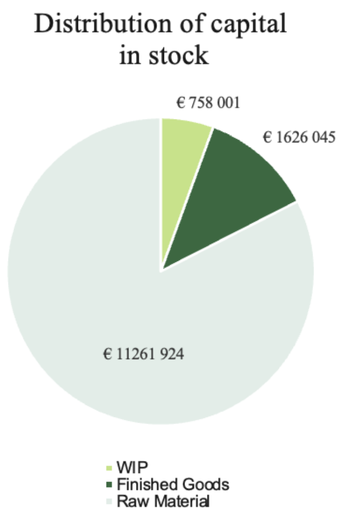

Figure 3.3: Distribution of capital in stock of RM, WIP, FG

3.4 Management model of RM stock levels

Inventory management is a critical aspect of supply chain operations, impacting both costs and customer satisfaction. This study explores the intricacies of inventory management within the context of Company Alfa's operations. Top management has recognized the importance of capital allocation, making stock management a focal point for analysis.

To conduct a comprehensive analysis of the stock management model, it is crucial to begin with a descriptive overview of raw materials (RM) and their stock levels, as well as the supplier landscape.

Raw material items and value

Company Alfa has to manage a high number of SKUs (16407 references), which are responsible for the aforementioned 11.2 M€ of capital. These items have generally small dimensions, enabling a great optimization of the warehouse organization. Packaging units are the units that represent a higher volume.

As it can be perceived through Table 3.1, the raw materials comprising the final assembly are the ones that represent a higher value (51.30%). These are commonly referred to as mechanical parts, typically constituting the metallic or plastic framework that provides support for the electronic elements. Additionally, the raw materials for SMT (Surface Mount Technology) primarily consist of electronic components, which tend to have a higher per-unit cost, represented by the value 38.25%.

Table 3.1: Distribution of Value of Raw Material and WIP between the production areas

Area of Production	Value
Final Assembly Raw Materials	51.30%
SMT Raw Materials	38.25%
PCBA (WIP)	1.94%
Not Defined	8.51%

Although at this moment 40% of the RM are not categorized, as illustrated in Table 3.1, it is expected that most are integrated into the SMT production area.

Stock coverage and turnover ratio

In light of a volatile market environment, the primary objective at Company Alfa's headquarters is to achieve an average inventory turnover rate of seven rotations for raw materials. This target serves a specific purpose, which is to ensure the company's agility and responsiveness in adapting to market fluctuations and demand variations.

It is noteworthy that the current inventory turnover rate stands at 0.42 rotations per year, as calculated from a comprehensive sample encompassing approximately 16407 different SKUs (Stock Keeping Units). This value is considerably below the desired target, underscoring the need for improvements in inventory management.

Furthermore, an average consumption coverage period of 470 days has been observed for the current inventory. Given this extended coverage duration, it becomes evident that Company Alfa should take proactive measures to align its inventory management practices with the stated objective. By doing so, the company can optimize its resource allocation, reduce carrying costs, and enhance its ability to meet customer demands swiftly and efficiently, thus mitigating the risks associated with market instability.

Non Cancelable Non Returnable items

A significant contributor to the high coverage average and the substantial invested capital can be attributed to the procurement of raw materials with Non-Cancelable Non-Returnable (NCNR) clauses. Raw materials subject to this clause typically pertain to items exclusively produced for a specific project, making them highly customizable components.

It is also notable that a substantial percentage of these components are dedicated to the Device X product family. Initially, this specific reference had very high demand forecasts (communicated by the car maker through VMI EDIs), which subsequently experienced a significant decline of nearly 50%. Consequently, as part of the NCNR raw materials, they remained in storage, tying up capital. As illustrated in Figure 3.4, 3.5 million Euros (32.4% of the total raw material value) corresponds to materials sourced from three suppliers exclusively dedicated to Device X.

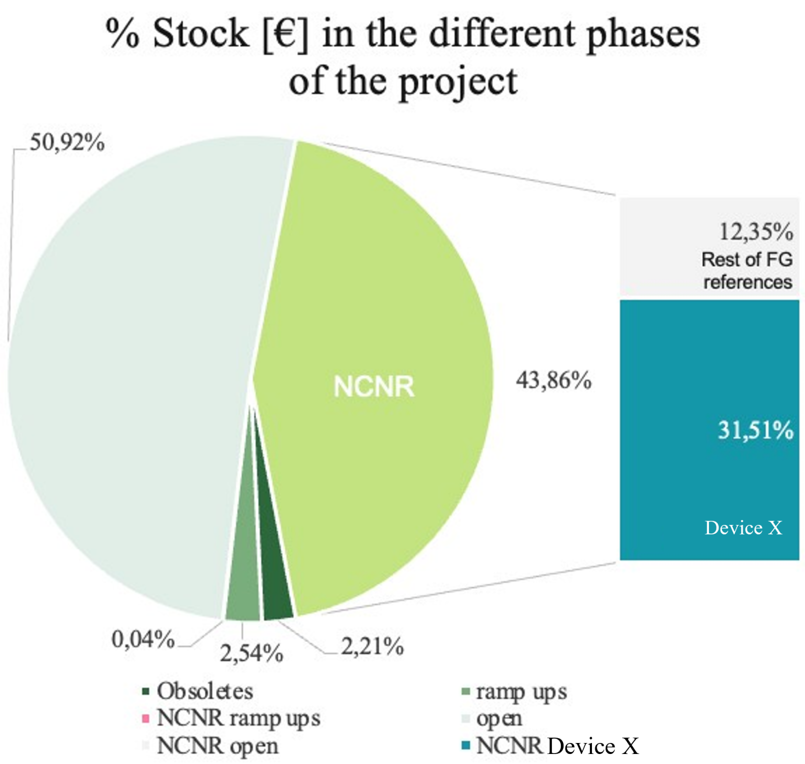

Figure 3.4: Stock in the different phases of the project

Life stage of products

The initial phase of every final product's development is the project and ramp-up stage. During this phase, Alfa's team collaboratively defines the product's requirements and characteristics in consultation with the end client. This process spans several months due to its iterative nature, as the production process must undergo testing on the production lines, and exacting quality standards must be met.

During this stage, numerous components need to be procured, and in certain instances, the minimum order quantities far exceed the actual requirements. Furthermore, some of these components may fall into the Non-Cancelable Non-Returnable (NCNR) category. Ramp-ups account for approximately 2.58% of the total value of raw materials.

The subsequent stage pertains to open projects, denoting active and commonly sold products that maintain consistent demand. These products typically have a life cycle ranging from 5 to 10 years, and when their ordered quantities begin to steadily decline, they transition into the Phase-Down stage. Currently, the ERP system lacks the capability to directly track this stage; instead, it relies on communication with the project's responsible personnel. As a result, the Phase-Down stage is categorized within the open stage, constituting a substantial portion of 94.78% of the total raw material value.

It is noteworthy that nearly half of the raw materials for open projects consist of Non-Cancelable Non-Returnable (NCNR) components, accounting for 43.86%. Additionally, 31.51% of these materials are associated with the Device X FG reference.

Finally, following the conclusion of mass production, Company Alfa is obliged to ensure the continuous production of 10% of the total output for a specific product reference. This production serves to fulfill guarantees and meet orders for a duration of 10 years, and these items are classified as Spare Parts. At the conclusion of this 10-year period, the products transition into obsolescence. Currently, the transition from the Open status to Spare Part status is a manual process and is not consistently executed, resulting in challenges related to data reliability. Furthermore, the transition from Spare Part to Obsolete status is also a manual process, rendering it outdated.

Consequently, a portion equivalent to 2.21% of the raw material value encompasses both obsolete and spare parts, highlighting the need for improved and more automated processes in this regard.

Supplier's overview

Table 3.2 is the result of calculations derived from an analysis involving 16407 SKUs and encompassing a total of 113 suppliers. While the data within the table serves as a reference point, it should be noted that these figures may not precisely mirror the real-world scenario. This discrepancy arises from the fact that the listed country corresponds to the location of the supplier's corporate headquarters, which may diverge from the actual site of production. In essence, a supplier might be headquartered in Europe while conducting production activities in Asia.

Table 3.2: Distribution of Supplier's Value through Country

Country	Value in Euros [%]	Number of SKUs [%]
Germany	50.20%	9.00%
China	12.10%	2.20%
Netherlands	6.10%	2.40%
Ireland	4.00%	0.01%
Spain	2.50%	0.60%
Portugal	2.30%	3.20%
Austria	2.00%	0.10%
Hong Kong	1.90%	0.30%
Taiwan	1.40%	0.10%
Others	3.30%	1.50%
Not Defined	14.2%	80.7%

Nonetheless, it is noteworthy that electronic components (SMT) are predominantly sourced from European manufacturers, with Germany standing out as a particularly prominent supplier. As delineated in the table, Germany accounts for the highest proportion of the company's raw material value (50.2%), constituting approximately 9.00% of the total SKUs held in inventory. Furthermore, it is important to highlight that Portugal's representation in the table primarily pertains to mechanical components.

Additionally, Company Alfa relies on an external warehouse, incurring a monthly cost of approximately €1.000, which further complicates stock management.

Notably, effective RM stock management is crucial due to customer order delays, resulting in the need for special freight shipments. This underscores the advantage of a more conservative approach to RM storage to reduce the necessity for special freight shipments.

Company Alfa employs the SAP platform as the cornerstone of its inventory management strategy. One of the primary challenges is the discrepancy between SAP-recorded stock and actual factory stock. This arises because stock consumption is primarily recorded based on production, omitting parts damaged during production or incorporated into pieces classified as scrap, still in the work-in-progress (WIP) stage. Additionally, the design phase of final products can be time-consuming, with minimum order quantities sometimes exceeding actual needs, leading to stock accumulation. Furthermore, electronic components have expiration dates that must be adhered to for device functionality throughout their lifecycle. Company Alfa's unique, client-specific final products often require specially developed components, particularly electronic ones. These components are procured in high minimum order quantities with non-negotiable volume changes over time.

Vendor Managed Inventory (VMI) Tool

Aligned with industry trends, Company Alfa adopts VMI for stock management. In this approach, automakers and suppliers exchange demand forecasts via EDI for current and upcoming weeks. The VMI tool calculates RM needs based on future order volumes, long-term forecasts, bill of materials, existing stock, and SAP-configured master data for each RM. Weekly updates of RM needs are sent. Suppliers are responsible for controlling lead times, given their access to 6 to 12 months of estimated needs. They must ensure that ordered quantities arrive as scheduled, and in case of delays, alternative solutions are negotiated. This flow is represented in Figure 3.5 which summarizes the information flow of the purchasing process of raw materials. A dedicated group of suppliers is assigned to each member of the procurement team to streamline operations.

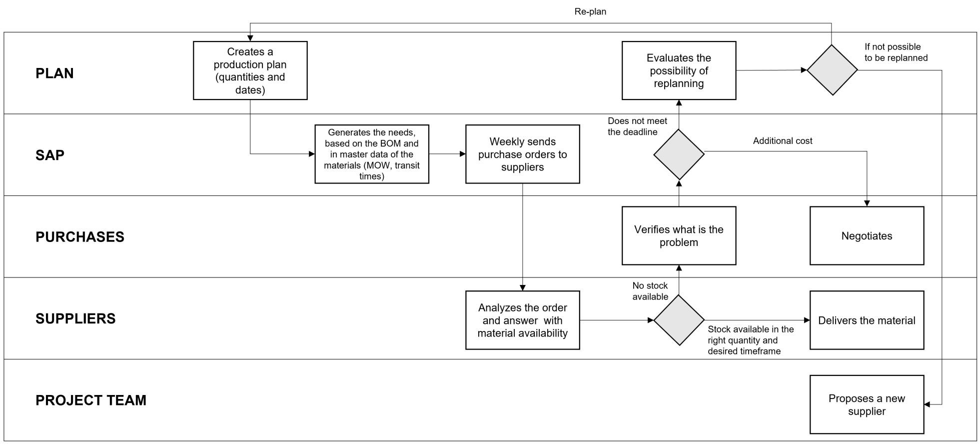

Figure 3.5: Information flow chart of the purchases process

3.5 Main Challenges in Current Raw Material Stock Management

Within Company Alfa's operations, significant challenges are evident in managing raw material (RM) stock levels. These issues have far-reaching effects on operational efficiency, financial performance, and customer satisfaction, aligning with our study's core objective. An immediate overview of the main challenges is provided and individually elaborated. This allows for a more concise focus on the main problems and potential derivatives.

Inaccurate Stock Recording and Visibility

The discrepancy between recorded stock levels in the SAP system and actual stock levels within the factory arises due to the nature of stock consumption, which is primarily recorded based on production output. This method does not account for parts that may be damaged during production or incorporated into pieces classified as scrap, which are still in the work-in-progress (WIP) stage. This lack of visibility into accurate WIP inventory poses a considerable challenge to stock management.

Long Lead Times and Procurement Challenges

Company Alfa contends with long lead times for the procurement of raw materials, which can significantly impact production schedules. Additionally, the company faces challenges related to minimum order quantities (MOQs) that often exceed actual requirements. These factors result in the accumulation of stock, tying up capital and hindering the company's ability to adapt to changes in customer orders and market demand promptly.

Non-Cancelable Non-Returnable (NCNR) Items

A significant portion of the stock is comprised of raw materials with Non-Cancelable Non-Returnable (NCNR) clauses. These materials are highly specialized and are typically produced exclusively for specific projects. While this level of customization is advantageous for meeting customer-specific requirements, it becomes problematic when demand forecasts change. The NCNR materials often remain in storage, tying up substantial capital and adding complexity to stock management.

Customer Satisfaction and Operational Urgencies

The challenges mentioned above have a direct impact on customer satisfaction. In an environment where customer orders frequently change and order quantities fluctuate, operational urgencies become a common occurrence. These urgencies demand efficient strategies for adaptation and resource allocation, affecting the company's ability to meet customer requirements in a timely and cost-effective manner.

Costs and Special Freight Shipments

Inefficiencies in stock management result in additional costs, particularly the need for special freight shipments to overcome stock-related challenges. According to historical data from Company Alpha's Group from 2022, the cost of such special shipments amounted to approximately 18.5 million € per factory. This emphasizes the advantage of a more conservative approach to raw material storage to reduce the necessity for such costly expedited shipments.

In summary, the AS-IS analysis underscores the pressing issues in the current state of raw material stock management at Company Alfa. These issues include discrepancies in stock recording, long lead times, challenges with MOQs, an overreliance on NCNR materials, and the subsequent impact on customer satisfaction and operational costs. Addressing these challenges is central to achieving the objectives of the study, which focuses on minimizing stock while maintaining service levels and reducing capital investment. In the subsequent phases of our research, we will explore recommendations and solutions to address these challenges effectively.

Chapter 4

Methodology

This chapter details the followed methodology, including the different stages involved in the implementation process and the tools and techniques used to monitor and evaluate the effectiveness of the proposed solutions. A detailed analysis of the obtained results is also provided, including the reduction in raw material stock levels, the improvement in production flexibility, and the optimization of procurement processes.

To counter production planning issues, there is a need to improve WIP visibility, enhance inter-team communication, and adopt a more strategic approach to stock management. By addressing these aspects, the company can navigate uncertainties more effectively, align production with demand fluctuations, and ultimately deliver improved customer satisfaction.

The chapter concludes with a discussion of the potential actions to preserve and improve the developed project, including the need for continuous monitoring and evaluation of the implemented solutions and the importance of maintaining a culture of continuous improvement within the company.

4.1 Root Causes

The methodology applied was developed with the Purchase and Logistics team's input. Four in-person half-day meetings happened with the whole team. The first was solely dedicated to finding the root causes of the possible misadjustment of the dimensioned raw material stock.

Hereafter, the wrong dimension of raw material inventories is assumed. From the perspective of the team, it is possible to reduce the in-house inventories, however, the analysis further conducted will validate or not this assumption.

The Ishikawa diagram was chosen to frame the exploration of the root causes. The typical 6M categories (man, machine, method, material, measurement, and Mother Nature/Environment) were adopted. From the listed root causes in B, it is important to highlight some topics.

- Obsolete and Spare Parts: Within the automotive supply chain, even after a given electronic device production has ceased, the supplier must guarantee any need for at least 10% of the total production for a 10-year time period. The raw materials used to produce these products are considered Spare Parts. After the 10-year period, the products are considered obsolete. Besides, since electronic devices have an expiring date associated, raw materials can be classified as obsolete earlier. At the moment, there is no consistent process of revising the obsolescence of the raw material, and the information cannot be retrieved directly from the information system.

- Master Data parameterized in SAP: Although the ERP system SAP calculates the needs by taking the real and expected orders, the calculation has always the input parameters into consideration. The most critical parameters are: Safety time, Goods Receipt (GR) Processing Time, Incoterm, and Minimum Order Quantity (MOQ). Safety time is parametrized taking the team's expertise and experience into account, and not based on any formula. The Incoterm, which affects directly the GR processing time, is not updated accordingly. As for Minumum Order Quantity, it was noted that the team that manages the the RM needs and deadlines and the team that initially negotiates prices and MOQ (which works centrally for the group to which Company Alfa belongs) do not establish consistent communication. Therefore the input data in SAP is not updated to the last price negotiations. ABC is performed automatically by SAP with sales history, and real and forecasted orders. Currently, there is no periodicity in the revision of these parameters.

- Non-Cancelable Non-refundable items are a source of excess inventory from the real needs, however, they are unavoidable for the customized components. The negotiation procedure is not standardized, therefore, there may be room for improvement.

- Negotiation with suppliers was deemed crucial, especially in terms of MOQs and the frequency of deliveries. Since the coverage in days of the quantities ordered must be at least the period between reception of the material.

- Absenteeism was considered one of the factors that most impacted the production plan, and therefore, the ordered quantities are inadequate for the real consumption of material. In fact, absenteeism is responsible for the sourcing of temporary staff to guarantee the production of the demand.

- Phase Down stage does not have a standard of operation, which is deemed as a source of excess inventory. Facing a reduction in orders, forecasts are less accurate and errors in the purchasing process may not be absorbed in the upcoming months.

In light of all the enumerated factors, the most significant factors can be summarized into five dimensions that impact the orders placed for Raw Materials (RMs): Master Data Parameterization, Supplier Negotiations, Formula of SAP, Forecast and Production Planning, Vendor-Managed Inventory (VMI).

Out of these five dimensions, it is worth noting that only Master Data Parameterization, Supplier Negotiations, and Forecast and Production Planning can be adjusted within the scope of the ongoing workshop. Company Alfa is part of a multinational corporation, and the global SAP Parameterization is controlled by the headquarters. Since other manufacturing units also utilize the same platform, the calculations have been optimized over the years.

Furthermore, the VMI method represents the standard approach employed within the automotive industry's value chain, as indicated in the literature review. All existing contracts with customers conform to this method, and numerous agreements with suppliers are established accordingly. Additionally, it is essential to emphasize that the VMI methodology facilitates a reduction in the Bullwhip effect, making it advantageous due to the enhanced visibility of needs throughout the value chain.

4.2 Analysis of the identified influencing dimensions

In the present section, an in-depth analysis of the existing challenges and potential solutions will be undertaken. This rigorous examination is based on the methodology developed in collaboration with the Purchase and Logistics team, involving a series of comprehensive discussions. The objective is to present insightful solutions aimed at optimizing Company Alfa's procurement and inventory management practices, thereby addressing the previously highlighted issues.

4.2.1 Master Data Parameterization

Solutions to tackle the challenges surrounding Master Data Parameterization will be presented. These issues involve critical elements including Safety Time, Goods Receipt Processing Time, Incoterms, Minimum Order Quantity (MOQ), and the need for periodic reviews.

4.2.1.1 International Commercial Terms (Incoterms)

A comprehensive analysis of transit times for electronic components revealed a misalignment with the contracted Incoterms. By definition in Company Alfa, transit times are set at 1 day for domestic suppliers and 5 days for European suppliers, with Asian suppliers being individually assessed. Consequently, all components from the same supplier were assigned the same transit time, even though these components may originate from different locations. This generalization occasionally led to the inadvertent disregard of the agreed-upon Incoterms during parameterization.

The accurate assessment of transit time discrepancies in accordance with the designated Incoterms is a complex undertaking, primarily owing to the presence of a designated address for the respective supplier, often corresponding to the supplier's headquarters, which may not align with the actual point of departure of the product. Consequently, an immediate review of transit times becomes unfeasible. To underscore the necessity and efficacy of this evaluation, the focus should be on Incoterms that absolve Company Alfa of transportation responsibilities. Within this category, the supplier assumes maximal responsibility for delivering components to the buyer, ideally resulting in negligible transit times. In this context, Incoterms such as DDP (Delivered Duty Paid), DDU (Delivered Duty Unpaid), and CPT (Carriage Paid To) hold relevance.

Electronic components were then chosen based on transit times defined as greater than 0.

Adjusting transit times resulted in a reduction of the supplier's lead time for these components. On the one hand, the reduction in supplier lead time yields notable advantages in terms of cash flow management. With shorter lead times, the organization can minimize its working capital requirements by decreasing the need for substantial funds to be tied up in maintaining high levels of safety stock, which were previously necessitated by longer lead times. On the other hand, the reduction in supplier lead time enhances overall inventory turnover, thereby reducing the risk of obsolescence and improving the efficiency of working capital utilization. Additionally, a leaner safety stock strategy promotes a more agile and responsive supply chain, allowing the company to adapt swiftly to changes in customer demand patterns or market dynamics. Table 4.1 lists the types of Incoterms, the number of references of each type, and the expected financial benefits of the designed solution. This methodology applied to only three types of Incoterms, allowed a freed cash flow of 89,887.6€, by changing less than 200 references.

Table 4.1: Types of Incoterms, Number of References, and Potential Financial Benefits

Type of Incoterms	Number of References	Transit Time	Potential Financial Benefit
DDP	170	5	47,918.4€
DDU	5	5	37,065.1€
CPT	4	5	4,904.2€
Total	**179**	**5**	**89,887.6€**

4.2.1.2 Lack of Lead Time Track

As previously alluded to, the Vendor-Managed Inventory (VMI) framework entails active supplier involvement in the comprehensive management of inventory. This active participation encompasses the oversight of stock levels, continuous monitoring of demand dynamics, and the initiation of timely replenishment orders at the precise juncture of customer consumption. The VMI approach hinges upon the analysis of real-time or periodic inventory data, affording the vendor the capacity to discern the optimal timing and quantity for inventory replenishment. Consequently, the vendor supports the responsibility of instigating procurement orders while efficiently orchestrating the logistical intricacies associated with delivering goods to the customer.

In the context of the present case study, the VMI system updates the inventory requirements on a weekly basis for all forthcoming weeks within a forward-looking horizon ranging from 6 to 12 months. This dynamic process facilitates the perpetual alignment of inventory with shifting demand patterns. It is noteworthy that the stipulated lead time agreement with customers stands at 4 weeks, equivalent to 20 business days or one calendar month. This fixed lead time signifies that suppliers assume no obligation to accommodate changes in demand for the four forthcoming weeks. In instances where fluctuations or alterations in demand transpire within this stipulated four-week window, the adjustment task necessitates a manual intervention, wherein the procurement team is required to recalibrate and align procurement activities with the emergent demand dynamics. It is paramount to recognize that suppliers reserve the prerogative to exercise their discretion in accepting or rejecting such demand alterations.

Collaboration between the customer and the vendor is formalized through a meticulously crafted VMI agreement. This contractual accord delineates the precise terms, delineation of responsibilities, and performance benchmarks, frequently encompassing specific specifications in regard to the nature of products, projected demand expectations, and the stipulated frequency of replenishment. Furthermore, a central authority within the Company Alfa Group is entrusted with the management of supplier lead times through the negotiation of contracts and associated terms. Day-to-day inventory management, however, falls within the purview of Company Alfa's operational sphere. However, the contractual lead time data, though solicited, could not be obtained within the stipulated time frame for this master thesis.

Furthermore, a noteworthy aspect of the operational landscape is the absence of visibility concerning supplier lead times from the beginning of production to the delivery of goods to the client's facility. The absence of a comprehensive tracking system complicates the assessment of supplier lead time variability. This assumes significance due to the fact that, on occasion, the stipulated quantities fail to be delivered punctually. Consequently, there arises a need to engage in negotiations with alternative suppliers or to adjust the procurement quantities accordingly. An additional pivotal consideration in this context is the computation of safety stock levels, a prerequisite that hinges fundamentally upon an accurate understanding of supplier lead time variability. The intrinsic relationship between lead time variability and the provisioning of safety stock underscores the indispensable nature of this data element within the broader framework of supply chain management and inventory control. Consequently, the absence of such insights presents a critical operational challenge that necessitates meticulous attention and resolution.

4.2.1.3 Safety Stock Definition

Safety Stock, as previously mentioned, heavily depends on the variability of raw material delivery and product demand.

Currently, Company Alfa only defines the Safety Time parameter, as described in Chapter 3, for net requirements calculation. This is the result of the team's consensus and further proven by the consulted literature, where safety time is applicable in cases of more uncertain delivery or production lead times.

Given that Company Alfa doesn't track actual delivery lead times from suppliers, its variability cannot be calculated. Moreover, the lack of historical data further constraints defining its oscillation. In fact, during the agreed period with the supplier, some units of the ordered item may be received, making it impossible to cross-check the order and receipt, as quantities and arrival dates may vary. Since VMI is used, purchase orders are only grouped after several weekly orders, so the number of purchase orders doesn't allow for this.

As a result, lead time can be approximated to the frozen time fence, which is 4 weeks (20 business days) for all contracts with suppliers. However, it is known that this frozen time fence is much more flexible for mechanical materials and those of Portuguese origin and can be as short as 5 days if there is a need to change quantities. Consequently, this approximation may be very rough. Thus, the references were approached with 3 different values: estimated, undervalued, and overvalued. The latter differs from the estimated value by a certain percentage according to the reference.

An overview of stock tracking of the company for the year of 2022 was reviewed. This analysis was divided due to the high number of references to be reviewed (more than 16,000). Therefore, the top 30 references in stock quantities were selected for review, which were used in the last six months and are not Non-Cancelable Non-Returnable (NCNR) since no visible results would be obtained within a 3-month scope. These references added up to the equivalent of 1.8 million euros (approximately 5.6 million components) in total, of which the safety stock of approximately 67% of these references range from 24% up to 51% of the total stock. This translates to a majority of references having at least a quarter of the total amount allocated to safety stock.

This analysis enabled to have a better perception on the real distribution of safety stock compared to the level of stock per material. It is important to note that this analysis was performed for a given day, and that the stock level varies day to day.

In a simplistic manner, reference y1y of raw material was chosen and the evolution of the stock level was represented graphically, in Figure 4.1. The defined safety time for reference y1y was 5 days and the MOQ is 1000 units. The average daily consumption is 2646.8 units. In this case, the safety time could be reduced up to 2 days, however, this was a conclusion taken from a discussion from the purchasing team.

To extrapolate this conclusion to any formula, this analysis has to be performed to a considerable sample of references. Within the development of this project, it was not possible to reach significant results.

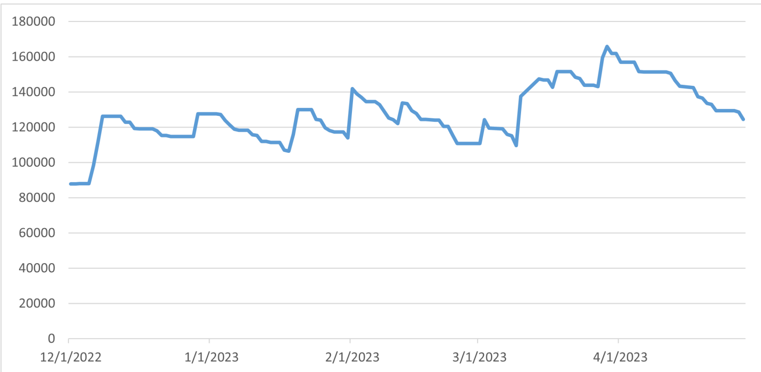

Figure 4.1: Evolution of stock level of reference y1y from the 1/12/2022 to 28/4/2022

4.2.1.4 Obsoletes and Spare Parts

Given the absence of a clear distinction between products that are approaching their end-of-life stage, designated as spare parts, and those that have already transitioned into obsolescence, the initial approach involved the establishment of a structured information framework.

Information regarding each reference or project is consolidated under the purview of the project manager, without a common database in place. To address this, a grid was constructed for each project manager to identify all projects under their responsibility (consult Appendix C for a simplified version). This grid allows them to attach order progress, and historical Bills of Materials (BOMs) for reference, classify the project's status, and record the total count of ordered electronic components.

This grid undergoes biannual updates, as the lifespan of these components tends to be relatively long, averaging around five years. Consequently, this approach enables the identification of references at various stages. Particularly with regard to spare parts, it permits the direct calculation of the quantity of components to be maintained in order to ensure service levels. Simultaneously, it facilitates the tracking of the transition of spare parts into obsolescence.

Obsolete materials are subjected to a higher-level decision-making process. They are initially assessed for value, potential component sales are explored, and disposal options are presented. Subsequently, these items are removed from the warehouse, with the primary benefit being the liberation of storage space.

Of the more than 245 000€ applied in this type of raw material, almost 27% of the value was deemed totally obsolete. Therefore, the valuation of the total Raw Material inventory is reduced in 66 000€.

The removal of these items has not been performed within the period of development of this dissertation. However, approximately 13 600 € in warehouse savings were estimated yearly. These were based on space occupation, mainly in the external warehouse (9 000 € in square meters freed yearly), better material flow (2 200 € in accidents and material circulation within the warehouse) and labor reduction (2 400 € for picking, storing and management activities).

4.2.2 Supplier Negotiations

4.2.2.1 Evolution of Non-Cancelable Non Returnable items

Currently, there are 72 suppliers offering NCNR components, contributing to a total of 1410 SKUs.

Table 4.2: Distribution of value of Non-Cancelable Non Returnable items

Number of references	Employment area	Value [€]
155	Project	262 024€
13	Spare Parts	28 035€
6	Obsoletes	6 582€
1236	Open	4 916 800€

Justifying the Values in the 4.2, it is natural that in the course of a development project, there is a significant investment in raw materials. Since this phase precedes the production stage, the consumption is not yet sufficient to deplete the ordered quantities. However, it is essential to be mindful of the expiration dates of electronic components and take into consideration that the project is still in the testing phase, so as not to procure components that may ultimately go unused. Maximizing the utilization of the same components across different references serves to reduce the uncertainty surrounding this consumption.

Regarding spare parts and obsolete items, the methodology applied will be consistent with that elaborated upon in the preceding section.

The primary negotiations are conducted by the central procurement team of Company Alfa's group, affording them a more competitive position due to their ability to negotiate at scale for various manufacturing units.

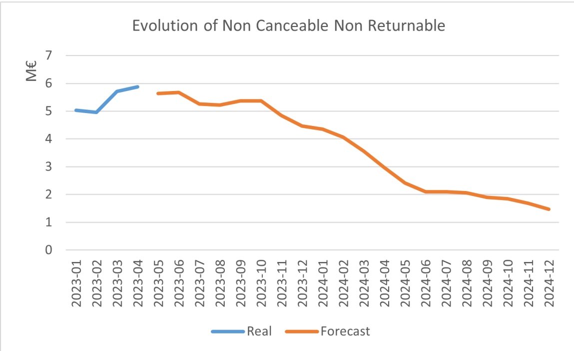

Figure 4.2: Evolution of Non Cancelable Non Returnable

In conclusion, there is little that can be done with regard to NCNR (Non-Cancelable Non-Returnable) items, apart from exercising increased diligence in the planning of requirements and demand forecasts.

From the visual representation, it is evident that the value of NCNR items tends to decrease over time. Nonetheless, it should be emphasized that the emergence of new NCNR items is a recurring occurrence, and thus, the complete elimination of this fraction is not to be expected.

4.2.2.2 Minimum Order Quantities and Frequency of Delivery

In the realm of modern manufacturing, optimizing operations to strike the right balance between efficiency and customer satisfaction is of paramount importance. This equilibrium often hinges on two key factors: minimum order quantities (MOQs) and the frequency of delivery. These aspects have significant implications for production planning and play a pivotal role in meeting customer demands while managing operational costs effectively.

The objective of this analysis is to identify MOQs that are misaligned with the delivery frequency of a given supplier and, ultimately, to pinpoint suppliers with misaligned delivery frequencies for all the materials they provide.

An indicator, denoted as X, is used to assess this alignment, calculated as follows:

$$X = \frac{MOQ}{(AverageDailyConsumption \times DaysBetweenSupplierDeliveries)}$$

When the X value tends toward:

Table 4.3: Analysis to the 9 identified references and respective savings

Material	MOQ	Avg Daily Cons.	X	Freq bet. Deliveries	New MOQ	Saved stock [days]	Saved stock [€]
x1x	192000	2284.8	16.81	5.00	50000	62	€ 7,201.2
x2x	100000	2.8	7045.75	5.00	5000	33467	€ 468,377.3
x3x	20000	87.2	45.88	5.00	500	224	€ 19,587.1
x4x	40000	150.3	53.22	5.00	3000	246	€ 17,077.4
x5x	31552	244.0	25.86	5.00	1000	125	€ 69,382.3
x6x	10800	83.5	25.88	5.00	1200	115	€ 3,943.4
x7x	22400	1.9	2352.27	5.00	500	11499	€ 117,671.0
x8x	16000	124.8	25.64	5.00	4000	96	€ 9,202.4
x9x	15000	141.5	21.20	5.00	5000	71	€ 26,017.8

1. $X \to 0$: MOQ is significantly lower than the average consumption between supplier deliveries, meaning that MOQ has little influence on the stock level.

2. $X = 1$: MOQ equals the average consumption between supplier deliveries, indicating that ordering a minimum lot size should adequately cover the consumption during the delivery period.

3. $X >> 1$: MOQ greatly exceeds the average consumption between deliveries, signifying that MOQ is dictating purchases, contributing to an undesirable stock level that is gradually consumed. It's important to note that procuring materials with X ratios of this magnitude poses a higher risk, particularly in projects that are in the phase-down stage due to the risk of obsolescence.

To determine a critical value for renegotiating Minimum Order Quantities, a threshold value denoted as 'B' was defined. Obsolete stocks and spare parts were excluded from this analysis. Additionally, in the initial iteration, NCNR (Non-Cancelable, Non-Returnable) stocks were excluded, as the values of 'B' were of a different magnitude.

From this analysis, the value of B was set as the third quartile of the X range (1st iteration: B = 8.6).

The initial iteration yielded 993 references from 58 suppliers that required review. This remained a considerably high number for a negotiation round. Consequently, only references with a total value exceeding €10,000 were considered, reducing the number to 27 references from 8 suppliers.

This list was submitted to the central department of the Alfa Company Group for MOQ renegotiation.

From the first analysis, it was possible to negotiate changes in 9 of the references. The indicator monitored for negotiation progress was the reduction in coverage days, calculated using the following formula:

$$\frac{MOQ_i - MOQ_f}{AverageDailyConsumption}$$

Table 4.3 summarizes the variables that most contributed to justifying the need for renegotiation. The team was able to negotiate interesting deals, that enable a total of 738.460€ in free cash flow. The benefit is not as direct, as a saving, but releases money to be invested in other areas, as well as frees space in the internal warehouse and optmizes material flow. It was not possible to estimate the economic benefit, considering the space liberation, however, it was possible to estimate better material flow, enabling labor reduction (2 400€/yearly for picking, storing and management activities).

4.2.3 Forecast and Production Planning

Production planning is the bridge between forecasting and efficient production execution. It involves converting demand forecasts into actionable plans, considering various factors such as production capacity, lead times, and supplier constraints. Effective production planning aims to strike a balance between meeting customer demand and avoiding overproduction.

Absenteeism and Variable Salary A comprehensive understanding of these topics sets the stage for a critical discussion on absenteeism and its relation to variable salary structures within the manufacturing environment.

Managing absenteeism in a manufacturing setting is a multifaceted challenge with far-reaching implications. Absenteeism can disrupt production schedules, reduce productivity, and strain workforce morale. To address this issue, organizations often implement variable salary structures that incentivize attendance, productivity, and quality.

The approach to combat absenteeism typically involves assessing individual absenteeism rates. This assessment is critical as it determines an employee's eligibility for variable salary incentives. Various criteria are used to evaluate absenteeism, with different levels of severity associated with corresponding rewards or penalties. For instance, minor delays may incur minimal consequences, while recurrent or prolonged absences may result in substantial penalties.

Simultaneously, the variable salary structure extends beyond absenteeism to encompass broader performance indicators. Productivity and quality are essential components of this system, with metrics like Overall Equipment Effectiveness (OEE) and quality control measures playing central roles.

OEE, while initially applied at the factory level, holds the potential for individualization in the future. It serves as an indicator of overall operational efficiency and can reward employees for contributing to enhanced productivity. Similarly, a focus on quality control, coupled with the incentivization of conforming components, emphasizes the importance of maintaining product quality even amidst increased production output.

As a result, the present thesis proposes a holistic approach to absenteeism management, coupled with variable salary structures, with the purpose of reducing absenteeism rates to a specific target, fostering a motivated and engaged workforce. Thus, iterations to the variable salary method will be undertaken to fine-tune its effectiveness until the desired absenteeism reduction goal of 6.5% is achieved. It is noteworthy that the current absenteeism level is at 11.2%, meaning that this metric is expected to be improved by 42%.

More specifically, it is proposed that strategies be delineated to *i) effectively manage absenteeism* and *ii) decrease absenteeism.*

Concerning *topic i) absenteeism management*, in instances where ensuring planned production cannot be achieved due to a shortage of personnel, the decision has been made to opt for the temporary cessation of entire production lines as opposed to altering the cycle times of multiple lines. This course of action specifically applies to production lines 13, 17, and 48, as they are responsible for manufacturing products catering to less stringent client requirements. This, in turn, affects a total of 81 distinct finished product references.

Secondly, pertaining to *topic ii) reducing absenteeism*, it was established to develop a variable compensation model predicated upon three key parameters: absenteeism, productivity, and quality. The allocation of weights to each of these parameters is contingent upon their relative significance, and these weightings have been jointly determined in collaboration with Company Alfa.

$$VariableRemuneration = Y(0.5 + 0.25W + 0.25Z) \quad (4.1)$$

The absenteeism variable is assessed individually, in accordance with the following weighting scheme:

Table 4.4: Percentage level for each range of unjustified delays

Number of unjustified delays	**Y (%)**
Instance of unjustified delay < 1 hour	100%
Instance of unjustified delay > 1 hour	50%
Instances of unjustified delay	0%

Contrarily, the definition of the two remaining parameters is carried out collectively, given their direct relevance to the overall outcomes of company operations. Specifically, with respect to productivity, it is not computed individually; however, the Overall Equipment Effectiveness (OEE) is consistently monitored. Nevertheless, owing to the inherent challenge of individualizing this parameter for each employee, as they may be assigned to multiple production lines within a single day, the decision has been made to consider the OEE parameter as reflective of the factory's overall performance. It is important to note that while this approach may temporarily forego the benefits associated with individualization in terms of motivation, once the capability for individual tracking becomes feasible, the OEE parameter will transition to an individual assessment.

Table 4.5: Percentual levels for each OEE range

OEE (%)	**%**
$[84\%, 100\%[$	100%
$[83\%, 84\%[$	50%
$[0\%, 83\%[$	0%

Following a similar rationale, the quality parameter will likewise be subject to evaluation, as heightened productivity should not come at the expense of diminished quality. Although quality is an inherent component of Overall Equipment Effectiveness (OEE), reinforcing this facet is imperative due to the critical significance of process self-control within the production process. Consequently, a heightened and incentivized emphasis on the critical assessment of component quality is instituted. Analogous to the OEE, individualizing this parameter presents inherent challenges; as such, it will be quantified as a ratio of components that fail a test in the production and are, therefore, sent to the Analysis department, compared to the total components manufactured. The subsequent step in achieving parameter individualization will involve segregation by production area, namely, Final Assembly, Pre-Assembly, and SMT (Surface Mount Technology).

Table 4.6: Percentual levels for each range of components' entries in the Analysis Departament

Parameter	**Range (%)**	**%**
% Analysis Entries	[0%,0.8%[	100%
% Analysis Entries	[0.8%,1%[	50%
% Analysis Entries	[1%,100%[	0%

It is noteworthy that in the context of worker absenteeism, particularly when the minimum attendance requirements are not satisfied, the worker will not receive a valuation for the remaining parameters.

To finalize, iterations of the variable reward method will be carried out until the targeted absenteeism rate of 6.5% is reached. These iterations may encompass modifications to both the variable remuneration structure and the weightings assigned to each variable. Considering the 300-people team that work in gemba in the three shifts, if this approach achieves the target level of absenteeism from 11.2% to 6.5%, 14 employees would be freed to other activities, or 14 temporary employees may not have their contract renovated. However, it is important to highlight that these results are not obtained straightforwardly and that this is an optmistic scenario.

4.3 Culture of Continuous Improvement

In order to develop a culture of continuous improvement, methodologies have been implemented at Company Alfa that not only encourage teams to motivate themselves, but also to take a critical look at the workshops they are developing, allowing them to achieve better results on various fronts. Project management methodologies were implemented, namely Mission Control and Steering Committee, as well as Standard Work methodologies.

Mission Control is a weekly meeting attended by the leaders of the various initiatives, with the aim of frequently checking the team's work planning. It is also an excellent way of encouraging the participation of all the leaders to share knowledge and support decision-making.

These meetings are based on visual tools that support the discussion of essential topics for improvement. They are organized with a standardized agenda starting with the attendance map, timetable and analysis of indicators and last approximately half an hour. The indicators include, in a more macro view, an analysis of final assembly productivity, monitoring of SMT OEE and the level of raw material stock. The indicators for the various workshops are then analyzed individually using A3, which also summarizes the latest actions taken, next ones and which need to be escalated to higher decision levels.

The Steering Committees are monthly meetings lasting approximately one hour which provide a more comprehensive view of the project. These meetings include not only the members of Mission Control, but also the plant management.

These meetings begin with the status of the various workshops, followed by an analysis of the global KPIs and a discussion on the countermeasures to solve problems. The Steering Committees allow good practices to be shared and tensions to be resolved.

Chapter 5

Conclusion

This chapter functions as the culmination of the research undertaken in this thesis, offering a succinct recapitulation of the principal discoveries and outcomes. Furthermore, it delves into the prospective relevance of these findings and underscores any constraints and unresolved questions that have arisen in the course of the present investigation, thus furnishing valuable points of reference for future scholarly pursuits. The content in question will be scrutinized within the context of the literature review, the methodological framework developed, and the practical outcomes derived during the course of this project.

5.1 Overview and Contributions

This section furnishes a comprehensive synopsis of the pivotal findings and contributions derived from the study. It endeavors to provide a concise encapsulation of the research objectives, methodologies employed, and the consequential outcomes.

The central aim of the present research was to enhance the procurement process within the electronic automotive industry, and the study's success is predicated on its ability to address the defined research questions.

In particular, the first research question - *What are the dimensions that impact the optimal raw material stock level in the electronic automotive industry?* culminated in the determination that the most influential factors impacting the orders placed for Raw Materials can be distilled into five dimensions: Master Data Parameterization, Supplier Negotiations, SAP Formula, Forecast and Production Planning, and Vendor-Managed Inventory.

The second research question intended to reflect on *How should the impacting dimensions be incorporated into the stock definition?*, where the identified dimensions where further analysed in the context of the case study's paradigm. It was concluded that the dimension of Master Data Parameterization encompasses elements such as Safety Time, Goods Receipt Processing Time, Incoterms, Minimum Order Quantity, and the necessity for periodic reviews. Supplier Negotiations encompass considerations involving the Evolution of Non-Cancelable Non-Returnable items and the Minimum Order Quantities and Frequency of Delivery. In addition, it is crucial to implement regular reviews of these parameters to maintain their accuracy and relevance. Furthermore, because effective production planning aims to find a balance between meeting customer demand and avoiding overproduction, the fourth dimension centers on ensuring the capacity to execute the predefined plan. In the context of this case study, this entailed an examination of absenteeism and its correlation with variable salary. To finalize, the Vendor-Managed Inventory dimension was scrutinized within the framework of Inventory Management Strategies, leading to the determination that in the specific sector under examination, a Vendor-Managed Inventory VMI framework stands as the most advantageous approach, as it is directly associated with reduced inventory costs and process responsiveness.

Summarizing the main results of this dissertation in Company ALfa, as for revising ERP parameterization, starting by Incoterms and Transit Times Revision, which was applied to only three types of Incoterms, resulted in a freed cash flow of 89,887.6€. Furthermore, revising obsoletes and spare parts raw material, out of the more than €245,000 invested in this raw material type, nearly 27% of the value was identified as totally obsolete.Consequently, the valuation of the total Raw Material inventory was reduced by €66,000. Considering the warehouse associated costs an estimated yearly savings of €13,600 was projected, based on freeing up space and reducing labor costs. Safety time parameterization shows promising results, however, for now, it is not possible to show the impact of such methodology.

Considering the negotiation with suppliers, specially in terms of MOQs, the team successfully negotiated deals that resulted in a total of €738,460 in free cash flow and it improved material flow and labor reduction of €2,400/year.

Lastly, to counter production planning issues arisen from high absenteeism levels, a target rate of 6.5% is expected to be reached, which could potentially free up to 14 employees.

While this analysis pertained to a specific company within the electronics automotive sector, its implications extend beyond the confines of this singular case. The identified dimensions, such as Master Data Parameterization, Supplier Negotiations, ERP Formula, and Vendor-Managed Inventory, represent fundamental aspects of procurement and supply chain management that hold relevance for the broader industry. The key findings related to optimizing inventory management, ensuring pricing accuracy, and enhancing process responsiveness are applicable principles that can be extrapolated to other firms operating within the electronics automotive sector. The publication of this study is anticipated to offer valuable assistance to other firms operating within the electronics automotive sector by providing a well-founded initiatives for enhancing their procurement and supply chain practices. Particularly, the insights and findings presented in this research illuminate key areas of focus, guiding other companies in the electronics automotive sector toward more effective and efficient supply chain and procurement management practices.

Therefore, while the specific strategies and parameters may vary from one company to another, the overarching lessons and best practices gleaned from this analysis hold the potential to benefit a spectrum of firms within the electronics automotive sector, offering valuable insights and guiding principles for optimizing their procurement and supply chain operations.

Particularly, it offers invaluable insights into enhancing procurement strategies, particularly in the domain of raw material stock management. By providing a holistic examination and optimization of procurement strategies, this study extends its contributions to the field. The findings unveiled here have the potential to assist enterprises within this industry to strike an equilibrium between reducing raw material stock levels and meeting service level requirements, ultimately leading to capital savings. Additionally, the study underscores the paramount significance of supplier selection and effective relationship management in the procurement process. This acknowledgment can serve as a catalyst for improving supply chain management practices among enterprises.

5.2 Limitations and Future Research

This section is dedicated to highlighting the constraints and unresolved queries that have arisen from the present study, with the overarching aim of pinpointing directions for future research.

Specifically, several promising avenues for future research within this domain warrant exploration, which aim to contribute to the ongoing enhancement of supply chain and procurement practices in the dynamic electronic automotive industry:

Supplier Selection and Relationship Management Strategies

Future research should delve into the effectiveness of different supplier selection and relationship management strategies within the procurement process. This investigation will consider a range of approaches, with a particular focus on Non-Cancelable Non-Returnable (NCNR) references. The objective is to gain a deeper understanding of strategies that yield the most significant benefits in this complex industry.

Reevaluating Safety Times and Lead Time Variability

A crucial research area involves reevaluating safety times while considering the actual variability in lead times. Understanding and mitigating lead time variability is essential for maintaining an efficient and responsive supply chain. Recalculating safety times to align with real-world lead time dynamics will be a pivotal step in achieving this goal and enhancing operational efficiency.

Extrapolating the analysis to processing all existing data

To highlight the parameters that appear to be maladjusted to the real client and supplier's panorama, it is of utmost importance to create a system that applies the tested methodologies automatically. This is possible recurring to tools like Microsoft PowerBi, and replicating the indicators that were deemed as the key drivers to decisions. From this point, the purchasing team is autonomous on the evaluation and possibly negotiation of parameters.

Enhancing the value chain with Pull planning in production

To improve the fulfillment of production plans and enhance the purchasing process, future research should focus on implementing production leveling systems tailored to Company Alfa's actual capacity. Additionally, exploring a sequencing system that can coordinate various production areas seamlessly and offer flexibility within the production process is essential. This research can address operational challenges and further enhance Company Alfa's efficiency and responsiveness.

An additional limitation of the study was the constraint imposed by the specific guidelines set forth by the Company Alpha group, which acted as the primary authority. Consequently, certain aspects were not subject to challenge or alteration, limiting the extent of analysis in those particular areas.

During the time frame of development of this dissertation, it was not possible to evaluate all the existing information, concerning raw material. Therefore, the methodologies should then be tested for different types of products, specially the lower-valued ones, that were neglect from the performed analysis.

Finally, it is crucial to acknowledge that although the dimensions identified in the present study may appear comprehensive, it is imperative to recognize the potential for further research in this field to unveil additional dimensions. Therefore, maintaining an openness to the prospect of expanding the spectrum of dimensions contributing to the enhancement of the procurement process is of paramount importance.

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Appendix A

Value Stream Map Development

Figure A.1 depicts an illustration of a value stream map that was crafted during an interactive workshop session. This session served as a platform for participants to engage in brainstorming, gain enhanced insights into the material and information flow, all while being physically present in the GEMBA.

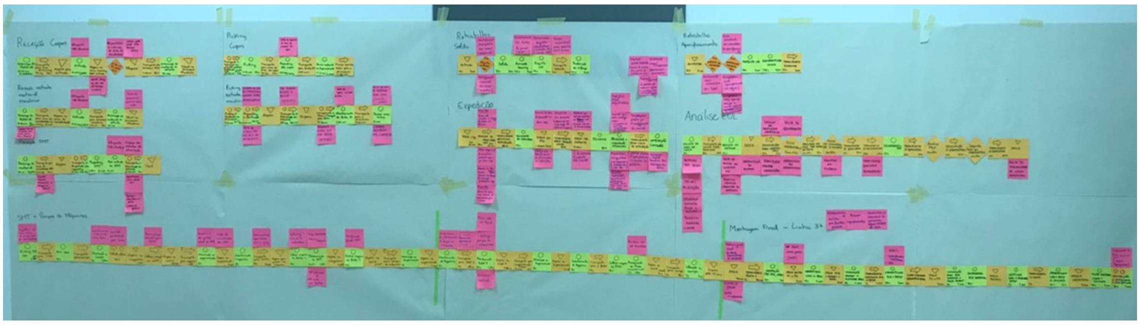

Figure A.1: Value Stream Map developed during workshop sessions

Appendix B

Fishbone Diagram

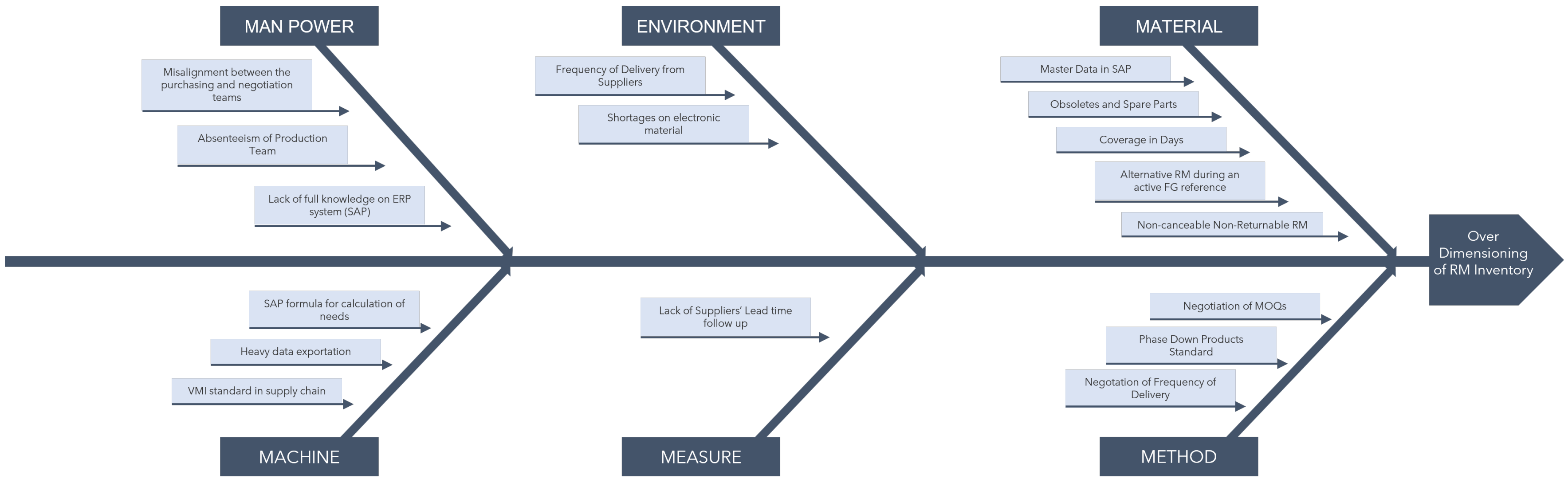

Figure B.1: Ishikawa Diagram developed with the Purchases team

Appendix C

Template for Project monitoring

Add New Project

Project Phase

		Last Update:	23/06/2023					
#	Project Name	Responsible	Opening Date	FG Ref	# Sold FG	BOM Code	Status	Obs.
1	Client X - Module W	X	14/06/2011	88041532	1504000.00	A874	Spare Part	
2								

Figure C.1: Table template for gathering information of the status of each project