Improvement of external manufacturing logistics in a multi-national consumer goods company

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Abstract

This thesis meticulously examines the external manufacturing logistics of Procter & Gamble - a leading company in the fast-moving consumer goods industry. It focuses on the essential aspects of inventory management, such as Raw and Packaging Material (RPM) management, Joint Economic Lot Sizing (JELS) of Finished Products (FP) and an overview of safety stock and storage costs.

This study aims to identify areas for improvement of the company's external supply chain management practices. The methodology utilised thoroughly analysed data collected through interviews with staff involved in the supply chain, sales and production history, and a literature review literature of supply chain management.

The performed analysis revealed several key findings. First, the Minimum Order Quantity (MOQ) of RPM was not optimal, resulting in excess inventory and increased storage costs. Secondly, the balance between the production of the bulk used in the FP, and the FP MOQ was not optimal, resulting in the excessive production of units, generating extra storage costs and costs of scrapping. Thirdly, the safety stock values in Contracted Manufacturers (CM) were not ideal, considering the current forecasted demands and its revision intervals were inadequate.

These findings have important implications for the P&G's external supply chain management practices. By tackling and improving the problems found during the analysis, P&G can potentially reduce inventory costs and improve customer service levels by adjusting the MOQ of raw materials, packaging materials, and the family MOQ. Similarly, by improving safety stock levels, the company can mitigate the risk of stockouts, lost sales or extra storage costs.

This study provides valuable insight into P&G’s external production logistics, resulting in potential savings of 1.5% of the total expense with CMs, and recommending improvement opportunities to enhance operational efficiency in inventory management.

Resumo

Esta tese realiza uma análise meticulosa da logística de produção externa na Procter & Gamble (P&G) - uma empresa líder na indústria de bens de consumo. Irá focar-se em aspectos essenciais da gestão de inventário, como a gestão de Matérias-Primas e Materiais de Embalagem, o Dimensionamento Económico da Produção de Lotes de Produtos Acabados (FP) e uma análise geral do stock de segurança e dos custos de armazenamento.

O objetivo deste estudo é identificar áreas de melhoria nas práticas de gestão da cadeia de produção externa da P&G. A metodologia utilizada consistiu na análise detalhada de dados obtidos através de reuniões com funcionários envolvidos na produção, registos históricos de vendas e produção, e ainda uma revisão da literatura sobre gestão da cadeia de fornecimento.

A análise realizada revelou várias descobertas importantes. Em primeiro lugar, a Quantidade Mínima de Encomenda (MOQ) das Matérias-Primas e Materiais de Embalagem não se encontrava otimizada, resultando em excesso de inventário e no aumento dos custos de armazenamento. Em segundo lugar, o equilíbrio entre a produção do conteúdo utilizado nos FP, e o MOQ do FP associados a esse conteúdo não era ideal, resultando na produção excessiva de unidades, gerando custos adicionais de armazenamento e custos de destruição. Em terceiro lugar, os valores de stock de segurança nas fábricas subcontratadas (CM) não eram ideais, tendo em conta as previsões de procura dos produtos, e os intervalos de revisão não eram adequados.

Essas descobertas têm implicações importantes para as práticas de gestão da cadeia de produção externa da P&G. Tendo por base a presente análise, a P&G pode potencialmente reduzir os custos de armazenamento e melhorar os níveis de serviço ao cliente, ajustando o MOQ das Matérias-Primas e Materiais de Embalagem e o MOQ dos lotes destinados a utilização nos FP. Da mesma forma, ao melhorar os níveis de stock de segurança, a empresa pode mitigar o risco de faltas de stock, vendas perdidas ou custos adicionais de armazenamento.

Esta análise fornece informações valiosas sobre a logística de produção externa da P&G, resultando numa poupança potêncial de 1,5% do total de despesas com CMs, e efetua recomendações de oportunidades de melhoria da eficiência operacional na gestão de inventário.

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Contents

1 Introduction 1
1.1 Project Scope and Motivation 1
1.2 The project at Procter & Gamble 2
1.3 Project objectives 3
1.4 Methodology followed in the project 4
1.5 Structure of the Dissertation 5
2 Literature review 6
2.1 Inventory Management 6
2.2 Theoretical Models in Inventory Management 7
2.2.1 Static Inventory management model 8
2.2.2 Dynamic Inventory management model 9
2.2.3 Stationary Inventory management model 11
2.2.4 Non-Stationary Inventory Model 12
2.2.4 Just-in-Time Model 12
2.2.5 ABC Analysis 13
2.3 Minimum Order Quantity 14
2.4 Excess Stock and Its Impact 15
2.5 Safety Stock Optimization 16
2.6 Regular Revision of inventory and Demand Variability 17
2.7 Joint Economic Lot Sizing 17
2.8 Demand Variability and Forecasting in Inventory Management 18
3 Description of the initial situation 19
3.1 Business Model 23
3.2 Raw and Packaging Materials 26
3.3 Joint Economic Lot Sizing 27
3.4 Storage and Safety Stock Analysis 29
4 Results of the performed analysis 32
4.1 Raw and Packing Material 33
4.2 Joint Lot Sizing 37
4.3 Safety and storage stock 41
5 Conclusions and Recommendations 43
References 46

Glossary:

AI – Artificial Intelligence
CM - Contract Manufacturer
ESS – External Supply Solutions
FFU - Feed for Use
FIS – Fixed Interval System
FMOQ - Family Minimum Order Quantity
FP - Finished Products
FQS – Fixed Quantity System
IDE - Inventory Disposition Expenses
JELS – Joint Economic Lot Sizing
MOE - Manufacturing Operating Expenses
MOQ - Minimum Order Quantity
MSM - Master Scheduling Manager
PIPO – Phase In Phase Out
P&G - Procter & Gamble
RPM - Raw and Packaging Material
T&W - Transportation and Warehousing

Equations:

Equation (1) - Economic Order Quantity formula.
Equation (2) - Cost of ordering and holding inventory.
Equation (3) - Function to minimize ordering and inventory holding costs.

Figure Index

Figure 1 – Contract manufacturers fee breakdown. [31] 3

Figure 2 - P&G Hair Care Europe Plants and Contract Manufacturers [31]. **Error! Bookmark not defined.**

Figure 3 - Types of demand classification based on the system's properties [27]. 7

Figure 4 - Overview of the ABC Classes, and characteristics – [31] 13

Figure 5 - P&G's Supply chain resilience plan [P&G] 19

Figure 6 - McKinsey outsourcing matrix for an Energy company segmenting activities along business criticality and comparative performance [31]. 20

Figure 7 – Schematic demonstration of the considerations to Outsource and Insource a product. [P&G] 21

Figure 8 – Free Issue business model steps in the sourcing of an order 23

Figure 9 – Full-Service business model steps in the sourcing of an order 24

Figure 10 – Direct Buy business model steps in the sourcing of an order 24

Figure 11 – Comparison between Safety Stock values and extra storage costs paid. 29

Figure 12 – Under Performing inventory subcategories and details. 30

Figure 13 -Evolution of NPI, UPI, Total Risk during the internship 30

Figure 14 - Evolution of total out-of-books liabilities during the internship 31

Figure 15 – Schematic demonstrating the distribution of the savings opportunities resulting from the analysis 32

Figure 16 – Representation of the optimal point for ordering – Concept of MOQ [P&G] 34

Figure 17 – Comparison in coverage between the in-use MOQ and the 4 levels MOQ strategy. 36

Figure 18 - Representation of forecasted demand for families of finished products grouped by formula 39

Figure 19 - Drivers of savings in the Joint Economic lot production 41

Table's Index

Table 1 – Properties taken under consideration when choosing an inventory management model. 8
Table 2 - Total delivered costs 22
Table 3 - Summary of the business model characteristics and ownerships..... 25
Table 4 – Example of the problems identified in the analysis. 28
Table 5 - Results from the increase of MOQ 35
Table 6 – Numeric demonstration of the proposed change to the FMOQ levels. 40

1- Introduction

1.1 Project Scope and Motivation

The efficient management of a supply chain is crucial for the success and competitiveness of any organization. Companies need to ensure that the correct quantities of materials and products are available when required to meet customer demand while minimizing costs and maintaining adequate inventory levels. One of the critical aspects of this task is the optimization of order quantities, inventory levels, and safety stock. These factors are interrelated; proper management can lead to significant cost savings and improved customer satisfaction [1].

A major challenge in supply chain management is determining the Minimum Order Quantity (MOQ) for raw materials, packaging materials, and finished products. The MOQ is the lowest quantity a supplier is willing to sell, and it plays a vital role in controlling inventory levels and production costs. An improperly defined MOQ can lead to excess stock and higher carrying costs, negatively impacting a company's financial performance [2]. Moreover, optimizing the MOQ for finished products is essential to meet customer demand without excess production and inventory costs [3].

One of the critical factors influencing significant variations in inventory levels is the fluctuation in customer demand. To cope with these fluctuations, companies hold a safety stock, which serves as a buffer against stockouts and potential disruptions in the supply chain. However, maintaining an excessive safety stock can lead to increased inventory holding costs and reduced cash flow, while insufficient safety stock may result in stockouts and lost sales [4]. Therefore, having adequate safety stock levels is critical to balance the risks and costs associated with inventory management [3,4].

In addition to the challenges related to MOQ and safety stock, the supply chain dynamics also present difficulties regarding the correct supplier selection, based on a range of factors including cost, reliability and capacity, the industry high competition level, and lack of information transparency, leading to sub-optimal decision making [20]. Companies must manage these complexities to ensure an optimal flow of materials and finished products within the supply chain, contributing to the organization's overall performance [21].

This project's primary objective is to comprehensively analyse the inventory management system currently in place within Procter & Gamble's Hair Care Europe Contracted Manufacturers (CM), to whom P&G outsources production capacity. The analysis will focus on Raw and Packaging Material (RPM) MOQ revisions Joint Economic Lot Sizing (the grouping of similar products to have a more efficient production) revisions, and safety stock and storage cost management

This study aims to identify inefficiencies within the current system, formulate solutions for it, and determine the benefits of implementing the solutions formulated.

1.2 The project at Procter & Gamble

This paper results from a deep study into the external manufacturing logistics of a large-scale organization – Procter & Gamble (P&G).

Procter & Gamble's Hair Care Europe business unit production is divided into nine Contract Manufacturers and two P&G Plants, as seen in Figure 1. Typically, P&G decides to outsource production to Contract Manufacturers (CMs) when there is not enough capability in the company-owned plants, or the initial investment required to set up the production lines is elevated. The network formed by the contract manufacturers is referred internally as External Supply Solutions (ESS).

This project's scope is to analyse and improve the efficiency and effectiveness of operations related to raw and packaging material (RPM) management, lot sizing, safety stock and storage costs.

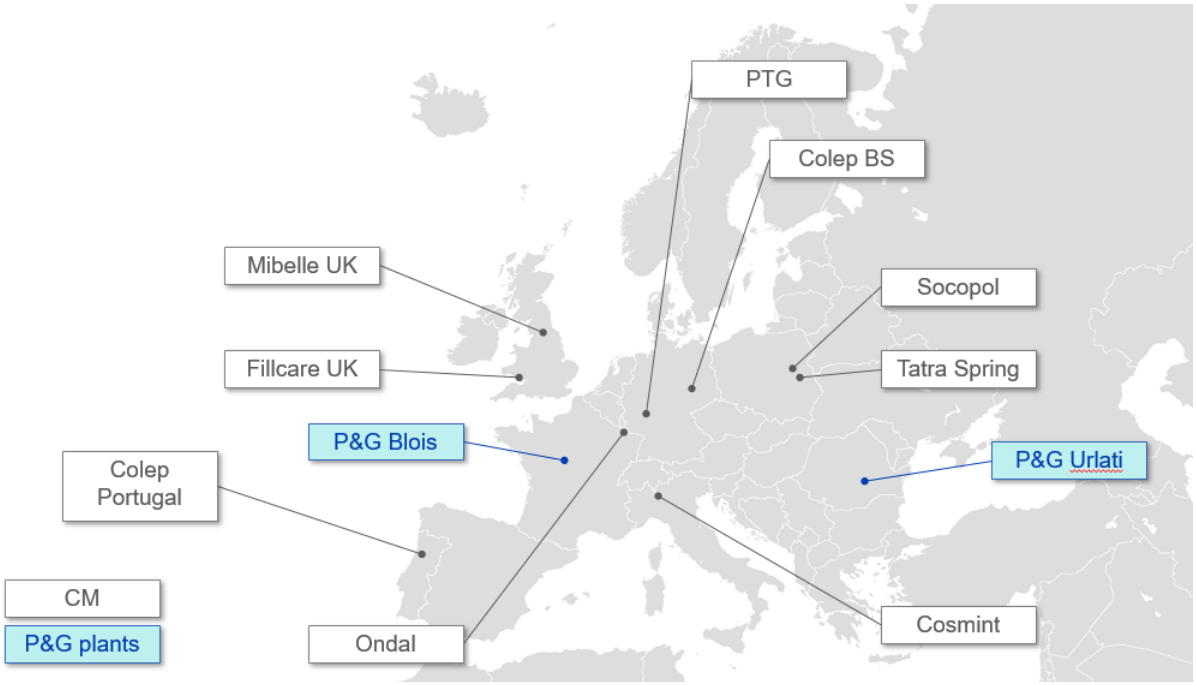


Figure 1 - P&G Hair Care Europe Plants and Contracted Manufacturers [31]

The efficient management of Raw and Packaging Materials (RPM) and Joint Economic Lot Sizing can significantly influence production schedules, inventory levels, and P&G's financial performance. The project's first phase consisted on the collection and examination of data related to RPM, due to the considerable percentage (57%) of the cost incurred by it in the ESS budget, as seen in Figure 2, which breakdowns the cost elements of ESS into Manufacturing Operating Expenses (MOE), raw materials and packaging materials. The data focused explicitly on metrics like supplier lead times and Minimum Order Quantities (MOQs), aiming to identify potential inefficiencies or areas for improvement.

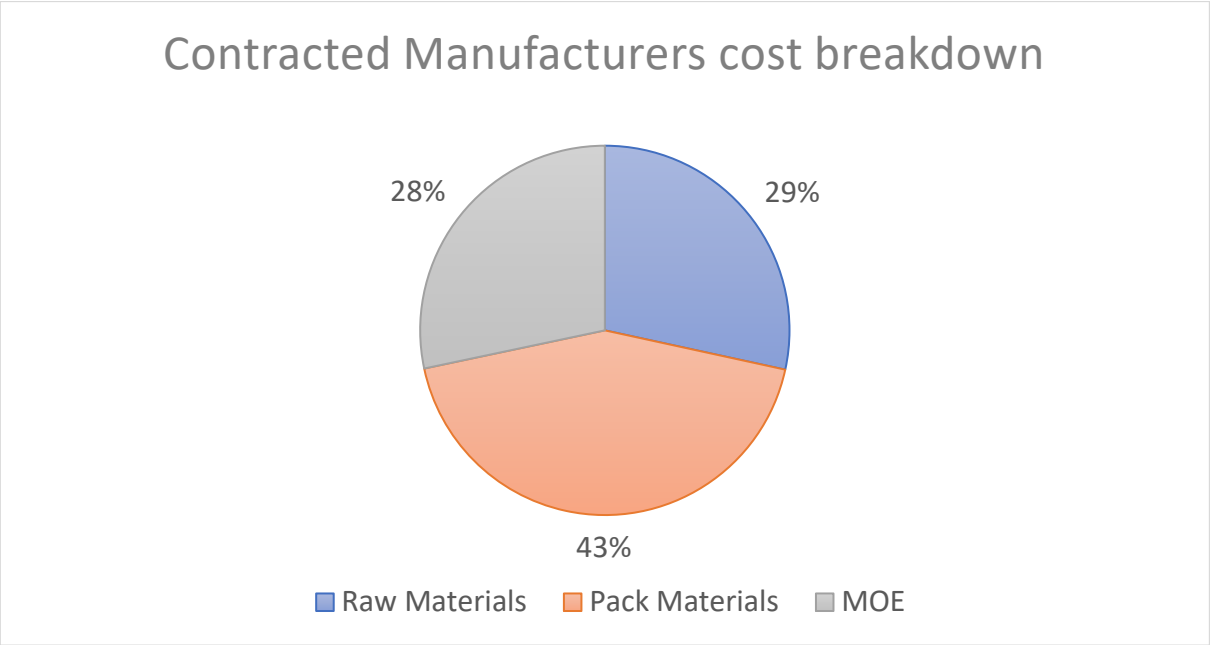


Figure 2 – Contract manufacturers fee breakdown. [31]

The second phase of the analysis project consisted of analysing and improving the Joint Economic Lot Sizing (JELS), which directly influences the production process. JELS is a production method that seeks to optimize production quantities in order to minimize the combined cost of setup, production, and storage over multiple products. The goal was to determine whether the current practices for the JELS and scheduling were optimal or whether alternative approaches could provide better results. This included looking at how different products are grouped and scheduled for production.

Finally, the project tackled safety stock and storage cost management. This aspect of inventory management can significantly influence the company's ability to meet customer demand. By scrutinizing current practices, the analysis sought to propose changes that could reduce storage costs and optimize safety stock levels.

In sum, the project's overall objective was to evaluate and propose improvements to the company's inventory management practices, to decrease costs, and enhance overall operational performance. The proposed recommendations resulting from the analysis, considered practical insights from the company's operations and theories from academic literature on inventory management.

1.3 Project objectives

The objectives of this research are multidimensional, aligning with both the theoretical underpinnings of inventory management and the practical realities organizations face. The primary goal is to explore and analyse the efficiency of the existing inventory management practices within Procter & Gamble (P&G). This investigation is carried out through the following specific objectives:

Theoretical Understanding: To enhance understanding of the inventory management concept, delving into existing theories, models, and principles that inform effective inventory management practices. This objective is realized through a comprehensive literature review encompassing academic research, industry reports, and other pertinent sources.

Situational Analysis: To analyse the existing inventory management situation within the organization. This analysis focuses on the organization's business models, Raw and Packaging Material (RPM) management, lot sizing principles, and stock situations.

Efficiency Evaluation: To examine the efficiency of the organization's RPM, Joint Economic Lot Sizing (JELS), and safety stock management using various inventory management models such as the Economic Order Quantity (EOQ) model, Dynamic Lot Size Model, and Fixed Quantity System (FQS) and Fixed Interval System (FIS) models.

Opportunity Identification: To identify potential areas for improvement and optimization within the organization's inventory management processes, to increase efficiency, reduce costs, and enhance overall operational performance.

Recommendation Development: To develop evidence-based recommendations for the organization, tailored to address the identified issues and opportunities. These recommendations are intended to guide the organization towards improved inventory management practices.

Knowledge Contribution: To contribute to the existing body of knowledge on inventory management by bridging the gap between theory and practice, providing a detailed case study of inventory management within a specific organizational context.

The achievement of these objectives will provide a comprehensive view of the organization's inventory management situation, offering insights into potential efficiency improvements and contributing to the broader discourse on effective inventory management.

1.4 Methodology followed in the project

The methodological design of this thesis aims to provide a robust framework for investigating the efficiency of inventory management within the organization in focus. Given the complex nature of the subject and the need to integrate various analytical techniques, a comprehensive approach has been employed. This methodology chapter outlines the procedures and practices utilized throughout the study, the rationale behind their selection, and their implementation.

The research design adopted in this study is mainly analytical, leveraging both qualitative and quantitative methods. This mixed-method approach enabled an exploration of a wide range of data types, enhancing the study's breadth and depth while ensuring a more comprehensive and nuanced understanding of the research problem.

The study initiated with a comprehensive Literature Review (Chapter 2) to establish a theoretical foundation and contextualize the research. An extensive exploration of previous academic studies, industry reports, and other relevant sources offered insights into established models and practices in inventory management, their applications, and their impact.

The next step involved data collection, primarily conducted through consultation with the supply chain stakeholders and extracting relevant data from the company's internal systems. The data acquired comprised numerical data (e.g., order quantities, safety stock levels, lead times, etc.) and descriptive data (e.g., inventory management procedures, lot sizing principles, etc.).

Various statistical and mathematical models were used for the quantitative analysis (Chapter 4). Raw and Packaging Material (RPM) data were examined using deterministic models, Joint Economic Lot Sizing (JELS) efficiency was investigated using the Dynamic Lot Size Model, and the safety stock and storage costs were analysed using the Fixed Quantity System (FQS) and Fixed Interval System (FIS) models. These models offered empirical insights into the organization's inventory management strategies and their efficiency.

On the other hand, qualitative data were primarily analysed using descriptive and thematic analysis, providing context to the quantitative findings, and highlighting potential

areas for improvement. This involved a detailed exploration of the initial inventory management situation (Chapter 3), the prevailing business models, lot sizing principles, and stock situations.

Several measures were employed to ensure the reliability and validity of the findings. These included data triangulation, meticulous data handling, the use of established analytical models, and continual engagement with the existing body of literature.

Finally, the results of the analyses were synthesized, and conclusions drawn in Chapter 5. The inference process was strictly evidence-based, relying on qualitative and quantitative findings. The decisions were subsequently evaluated against the theoretical framework constructed in the literature review, ensuring that the results contribute meaningfully to the existing body of knowledge.

This methodology offered a rigorous and comprehensive approach to addressing the research objectives, striking a balance between theory and practice, and fostering a deeper understanding of the intricate dynamics of inventory management within the organization under study.

1.5 Structure of the Dissertation

The present dissertation follows a structured and systematic flow conducive to comprehensively understanding the developed project. It is divided into five key chapters, each addressing a distinct facet of the overarching theme.

Chapter 1 briefly introduces the study, its background, research objectives, and the motivation behind undertaking this research. This chapter sets the stage for forthcoming in-depth discussions and paves the way for a comprehensive understanding of the research domain.

Chapter 2, the Literature Review, establishes a theoretical foundation for the study. It introduces critical concepts pivotal to the realization of the project, such as various inventory management models, lot sizing principles, safety stock parameters, and other related concepts. By reviewing and synthesizing the existing body of knowledge, this chapter creates a context for the subsequent empirical analysis and aids in identifying gaps in the existing literature.

Chapter 3 provides a detailed description of the initial situation, serving as the empirical bedrock upon which the study is constructed. This chapter is subdivided into four sections. Section 3.1 delineates the existing business models, Section 3.2 elaborates on the Raw and Packaging Material (RPM), Section 3.3 discusses Joint Economic Lot Sizing (JELS), and Section 3.4 outlines the current stock situation.

Chapter 4 presents the results derived from the analysis performed in the previous chapter. This chapter is further divided into three sections: Section 4.1 discusses the findings about the RPM, Section 4.2 elucidates the implications of JELS, and Section 4.3 dissects the outcomes related to safety stock and storage costs. By comparing these findings with the theoretical concepts discussed in the literature review, this chapter provides a deeper understanding of the implications of various strategies on the inventory management process.

Finally, Chapter 5 encapsulates the conclusions drawn from the analysis and recommendations for improvements to be performed and implemented. It synthesizes the key findings, discusses the implications of the results, and provides suggestions for future research.

Together, these chapters form a cohesive, comprehensive narrative that bridges the gap between theoretical understanding and empirical realities, offering valuable insights into the complexities of inventory management in the context of the studied organization.

2 Literature review

Supply chain management has experienced profound shifts over the past few decades, with increasing emphasis on efficiency, cost reduction, and sustainability. This transformation has been driven by numerous factors such as globalization, technological advancement, growing competition, and rising customer expectations. Amid these changes, inventory management has emerged as a critical area of research and practice, particularly regarding order quantity optimization, excess stock management, safety stock optimization, and joint lot production.

This chapter aims to provide a comprehensive literature review focusing on these topics, beginning with the overarching theme of inventory management, highlighting its importance in the broader context of supply chain management, and the theoretical models that guide its practice, while also delving into the Economic Order Quantity model, a fundamental tool for determining optimal order quantities.

2.1 Inventory Management

Inventory management is vital in any organization’s operations, balancing inventory costs and customer service levels. Effective inventory management can minimize costs, increase customer satisfaction, and improve a company's financial performance [5]. Such effectiveness may be achieved through demand forecasting, order quantity optimization, and inventory control techniques.

Inventories are established to facilitate a company's regular operations. An appropriate and timely formulation of an optimal inventory control strategy can liberate a substantial portion of assets tied up as stocks, thereby enhancing resource efficiency [1]. At its most basic level, inventory management involves controlling the inventory levels of raw materials, work-in-progress goods, and finished products to meet customer demand while minimizing inventory holding costs. The fundamental challenge lies in predicting the uncertainties of supply and demand [1]. However, with technological advancements and data analytics, organizations can forecast demand and optimize inventory levels more accurately.

Despite the existence of millions of distinct product types in our economy, inventory control boils down to two fundamental decisions: what should be the size of an inventory replenishment order, and when should an inventory replenishment order be placed [1,5].

Inventory management objectives often simplify the issue of deciding whether it is more profitable to act quickly but at a higher cost or to act more slowly but at a lower cost. The ideal inventory control strategy minimizes the cumulative costs associated with production, storage, and inventory shortages per time unit or for a specific (infinite) period [1].

Product perishability and substitutability must also be considered in inventory management. To avoid spoilage and waste, inventory must be carefully managed for perishable items, such as food or pharmaceuticals [8]. Meanwhile, for substitutable items, where customers are willing to accept a similar product if the desired item is unavailable, inventory management strategies must consider the trade-off between offering a wide variety of products and the increased complexity and cost of managing more stock-keeping units (SKUs).

2.2 Theoretical Models in Inventory Management

Theoretical models play a pivotal role in inventory management by ensuring operational efficiency and cost effectiveness and defining when and what quantity of the item in analysis should be ordered.

Inventory management models vary based on the type of information available regarding the system's properties. If the model parameters' values are precisely known, the corresponding mathematical model is deterministic. The models are stochastic or probabilistic when system parameters are random variables with known probability distribution. If all the model parameters remain unchanged over time, the model is deemed static, and if they change, it is dynamic. Stationary models are helpful when making a one-time decision about stock levels for a specific period. In contrast, non-stationary models come into play for sequential decision-making about stock levels or to adjust prior decisions in response to changes [27]. In Figure 3 a scheme demonstrates the divisions of the demand classification, based on the system's properties.

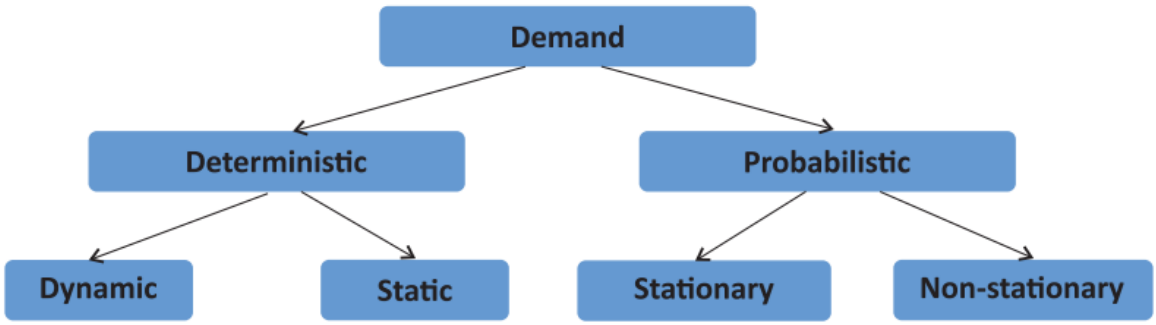


Figure 3 - Types of demand classification based on the system's properties [27].

To correctly choose the model to use, further system properties should be considered beyond the demand type. In Table 1, several properties taken under consideration for the choice of model are presented, and their respective characteristics.

Inventory management is a complex but crucial aspect of supply chain management. Despite the many challenges, effective inventory management can significantly improve a company's operational efficiency and financial performance. As such, it is an area of continued research and innovation. Some of the theoretical models currently used for inventory management are presented in the next sections.

Table 1 – Properties taken under consideration when choosing an inventory management model.

Lead Time considerations	The temporal dimension between the placement and receipt of an order, known as lead time, carries significant weight in model selection. Any variability in lead time can directly impact the necessary safety stock levels and subsequently influence the choice of an inventory model.
Number and interrelation of items	The scale and complexity of inventory items also play a role in the choice of a model. When the inventory consists of multiple items, especially with interdependencies among them (as seen in bill-of-material scenarios), a model capable of handling this level of complexity is required.
Supply Chain Structure	The supply chain structure within which the organization operates can affect model choice. The dynamics of managing a single warehouse versus a multi-echelon network, for instance, can significantly influence the choice of an inventory model.
Cost factors	Each inventory management model treats costs differently. Thus, an understanding of the organization's holding, ordering, and shortage costs is essential to align the model with the financial reality of the business.
Product nature	The product type identifies and considers specific product characteristics, such as perishability or repairability. Item deterioration during storage is a natural process that inventory policy cannot disregard and may vary across storage places.
Demand nature	Understanding of demand patterns is the bedrock upon which all inventory management models are built. The model selected must have the capacity to adequately handle the nature of demand - be it stationary or non-stationary, static or dynamic.as previously seen in Figure 3.

2.2.1 Static Inventory management model

Static inventory models play a significant role in inventory management and supply chain optimization. As the name suggests, these models operate under the assumption that the rate of demand is constant and predictable over time. It implies that the demand for an item during the replenishment lead time remains fixed, and hence the reorder quantity can also be set as a constant.

These models are suitable in environments where the demand for goods remains relatively consistent over time, with minimal variation. Industries that deal with staple goods or items with a steady consumption rate often employ static inventory models.

A prominent example of a static inventory model is the Economic Order Quantity (EOQ) model. The EOQ model is the most known tool in the Static Inventory Model category, assuming demand is constant and predictable. Consequently, the model provides a one-time decision on the optimal inventory quantity to order. The decision variables, such as order quantity, do not change over time in response to shifts in the inventory system or demand.

Initially presented by Ford W. Harris in 1913, the Economic Order Quantity (EOQ) model has since been expanded upon and adapted to suit various organizational needs [5]. This model is designed to determine the optimal order quantity that minimizes total inventory costs, including ordering, carrying, and shortage costs. The model is rooted in the assumption of a constant, deterministic demand rate and constant lead time, which, while simplifying the analysis, may not always align with real-world scenarios where demand and supply conditions

can be highly dynamic and uncertain. The EOQ formula is presented directly below, in Equation (1):

$$EOQ = \sqrt{\frac{2*D*S}{H}} \quad (1)$$

Where:

D is the annual demand

S is the ordering cost per order

H is the annual holding cost per unit

Various adaptations of the EOQ model, such as the Probabilistic EOQ (also known as the Q-model) and the EOQ with planned shortages (also known as the S model), have been introduced to address these conditions [5].

Inventory management becomes even more complex in multi-echelon supply chains, where materials flow through multiple stages from suppliers to end customers [5]. Various multi-echelon inventory models have been studied and highlighted the importance of coordination across distinct phases of the supply chain to reduce the bullwhip effect, a phenomenon where minor changes in customer demand can cause more significant fluctuations upstream in the supply chain.

2.2.2 Dynamic Inventory management model

In the field of inventory management, dynamic inventory models constitute an essential category that caters to varying demand over time. These models adapt to changes in demand, providing a flexible approach to inventory management by adjusting order quantities dynamically in response to the changing demand. This model recognizes that demand is not always constant or predictable. For instance, the demand for certain products or materials may be influenced by seasonal variations, economic trends, or specific market events. This unpredictability necessitates a dynamic approach to inventory management that can respond effectively to these changes.

At the heart of a dynamic inventory model lies the principle of adjusting ordering decisions according to fluctuating demand. The model uses historical demand data along with predictive analytics to anticipate future demand and adjust order quantities accordingly. This dynamic adjustment allows organizations to maintain optimal inventory levels, thereby preventing overstocking or stockouts and ensuring high service levels.

One of the most know dynamic inventory models is the Dynamic Lot Size Model, also known as the Wagner–Whitin model, proposed by Harvey M. Wagner and Thomson M. Whitin in 1958, is a dynamic programming approach designed to solve the lot-sizing problem where demand varies over time. The model aims to minimize total inventory cost over a finite and discrete planning horizon while satisfying the demand for each period without any shortages, considering both setup costs and holding costs in its formulation [28].

The model considers that future costs are affected by current decisions. Therefore, it calculates the total cost for different possible decisions and selects the one that minimizes these costs by establishing a trade-off between setup costs and holding (or storage) costs, aiming to find the point at which the cost of holding inventory is balanced with the cost of ordering or setting up a production run [28].

The cost of ordering and holding inventory for periods i through j can be represented as seen in Equation (2):

$$C(i,j) = S + H * \sum(t-i) * D_t \text{ , for i} \leq \text{t} \leq \text{j} \quad (2)$$

Where:

i is the start of the period

j is the end of the period

D_t is the demand at period t

S is the setup (ordering) cost per order

H is the holding cost per unit per period

C is the total cost for the period

The objective is to minimize the total cost over all periods, or as demonstrated in Equation (3) in numerical terms:

$$Min \sum C(i,j), \text{ for all i and j} \quad (3)$$

Unlike static models such as the EOQ, the Dynamic Lot-Size Model allows for variable order timing and quantity. It involves solving a dynamic programming problem to determine the optimal order quantity and timing that minimizes the total cost.

One practical example of using the Dynamic Lot-Size Model is in retail inventory management where demand is highly seasonal. Retailers can use the model to decide how much inventory to order and when to place orders, considering both the setup and holding costs. The model provides the flexibility to adapt to changes in demand over time, which can be particularly useful during peak seasons such as the holidays.

The Wagner-Whitin model is highly respected for its mathematical rigor and adaptability to dynamic environments. However, the model has also been criticized for its computational intensity, especially for long planning horizons and complex demand patterns. As a result, various heuristics, and approximation methods, such as the Silver-Meal heuristic have been developed to provide more computationally efficient solutions [28].

The Silver–Meal heuristic, developed by Edward A. Silver and H. C. Meal in 1973, is a simpler alternative to the Wagner–Whitin model. This heuristic iteratively extends the order quantity until the average period cost (consisting of the setup and inventory holding costs) rises. Here, the model focuses on the incremental cost per period of adding a demand period to the lot size. It calculates the average cost per period for each additional unit added to the order quantity. When this average cost rises, the model stops increasing the lot size and starts a new order cycle [27].

The Silver-Meal model's application involves a detailed examination of the product and demand characteristics at the Contract Manufacturer (CM), comparing the forecasted demands and the cost implications of varying order quantities. The model could help streamline inventory management and reduce associated costs [27].

The Dynamic Lot-Size Model assumes that the demand for each period is known and deterministic. In situations where demand is uncertain, stochastic inventory models may be more suitable. Despite these limitations, the model provides a valuable framework for understanding and managing the trade-off between setup and holding costs in a dynamic environment.

2.2.3 Stationary Inventory management model

The Continuous Review Policy, or Fixed Quantity System (FQS), is an example of a stationary model. Here, inventory levels are reviewed continuously, and a fixed quantity is ordered when the inventory level hits a pre-determined reorder point.

A replenishment order is placed whenever the inventory level drops to a predetermined order point. The quantity of the order remains constant, but the frequency of orders may vary depending on the rate of inventory consumption. This strategy is designed to ensure that there is always sufficient stock to satisfy demand until the next order arrives, thus minimizing the likelihood of stockouts.

The FQS model primarily concerns two fundamental decisions: determining when an inventory replenishment order should be placed (the reorder point), and how large the replenishment order should be [1]. The key to the efficient functioning of the FQS lies in carefully calculating these two parameters.

Several factors are considered while determining the reorder point, such as the lead time demand, the rate of demand, and the desired service level. Organizations can accurately forecast these variables by carefully analysing past data and demand patterns, thus setting a practical reorder point.

The order quantity in an FQS is typically determined based on economic order quantity (EOQ) models, which attempt to balance ordering costs and holding costs to identify the most cost-effective order quantity [1, 29].

While the FQS offers several advantages, such as the simplicity of implementation and suitability for stable demand, it also has limitations, requiring constant monitoring of inventory levels and may lead to increased administrative costs due to frequent orders. In the face of erratic or seasonally fluctuating demand, an FQS may not be the most efficient strategy [29].

The Fixed Quantity System is a critical inventory management strategy focusing on maintaining a constant order quantity while the reorder point varies based on the average consumption rate and the safety stock levels, depending on the service level desired. It offers several benefits in reducing stockouts and ensuring a continuous supply of goods, but its efficiency largely depends on the predictability of demand and lead times. The choice of this system needs to be validated against the characteristics of the supply chain under consideration [29].

2.2.4 Non-Stationary Inventory Model

The Periodic Review Policy, or Fixed Interval System (FIS), is an example of a non-stationary model. In this model, inventory is checked at fixed intervals, and the order size varies depending on the current inventory position. The model is based in situations where the demand varies over time (seasonality or trend), i.e., the statistical properties of the demand change over time [1].

Among the inventory management strategies deployed in diverse industries, the Fixed Interval System merits attention due to its unique approach towards managing stock replenishment, carried out at regular intervals, irrespective of the current inventory level.

Two primary determinants characterize the Fixed Interval System: the fixed time interval between consecutive orders and the variable order quantity determined based on the inventory level at the time of review [1]. The time between reviews remains constant, while the order quantity varies according to the current inventory level and the anticipated demand during the next review period [30].

The FIS's operational mechanics involve reviewing the current inventory level at each fixed interval. At this point, an order is placed to replenish the stock up to a pre-determined target inventory level. This target level is usually set to satisfy anticipated demand during the time it takes to receive the new order (lead time) plus the time until the following review [30]. The use of the non-stationary model is particularly common in industries with a broad range of SKUs, such as supermarkets and general merchandise retailers, as it simplifies the order placement process by allowing for a consolidated review and order for multiple items simultaneously.

However, the model presents limitations, such as the possibility of not being responsive enough to cater to a sudden surge in demand between review periods, leading to potential stockouts. Moreover, due to the variation of order quantities, prediction and management of freight costs, warehouse space, and labour requirements may be challenging.

2.2.4 Just-in-Time Model

The Just-in-Time (JIT) model is an inventory management strategy aimed at streamlining a company's manufacturing and distribution processes to increase efficiency, reduce waste, and minimize costs. This method is driven by actual demand rather than anticipated demand, thus implying production is only undertaken when there is a confirmed order [22].

At its core, JIT is based on a pull system instead of a push system. In the latter, production is driven by projected demand, while in the former, production is initiated based on actual demand. By focusing on actual sales, the JIT approach minimizes the chances of overproduction and inventory obsolescence. The JIT model also promotes smaller batch sizes, further reducing inventory holding and handling costs, and ensuring quicker response to changes in customer demand [23].

One of the main principles of JIT is the focus on continuous improvement or "Kaizen". The idea continually seeks and implements small, incremental process changes to improve efficiency, quality, and productivity [24].

However, it is essential to note that while JIT offers several potential advantages, it is not without its challenges. This model requires exceptionally reliable suppliers and highly accurate demand forecasting, and it may leave companies vulnerable to supply chain disruptions [25].

2.2.5 ABC Analysis

The ABC analysis model is a technique for classifying inventory items based on their relative importance. Introduced by H. Ford Dickie in 1951, the model categorizes inventory into three groups: 'A' items are high-priority items with significant cost implications, 'B' items are medium-priority items, and 'C' items are low-priority items that are inexpensive or have a minimal impact on customer service [21]. This technique helps businesses focus their resources and control efforts where they will have the most impact.

The 'A' items are the most valuable products for a company in terms of revenue generation, annual consumption value, or another organizational metric. They typically represent 10-20% of total items but account for approximately 80% of the yearly cumulative consumption value. These items are tightly controlled, have accurate records, and receive regular and frequent reviews. They often have low inventory levels due to the prohibitive cost associated with carrying such inventory, and a significant amount of managerial time is spent on managing these items to ensure stockouts do not occur.

The 'B' items fall in the middle regarding annual consumption value. They account for approximately 15% of the yearly cumulative consumption value. The inventory levels and ordering points for 'B' items might be reviewed less frequently than those for 'A' items, and the forecasting methods for demand might not be as sophisticated.

The 'C' items account for the most sizable portion of the inventory in terms of the number of items (typically around 50% of total items). Still, they contribute the least to the annual consumption value, usually only about 5%. 'C' items have minimal managerial control given their lower monetary impact. Records may not be as meticulously maintained, and inventory control measures might be relatively simple. The procurement process for these items may often be automated.

In Figure 4 an overview of the distinct classes of items and their characteristics is presented to provide further enlightening on the subject.

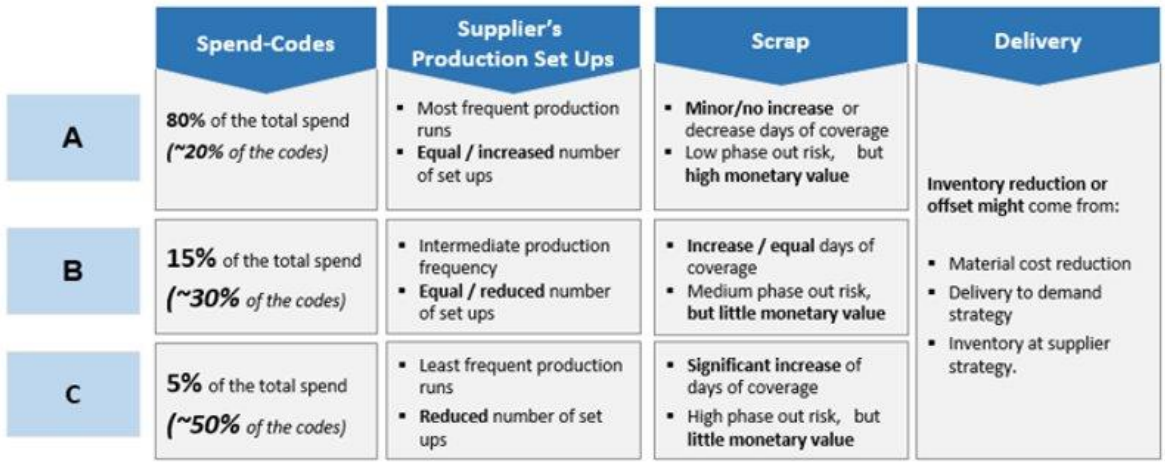


Figure 4 - Overview of the ABC Classes, and characteristics – [31]

Implementing ABC analysis allows companies to focus their inventory control efforts on the items that provide the most value. It leads to a better service level and lower investment in inventory, providing an efficient and cost-effective inventory control system.

The steps for implementing an ABC Analysis are:

1- Identify the items and their annual consumption value. The annual consumption value is calculated as the annual demand multiplied by the cost per unit.
2- Rank the items based on the annual consumption value from highest to lowest.
3- Calculate the cumulative annual consumption value.
4- Categorize the items into class A, B, or C based on their cumulative annual consumption value.

However, it is worth noting that the ABC analysis is only a part of overall inventory management and should be used with other models and techniques to control and optimize inventory effectively.

In sum, each model offers unique insights and benefits, and the choice between them depends on numerous factors, including the company's objectives, the nature of demand and supply, the reliability of suppliers, the costs of holding and ordering inventory, and the acceptable risk level of stockouts. Therefore, aligning inventory management models with the broader business strategy and operational context is essential. It is also worth noting that these models are not mutually exclusive and can be combined to address various aspects of inventory management.

2.3 Minimum Order Quantity

Achieving an ideal balance between the production processes while maintaining economic feasibility poses challenges, thereby underlining the significance of the Minimum Order Quantity (MOQ). The optimization of MOQ is important for managing inventory costs and improving supply chain efficiency. MOQ refers to the smallest amount of a specific product that a supplier is willing to sell, and it should balance the ordering and holding costs, resulting in a minimized total inventory cost. This principle is at the heart of the previously discussed EOQ model [5], which offers a solution to balance ordering and holding costs. However, its assumptions often diverge from real-world supply chain dynamics, highlighting the need for more comprehensive models considering MOQ constraints.

The repercussions of MOQ extend far beyond its apparent simplicity. When higher than the demand, surplus inventory triggers escalating carrying costs, potential obsolescence, and wastage. Conversely, an MOQ lower than demand leads to frequent orders, surging ordering costs, and risk of stockouts. Hence, balancing meeting MOQ and preventing excess inventory is desirable and essential for an efficient and cost-effective supply chain [4].

Numerous studies have examined the EOQ model and its variations, contributing to a rich body of literature on MOQ optimization. However, the findings and methods employed vary across studies, reflecting the complexity of real-world inventory problems.

In the original EOQ model, demand is assumed to be constant and deterministic. Under this assumption, the optimal order quantity can be easily calculated using Equation (1). However, this simple model often falls short in complex, real-world scenarios where demand is uncertain and other expenses, such as transportation and purchase costs, come into play [5].

Several researchers have proposed modifications and extensions to the EOQ model to address these limitations. For instance, the EOQ model, with backorders, allows for temporary stockouts and fulfilling them when the inventory is replenished. This model provides a more flexible approach to managing demand variability and introduces additional backorder costs [26].

Another significant variation of the EOQ model is the quantity discount model, which considers price reductions suppliers offer for larger order quantities. These models can provide substantial cost savings in certain situations. However, the models also have limitations as they

assume that the discounts are constant and do not consider other factors that might affect the supplier's pricing strategy [6].

Researchers have recently incorporated more advanced analytical techniques into MOQ optimization, such us stochastic programming models for MOQ optimization under uncertain demand and price. This model uses probability distributions to represent uncertainty and solves the problem using mathematical programming techniques.

The advent of machine learning has also opened new possibilities for MOQ optimization with deep learning models that dynamically adjust MOQ based on real-time demand and supply information [10]. Their approach significantly improved cost reduction and service level achievement in a simulation study.

Despite these advancements, there are still gaps in the research, such as interconnectedness of different inventory decisions. For instance, the decision on MOQ affects and is affected by other choices such as safety stock level and reorder point. This indicates a need for more integrated models that consider these interactions.

2.4 Excess Stock and Its Impact

Excess stock, often called as overstock, results from a situation when a company has more stock than needed to meet customer demand. This surplus of goods can create several challenges and inefficiencies in a supply chain, making it a crucial issue to address for organizations aiming for optimal inventory management [5, 18].

There are multiple reasons for the accumulation of excess stock. They could range from overestimating demand to an inability to accurately forecasting seasonal fluctuations, or simply due to non-optimal MOQs (Minimum Order Quantity) that force the company to order more than necessary [4]. While having surplus inventory might seem like a safety net against demand uncertainties, the costs associated with holding an excess stock can significantly impact an organization's bottom line due to the underlying various components such as storage costs, insurance, taxes, and the cost of capital tied up in inventory. Additionally, higher inventory levels increase the risk of product obsolescence, spoilage, and waste. These risks can lead to significant financial losses for industries dealing with perishable goods or rapid technology cycles [5].

Furthermore, excess stock can lead to less visible but equally damaging issues. For example, having more inventories might conceal production and supply chain inefficiencies, such as low-quality suppliers or long lead times. Moreover, it could lead to cluttered warehouses, reducing operational efficiency and increasing the likelihood of errors in order picking and shipping [1, 18].

Various strategies have been proposed in the literature to reduce excess stock, such as improving demand forecasting accuracy. Advances in data analytics and machine learning have enabled companies to analyse complex demand patterns and improve their forecasting accuracy, thereby reducing the need for excess inventory [7]. Sales and operations planning (S&OP) is another strategy that has been widely adopted by organizations to balance demand and supply. By aligning sales forecasts with production planning, S&OP helps to ensure that the right amount of inventory is available at the right time, reducing the likelihood of excess stock [8].

Other inventory reduction initiatives, such as lean management and Just-In-Time (JIT) production, aim to minimize inventory levels throughout the supply chain. These initiatives require close coordination with suppliers and accurate demand forecasting but can lead to significant cost savings and operational improvements when implemented correctly [4].

Managing excess stock is a complex but essential aspect of inventory management. Companies can improve their supply chain efficiency and financial performance by understanding the causes and impacts of excess stock and implementing effective strategies to reduce it.

2.5 Safety Stock Optimization

Safety stock is an additional stock kept on hand to prevent demand or supply lead times variabilities. While safety stock can reduce the risk of stockouts and lost sales, it also increases inventory carrying costs. Therefore, determining the optimal safety stock level is a critical decision in inventory management [5].

Safety stock levels are determined based on the desired service level, which is the probability of not running out of stock during a replenishment lead time. A higher service level requires a higher safety stock but also increases carrying costs. Conversely, a lower service level reduces inventory costs but increases stockout risk [1].

In the classical inventory models, safety stock is often calculated based on the standard deviation of demand and lead time variability. However, these models assume that demand and lead times follow normal distributions, which may not be the case in real-world scenarios, and they do not consider other factors that can affect safety stock requirements, such as demand seasonality, trend, and the risk of supply disruptions [9].

In recent years, several studies have proposed more sophisticated models for safety stock optimization. For instance, a model that considers both demand and lead time variabilities in determining safety stock levels outperformed the traditional models regarding service level achievement and inventory cost reduction [9]. Some researchers have also incorporated safety stock optimization into multi-echelon inventory models, such as having safety stock placement in supply chain networks, considering both centralized and decentralized decision-making scenarios, highlighting the importance of coordinating safety stock policies across distinct stages of the supply chain to minimize total system-wide costs [1].

The advent of advanced analytics and machine learning has also brought new opportunities for safety stock optimization. Machine learning approaches were developed to dynamically adjust safety stock levels based on real-time demand and supply information, showing significantly reduced stockouts and inventory costs in a simulation study [10].

Safety stock optimization is a complex but crucial task in inventory management, as it involves a delicate balance between service level, demand and supply variability, and inventory costs. With the advancement of analytical and computational tools, companies can tackle this challenge more effectively and significantly improve their supply chain performance.

2.6 Regular Revision of inventory and Demand Variability

Regular revision of inventory policies and the consideration of demand variability are two fundamental aspects of effective inventory management. Inventory policies, including their parameters, such as order quantities and safety stock levels, are not static. Still, rather, they need to be updated regularly to reflect changes in demand, lead times, costs, and other operational conditions [5]. In traditional inventory models, such as the EOQ model, demand is assumed to be constant or deterministic. However, demand is often variable and uncertain in real-world scenarios, which are influenced by several factors, including market trends, seasonal patterns, economic conditions, and random events. This demand variability can significantly affect inventory performance, leading to stockouts or excess inventory if not effectively managed [1].

Demand forecasting is a commonly used method to estimate future demand and manage its variability. With accurate demand forecasts, companies can make informed decisions about order quantities, safety stock levels, and other inventory policies. However, demand forecasting is challenging due to demand patterns' inherent uncertainty and complexity [7].

Several studies have explored different methods for demand forecasting and their impacts on inventory performance, such as the comparison of the performance of various forecasting methods, including time series models, causal models, and judgmental forecasting, affecting inventory costs and service levels significantly, highlighting the importance of selecting an appropriate forecasting method for each specific situation significantly [7]. Machine learning has also been applied to demand forecasting, offering new ways to handle complex and non-linear demand patterns.

Regular review of inventory policies is another essential practice in inventory management. As business conditions change, the optimal inventory policies may also vary. Therefore, companies must regularly review their inventory policies to ensure they are still relevant and accurate. This process can be supported by performance measurement and control systems that monitor vital inventory metrics, such as stockout rate, fill rate, and inventory turnover [5].

Regularly revising inventory policies and managing demand variability is crucial to achieving optimal inventory performance. By incorporating these practices into their inventory management processes, companies can improve their adaptability to changing conditions and enhance their supply chain performance and agility.

2.7 Joint Economic Lot Sizing

Grouping products into lots based on commonality in manufacturing processes, characteristics and content can streamline production and increase efficiency. This strategy is commonly used in various manufacturing settings, especially in cellular manufacturing, flexible manufacturing systems, and job-shop scheduling environments.

Early efforts to group parts into ‘families’ can be traced back to 1963 when the group technology concept was introduced [11]. It is based on the idea of grouping parts into families based on their design or production features, helping the simplification of planning, scheduling, and control of the manufacturing systems, leading to increased operational efficiency. The algorithmic approach is one of the most effective ways of grouping parts, playing a vital role in the increase of efficiency of groupings, highlighting the role of similarity coefficients, hierarchical clustering, and graph theory-based methods [12, 19].

Group technology principles were also applied to production scheduling, aiming for part-families to reduce complexity and improve scheduling systems' effectiveness. Part-families'

role in production flow analysis enables the transformation of a job-shop into a cellular manufacturing system, significantly reducing flow times and work-in-progress [13]. In the realm of artificial intelligence and machine learning, part-family formations approaches based on deep learning are increasingly more common, showing that machine learning algorithms could effectively handle the complexity and uncertainty of real-world manufacturing environments, significantly improving the performance of part-family formation [14,19].

The practice of grouping products into families based on shared content or production characteristics is a well-established strategy in manufacturing optimization. Further intersections with emerging technology and sustainability trends, offering new ways to enhance production efficiency and effectiveness, are currently being explored and implemented [19].

2.8 Demand Variability and Forecasting in Inventory Management

Inventory management is intrinsically linked to demand and its variability. Variations in demand can influence the level of safety stock maintained and the Minimum Order Quantity (MOQ) stipulated. Hence, effective forecasting techniques are essential to ensure optimal inventory management, enabling businesses to predict future demand and adjust their inventory levels accordingly.

Demand variability refers to the fluctuations or changes in demand for a product over a certain period [1]. This variability can result from multiple factors such as seasonality, economic conditions, competitive actions such as pricing changes or promotional activities, customer behaviour changes and macroeconomic factors. Variability in demand often leads to challenges such as stockouts or overstocking, which can significantly impact a company's profitability and customer satisfaction [9, 17]. It represents a significant challenge in inventory management, affecting two crucial elements: safety stock and MOQ [17].

Given the impacts of demand variability on safety stock and MOQ, companies need reliable forecasting techniques to predict future demand and align it with their inventory decisions. Different methods exist for forecasting demand, each suitable for different contexts. The simplest forecasting method is the time series model, which uses historical sales data to predict future demand using autoregressive integrated moving averages and exponential smoothing, giving more weight to recent data [15]. Other models, called “Causal” models, on the other hand, incorporate factors that influence demand, such as economic indicators, marketing activities, and seasonal patterns, becoming increasingly accurate but are also more complex to develop and use. Machine learning and artificial intelligence have recently been applied to demand forecasting with remarkable success due to their capability to handle vast amounts of data and complex relationships, often leading to more accurate predictions [16].

Demand variability can be managed through various strategies, including safety stock, responsive supply chain design, and demand management. A responsive supply chain design aims to improve the supply chain's ability to quickly respond to changes in demand. Demand management involves influencing demand patterns through strategies such as price adjustments or promotions [16].

3 Description of the initial situation

As presented in the introduction, this paper aims to present the analysis and improvements performed in the Hair Care Business Unit at Procter & Gamble Europe. The Hair Care Business Unit has 4 distinct brands of products being Head & Shoulders (H&S), Pantene, Herbal Essences and Aussie. As a combination of these four brands, there is a universe of more than 1300 Stock Keeping Units (SKU) produced across 2 P&G owned plants and 9 contracted manufacturers plants, in Europe.

Face of supply chain disruptions brought on by the COVID-19 pandemic, the fast-moving consumer goods industry, where P&G is included, had to reconsider, and reassess the supply chain strategies, aiming for resilience and adaptability. The strategic approach adopted by P&G pivoted towards four primary topics, which are shown in Figure 5.

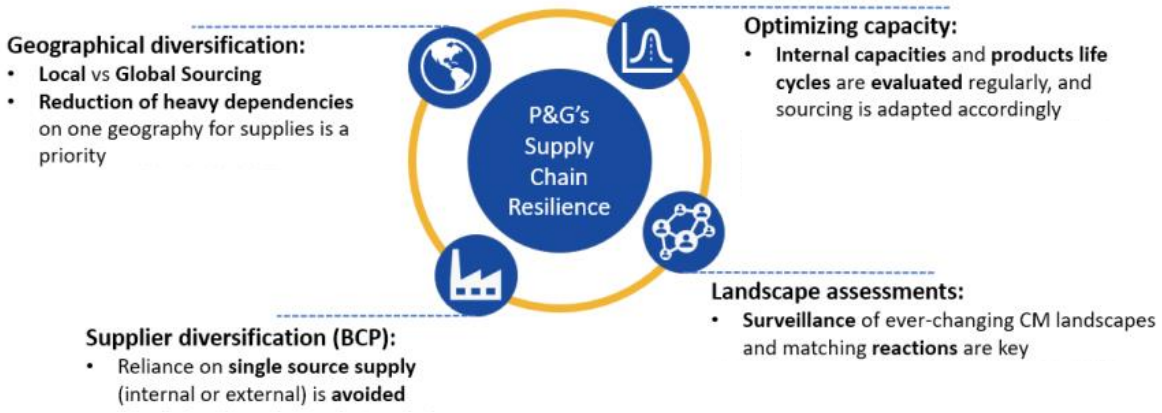


Figure 5 - P&G's Supply chain resilience plan [P&G]

Geographical Diversification is the primary topic, arising from recognizing the risk of heavy reliance on a single geography for supply requirements. P&G has shifted towards a balanced blend of global and local sourcing, mitigating risks associated with regional disruptions and supporting local economies, creating a more robust and resilient supply network.

As part of the Supplier Diversification, meant to avoid the dependency on a sole source of supply, either internal or external, P&G implemented a diversified supplier base as part of its Business Continuity Planning (BCP), ensuring a steady supply flow, even in the face of potential disruptions to a sole source.

Regular evaluations of internal capabilities and product life cycles became integral in P&G's strategy to optimize its capacity. Adapting sourcing strategies to these assessments made it possible to manage production capacity better, reduce inefficiencies, and swiftly respond to shifting market demands.

The External Supply Solutions (ESS) assessment revealed constant changes occurring at Contract Manufacturers (CM). Considering this, P&G has prioritized ongoing surveillance and timely responses, by keeping a pulse on the industry trends, technological advancements, and market dynamics, and consequently adapting strategies to maintain supply chain resilience effectively.

By incorporating these four topics, P&G demonstrated a proactive approach to navigating the uncertainties and challenges brought by the global pandemic, pivoting towards

a robust framework for managing future disruptions in the supply chain and positioning the company to respond effectively to the evolving business environment.

Over the past 10 years the outsourcing landscape and usage of CMs has radically changed. Industries (including the fast-moving consumers) have come to realize that there are opportunities to manufacture and innovate by leveraging external resources. When analysing the prospect of outsourcing, a spectrum of strategic choices can take place, such as core versus non-core products, early phase or declining volume in the product lifecycle, small volume or complex SKUs, modern technology testing or white space expansion or localization. An example of the decision matrix similar to the one applied in the fast-moving consumer goods industry is presented in Figure 6, exemplifying the criteria used to decide whether subcontracting is beneficial for the company.

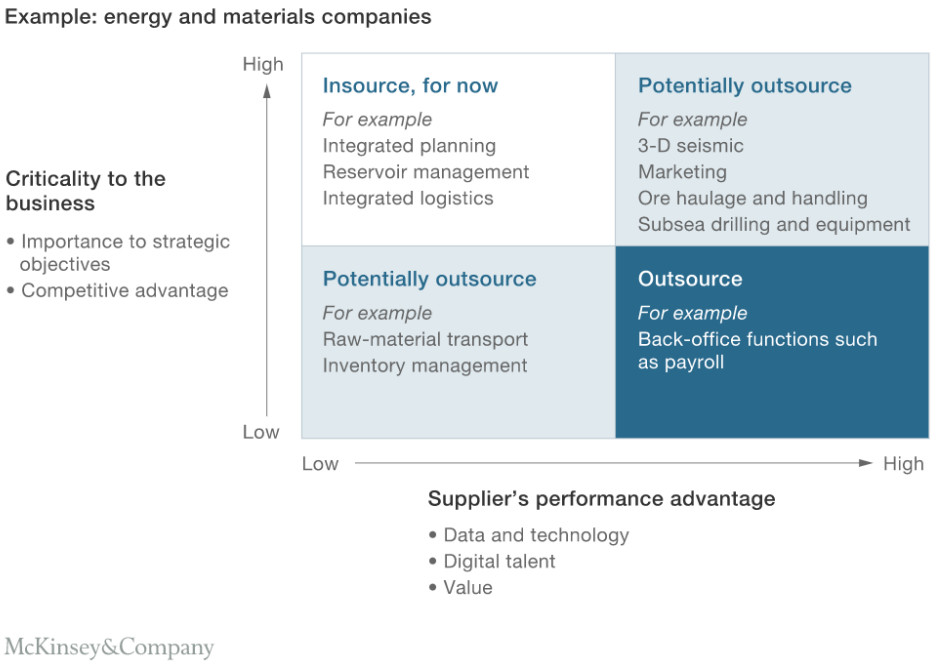


Figure 6 - McKinsey outsourcing matrix for an Energy company segmenting activities along business criticality and comparative performance [31].

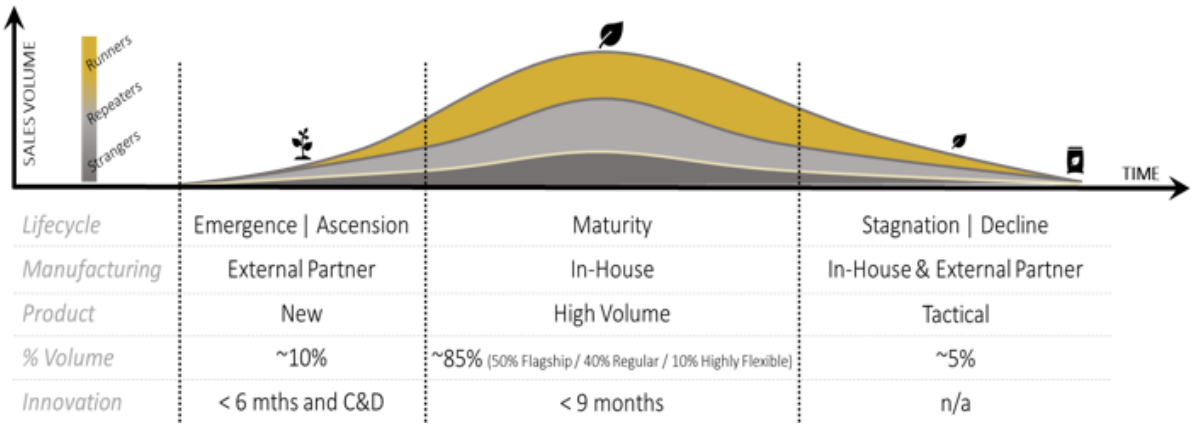
Each of these possibilities has taken place across several industries, with numerous successes across many categories and regions where the strategy to outsource production to CM's delivered outstanding results on localization, product innovation, speed to market and investment risk reduction. Some examples in which industries have outsourced productions are in the pharmaceutical industry, where Fareva manufactures all Pfizer's Viagra globally, in the electronic industry, where Apple owns the design of its products and Foxconn owns manufacturing, in the hotel sector, in which Marriott does not own most of their hotels, and also in the fast-moving consumer goods sector, where Henkel and Unilever announced their decision to go more outside to innovate faster and improve their capital as % of sales.

The decision to outsource depends on multiple parameters like future growth level, available internal and external capacity, and external ability to innovate and cultivate a new volume growth, etc.

Until the 2021/2022 fiscal year, P&G was progressively increasing the volume assignment to CMs, primarily due to products related to new initiatives (novel products that are new in the markets), for which a strategic decision is made to manufacture them as fast as possible and with the least initial investment potential. In a P&G owned plant, such would not be feasible due to the infrastructural and financial requirements of setting up new production lines and the time to assemble it.

Considering these setbacks, the most time and cost-efficient mode of having the products on the shelves is to attend to the CM to produce them, even though it has a worst cost structure compared to the equivalent production in a P&G owned plant. This strategy also allows the withdrawal of the product from the markets if the demands are not as expected, without having to incur all the costs if it was produced in a line in one of the company's facilities, making this strategy very agile.

Figure 7 presents a graphical demonstration of which products and the subjacent characteristics they should have to be considered in an outsourcing or insourcing project.



Lifecycle	Emergence | Ascension	Maturity	Stagnation | Decline
Manufacturing	External Partner	In-House	In-House & External Partner
Product	New	High Volume	Tactical
% Volume	~10%	~85% (50% Flagship / 40% Regular / 10% Highly Flexible)	~5%
Innovation	< 6 mths and C&D	< 9 months	n/a

Figure 7 – Schematic demonstration of the considerations to Outsource and Insource a product. [P&G]

Due to a significant increase in subcontracting in recent years, a corresponding decline in the oversight of raw and packaging material production and procurement has been noticed. This situation has led to a rise in unrecorded liabilities at CMs locations, contributing to the peak levels of inventory disposal costs currently witnessed. These circumstances bring into question the effectiveness of the existent production values and supply chain efficiency. The comparative lack of control is especially conspicuous when benchmarked against the regulatory oversight typically exercised within proprietary manufacturing facilities. Consequently, a proposal to scrutinize the operational effectiveness of the external supply solutions' production and supply chain processes was mooted. This initiative was informed by apprehensions voiced by the External Supply Solutions (ESS) supervisor, who perceived sub-optimal performance in the operation.

Given that the Hair Care division at P&G works with nine CMs, the data requirements to carry out a comprehensive analysis on each of these entities would be both overwhelming and time-consuming. This not only pertains to data collection and cleansing but also to the actual analytical processing. In light of these considerations, the decision was made to concentrate the analysis on the largest CM, henceforth referred to as CM-1. This CM was distinguished not only by its considerable footprint in the CM ecosystem, accounting for 60% of the total ESS expenditure, but also for the complexity of its product portfolio, involving highly specialized hair treatment and oil products, amounting 80% of the product complexity within the ESS. By focusing on this dominant CM, the analysis seeks to identify potential areas of inefficiency, streamline operations, and enhance value within the ESS supply chain.

Despite the agility conferred by outsourcing strategies, they are frequently sub-optimal, burdened by logistical complexities that result in overproduction and lack of supervision. This invariably gives rise to underperforming inventory (UPI) or inventory disposition expenses (IDE). In view of these repercussions, an intervention within the external manufacturing supply chain was deemed necessary to curtail the escalation of UPI and IDE.

Before conducting the analysis on the largest CM, an exploration of the cost structure of a product is essential to discover what could be leveraged in order to improve the total delivered costs. Total delivered costs is a P&G term which represents the cost incurred in the conversion of raw and packaging materials into finished products and distribution of product to customers (equivalent to the cost of the goods sold), which can be found in Table 2.

Table 2 - Total delivered costs

Raw and Packaging Material costs (RPM)	Commonly, the most significant part of total delivered cost. Marketing and Research & Development (R&D) define the desired product performance and consumer benefits for the target consumer of product and packaging. Once the R&D department has designed the product and packaging, the purchases department source the required materials at best value for the company. The underlying raw materials (e.g., polypropylene, ethanol, cardboard, etc.) are a key driver for the product and packaging costs.
Manufacturing Operating Expenses (MOE)	Costs involved in converting raw and packaging materials into a finished product, ready to be shipped to a customer. It is influenced by process reliability, productivity, demand fluctuation and SKU complexity. It includes: · Depreciation of the installed machinery and buildings (fixed assets). · Wages and salary of the required staffing to operate the line. · Utilities (electricity, steam, water, etc).
General manufacturing costs	Costs not explicitly associated with producing a specific product include charges for experimental orders of new products, write-offs of obsolete equipment, etc.
Transport & Warehousing	T&W (Transport & Warehousing) includes the costs incurred to store and ship the finished product to a customer. Pallet efficiency, inventory levels and transport efficiencies drive T&W costs.
Other Total Delivered Costs	Includes scrapping costs (Inventory disposition expense), environmental fees & taxes and warranty fees mainly.

Considering the proposal covering an analysis across CM-1, the strategic decision was made to start the investigation from the area commanding the most significant part of the spending, which in this instance was the Raw and Packaging Materials (RPM). This approach underlines a structured and phased plan for improvement, starting with areas of highest expenditure and complexity, thoroughly examining every aspect, specifically in the context of MOQ optimization and safety stock management, aiming to comprehend the fundamental dynamics of the RPM inventory and provide light on how present procedures affect the overall efficacy and cost-effectiveness of supply chain operations.

3.1 Business Model

The investigation revealed the presence of three distinct business models in procuring Raw and Packaging Materials (RPM): Free Issue, Full Service, and Direct Buy. Each model represents a different approach to sourcing the RPM, involving alternative degrees of control and responsibility.

In the Free Issue model, RPM are ordered, paid for, and supplied to the Contract Manufacturer (CM) by P&G. The P&G planner is responsible for supplier reliability and communicating any potential risks and issues as the client company. This model offers the highest degree of control, allowing P&G to directly manage the RPM inventory, including selecting suppliers, negotiating pricing, determining order quantities, and timing deliveries. However, it also entails the highest level of responsibility and management effort, as P&G bears the burden of assuring the timely and adequate supply of the RPM. A scheme of the Free Issue business model is depicted in Figure 8, showing the logistical stages of creating an order.

This business model is standard within the P&G supply chain, particularly when a P&G plant is located close to the CM facilities, which happens in the CM-1, the biggest CM in the Hair Care department. Here, a reoccurring situation materializes since the P&G facility has a minimum production quantity of 8-ton bulks due to technical restraints of the production lines. Such a significant quantity represents a risk of potential waste if the CM production lines are not meticulously organized and with the respective necessary capacity.

Considering the above mentioned, only the finished products with high forecasted demands are produced through this business model.

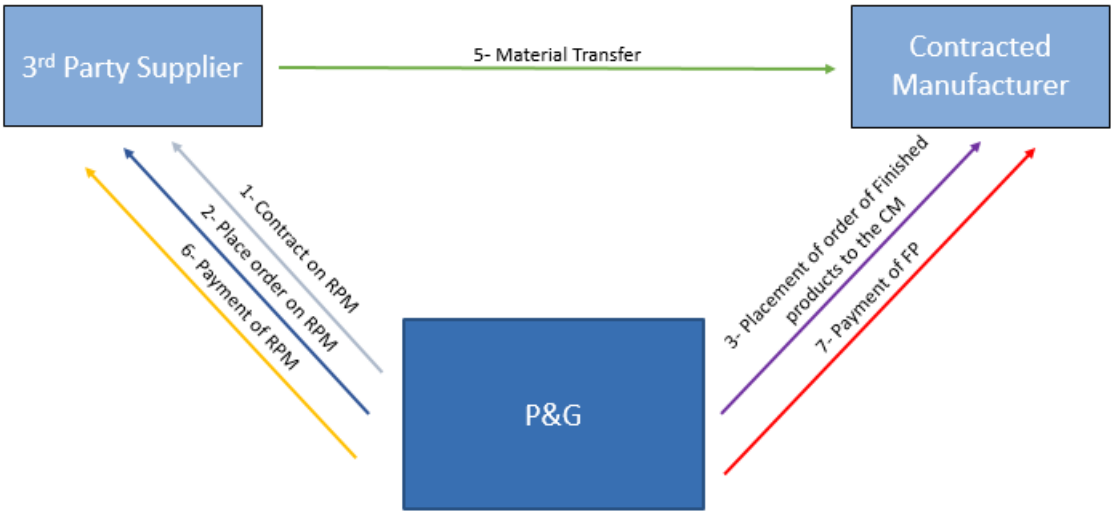


Figure 8 – Free Issue business model steps in the sourcing of an order

In contrast, the Full-Service model delegates the entire RPM procurement procedure to the producer. Raw and packaging materials are sourced and paid for directly by the CM, which manages the supplier's reliability. As one of several producer clients, P&G has little direct influence over RPM sourcing under this model. The producer can order the RPM according to their requirements and preferences, with little to no input from P&G's side. While this model minimizes management efforts and risk exposure, it limits the ability to optimize the RPM inventory per specific requirements and cost objectives. A scheme of the Full-Service business model is depicted in Figure 9, showing the logistical stages of creating an order.

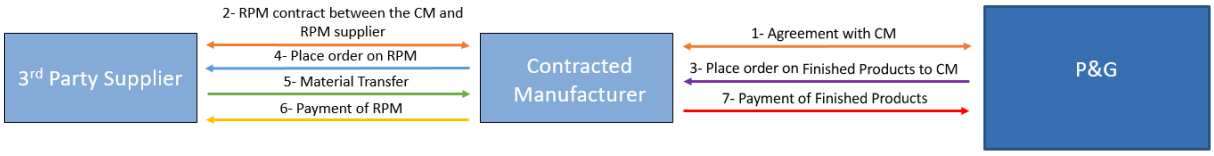


Figure 9 – Full-Service business model steps in the sourcing of an order

Finally, the Direct Buy model represents a middle ground between the Free Issue and Full-Service models. Under this model, raw and packaging materials are ordered and paid for by the CM, from a P&G-determined supplier, at P&G-agreed prices (Including Terms & conditions). This arrangement enables some control over the RPM procurement, particularly in pricing, while leveraging the producer's operational capabilities to manage the RPM inventory. A scheme of the Direct Buy business model is presented in Figure 10, with the logistical phases of creating an order.

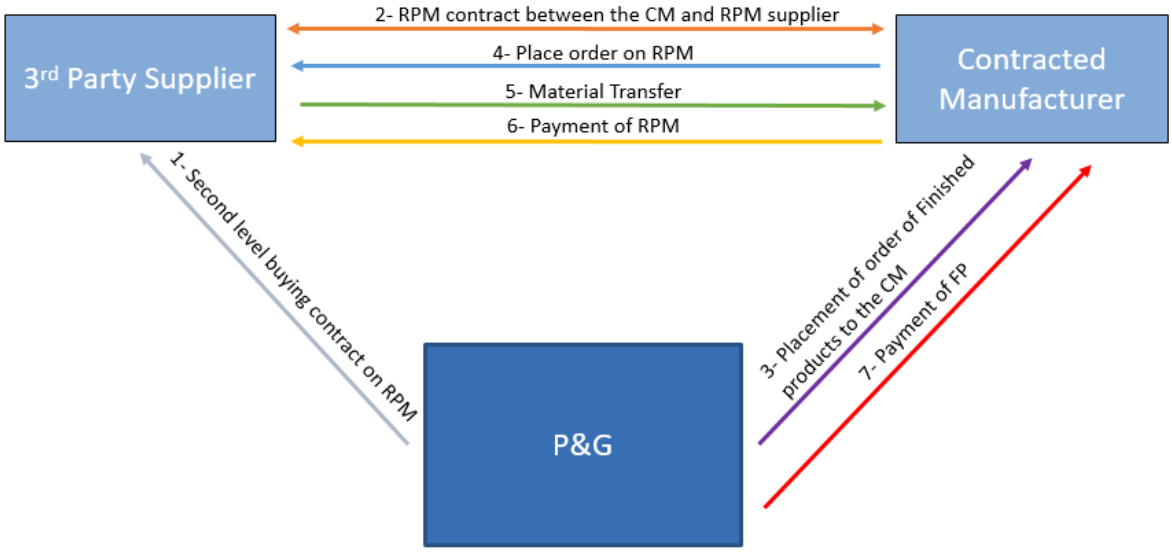


Figure 10 – Direct Buy business model steps in the sourcing of an order

It was found that the business model varied depending on the type of material. The Direct Buy model was commonly used for packaging material, enabling negotiation directly with the suppliers and influencing the procurement process. However, for the raw materials, the Full-Service model was the most used due to prevalent usage with the high number of clients of the producer. This situation limited the ability to influence the RM (Raw Material) procurement directly, posing a challenge to optimizing the RPM inventory. A summary of the current business models in place and their characteristics is presented in Table 3.

These findings underscore the importance of considering the business models in the inventory optimization efforts, and by understanding the specific characteristics and constraints of each model, it is possible to develop more tailored and practical strategies to improve RPM inventory management, even in situations where direct control is limited.

Table 3 - Summary of the business model characteristics and ownerships.

Business Model	Characteristics of Business Model	RM Planning	RPM Negotiation	Sourcing P2P	Inventory Ownership
Free Issue	High spends, critical material for P&G RPM are protected or supplied by P&G Low resource requirement CM has no financing capability CM has no planning capability	P&G	P&G	P&G	P&G
Full Service	Low Spend and risk profile P&G has no meaningful commercial purchase price advantage High resource requirement (manual packaging operations) Supplier has financing capability Supplier has planning capability	CM	CM	CM	CM
Directed Buy	RPM are secured by the CM, with a commercial purchase price advantage by P&G CM has planning capability High resource requirements and added complexity	CM	P&G	CM	CM

3.2 Raw and Packaging Materials

In an initial examination of the supply chain logistics related to the Raw and Packaging Materials (RPM), several instances where the Minimum Order Quantity (MOQ) significantly surpassed the stipulated Feed For Use (FFU) guidelines were found. It was also unearthed that the lead times in certain scenarios extended up to 189 days (about 6 months), an extraordinary time that presents considerable challenges to efficient supply chain management.

Having uncovered these preliminary findings, a comprehensive examination of the raw and packaging materials processing was undertaken, focusing mainly on the cases identified as problematic in the initial appraisal. The outcome of this detailed investigation led to a series of recommendations seeking to enhance the efficiency and responsiveness of our supply chain logistics.

Having the correct MOQ value is of great importance within P&G's supply chain, due to its use as the standard unit for placing orders (or multiples of it), since the contracts and price negotiations are based on its value. Suggestions were made to either increase or decrease the MOQ in specific instances, where adjustments were calculated by incorporating principles from the Silver Meal and Economic Order Quantity (EOQ) model, as seen in Chapter 2.1, to minimize total inventory costs, including holding and ordering costs. Nonetheless, the suggested adjustments were carefully deliberated, ensuring the resultant MOQ levels continue to comply with the existing FFU guidelines.

Further, the evaluation revealed circumstances in which supplier changes would be beneficial and possible, having in mind the business model in place, predominantly on the situations where the lead times were excessively lengthy and therefore, unsuitable for the desired agility and high standards set for the product supply chain. Changing suppliers is a crucial decision that requires rigorous scrutiny of prospective alternatives regarding their reliability, product quality, cost-effectiveness, and capacity to meet P&G's lead time requirements.

The strategy of modulating MOQs addresses the immediate issues unveiled in our supply chain logistics, However, these strategies should be employed as part of a dynamic, ongoing process. The nature of supply chain management requires continual review and adjustment to acclimate to evolving market conditions, supplier dynamics, and internal requirements. As such, part of the result of the study should guarantee the implementation of systems to correctly review and modify the MOQ values to meet the forecasted demands. This holistic and dynamic approach to inventory and supply chain management ensures the resilience and efficacy of production operations, ultimately contributing to the business's sustained success.

The first part of the detailed examination of the RPM SKUs consisted in detecting the cases where the current MOQ was potentially originating underperforming inventory or even Inventory Disposition Expenses (IDE), since it originates costs, as opposed to the case where the MOQ is not optimal and could be improved to completely fulfil the demand, representing an opportunity for savings, but not incurring in extra costs. The data collected showed that 410 out of 1187 SKUs have a MOQ coverage higher than three-months, in accordance with the current forecasted demands. This demonstrated a substantial overstocking scenario, more critically so as in certain instances, the actual inventory level exceeded the safety stock levels currently in place by fivefold.

This accumulation of excess inventory becomes more concerning as amongst these 410 overstocked items, it was found to exist 70 SKUs with outstanding purchase orders, despite demand being entirely satisfied for the imminent three months. A critical disconnect between procurement processes and actual demand, or between the mechanisms in place to initiate the order and the forecasted demand, lead to unnecessary inventory accumulation, potential obsolescence, and potential financial losses. Given the gravity of the situation, a study was

launched to discover the current triggers originating the unnecessary orders found to be taking place.

Moreover, it is worth noting that these findings emphasize an issue of non-compliance with the Feed for Use (FFU) criteria, which stipulates that no RPM order should exceed 30 days of forecasted demand coverage.

It was found that due to the Full Issue business model in existence for the raw materials, and since the CM-1 has many clients beyond P&G, it would be hard to influence the values of the MOQ's for the Raw Materials. The only possibility of making any change would be to attempt to influence a more convenient MOQ or change of supplier, given the volume of business from P&G, however, it is not something to take lightly.

These observations underscore the need for a comprehensive re-evaluation of inventory management practices. Addressing these discrepancies requires an enhancement in demand forecasting accuracy, implementation of adaptive inventory control measures and procurement processes that are more responsive. Striking a balance between maintaining adequate stock levels to meet customer demand and avoiding overstocking that results in financial burden or obsolescence is crucial. Implementing these changes can foster operational efficiency, cost-effectiveness and assure the long-term robustness and profitability of the supply chain.

3.3 Joint Economic Lot Sizing

The effectiveness and efficiency of supply chain management are fundamental to the success of any manufacturing organization. Addressing inefficiencies early in the supply chain process mitigates the ripple effect of costs and operational challenges downstream. The compounding effect of these early inefficiencies can result in higher Manufacturing Operational Expenses (MOE), increased Transportation & Warehousing costs, and increased storage costs. As such, strategic and proactive interventions at the early stages of the chain can potentially drive considerable cost savings and operational efficiencies.

A critical examination of the beginning of the supply chain was performed to ensure efficiency improvements. The aim was to recognize and correct any inefficiencies early in the chain to prevent the ensuing cascade of costs. The analysis was conducted with similar standards to the one conducted for the Raw and Packaging Materials (RPM), with the collection of data from P&G's software, regarding the demands for the Finished Products (FP) that resulted from the joint production in the same assembly line, grouped in families by the content of the product and varying in sizes. Master data regarding the quantities and provenience from the bulks related to the families was also collected. The data was then compiled and analysed, considering the historical and forecasted demand.

After collecting the data, a comparison between the bulk and FP associated with it was performed as an attentive to measure the effectiveness of both the MOQ of the bulk and the MOQ of the FP.

An initial investigation found that there were two business models in place, Free Issue, and Full Service. The Free Issue business model represent the case where the CM is not responsible for producing the Raw Materials. In this case, the bulk of formula (content inside the bottles), being only responsible for the packaging process. On the other hand, the full-service business model represents the situation where P&G pays for the FP and does not have any contact with the RM sourcing whatsoever.

For CM-1, in the cases where the business model in place was the Free Issue, the bulk of formula was produced in a P&G owned plant and shipped to CM-1, due to the lack of capacity in the plant. After a more thorough look, it was found that the bulks coming from the P&G plant

were in fact inadequately large compared to the finished products MOQ's in place, originating either waste when the bulk was not exhausted or production of potentially underperforming inventory of finished products. For the first option, it was also discovered that the cost of scrapping the bulk represents 80% of the value of the complete bulk, meaning that in the cases where the bulk is not exhausted and is then sent for scrap, P&G could face losses that amount the cost of the content of the bulk and the cost of scrapping.

In the case of full service, P&G had no influence other than what is defined in the production contract. For this business model, 93 different formulas were found, linked to 370 FP, which, in most cases, only vary in the label of the location it will be shipped to and in the different packaging sizes.

As such, the CM-1 was grouping the production in "families", where the criteria chosen for the grouping was the content of the FP, as a way of improving the efficiency of the packaging process, through the reduced number of changeovers and technical restraints associated to the cleaning of the material. This grouping resulted in the bulk production of the content, referred to as Family MOQ (FMOQ)

Upon further analysis and contact with CM-1 employees responsible for the production, it was discovered that the balance between the FMOQ and the linked FP MOQ was not perfectly balanced due to the evolution of the demand of the FP and the lack of updates in conformance on a formula MOQ level. This situation occurred due to the inadequate periodic reviews of the contract terms between CM's and P&G, leading to inefficiencies.

After more careful analysis, it was discovered that in 55% of the cases, the MOQ requirements for the FP were larger than the scheduled production value provided by the linked bulk. This discrepancy meant that the production based on the FMOQ failed to meet the demand for the FP, originating in the need for additional production runs and the subsequent increment of extra costs.

On the other hand, in 30% of the cases, the FMOQ exceeded the requirements for the FP. This overproduction resulted in extra quantities of the product that were not needed, leading to waste and inefficiencies. It also tied up resources that could have been used more effectively elsewhere. An example with details for the two cases mentioned before can be found in Table 4. In the first case, 2 production runs needed to be executed to fully cover the FP requirements, since there was a 40% difference between the requirements and availability. In the second case, it is shown that the FP requirements only fulfil 45% of the FMOQ, resulting in the overproduction of FP, potentially generating underperforming inventory and, in the worst-case scenario, Inventory Disposition Expenses (IDE).

Table 4 – Example of the problems identified in the analysis.

Problem identified	Product type	FP Requirements (M IT)	FMOQ (M IT)	FP Requirements vs FMOQ
FP requirements > FMOQ	300 ml bottle	39	28	140%
FP requirements < FMOQ	680 ml bottle	4	9	45%

The remaining 15% of the cases involved only one FP associated with the batch or formula produced. These cases added extra complexity to the production systems, requiring

unique setup and processing conditions for a sole product, limiting the potential for economies of scale and process standardization. Since eliminating products was not an option, the focus concentrated on the remaining 85% of cases, and further analysis was performed to develop a solution for the presented problems.

3.4 Storage and Safety Stock Analysis

Due to the two supply chain problems mentioned above - the suboptimal MOQ values for Raw and Packaging Materials and the misalignment between the Family MOQ (FMOQ) and Finished Product (FP) MOQ – the stock levels escalated significantly, exceeding the agreed quantities for safety stock, giving rise to surplus costs.

A preliminary analysis indicated that the safety stock levels are sub-optimal, contributing to the overstocking or stockout problems. The safety stock, designed as a buffer against demand and supply uncertainties, appears not to be revised regularly nor tailored to the demand variability. This static and one-size-fits-all approach to safety stock management does not reflect the dynamic and uncertain nature of demand, leading to either excess safety stock that unnecessarily inflates inventory costs or inadequate safety stock that exposes the company to stockout risks.

These extra costs manifest in two ways: if the stock remains unused (i.e., no demand) for more than 180 days, the holding costs, including warehousing, insurance, and potential depreciation, accumulate and become a financial burden; if the stock exceeds the pre-agreed safety stock levels, additional holding costs occur, as well as opportunity costs, as tied-up capital could have been used more productively elsewhere.

The situation has steadily worsened, with stock levels rising from the safety stock levels to approximately 25% of extra storage costs in June of the current year, as shown in Figure 11. This substantial increase represents a generous portion of the inventory and significantly impacts the budget.

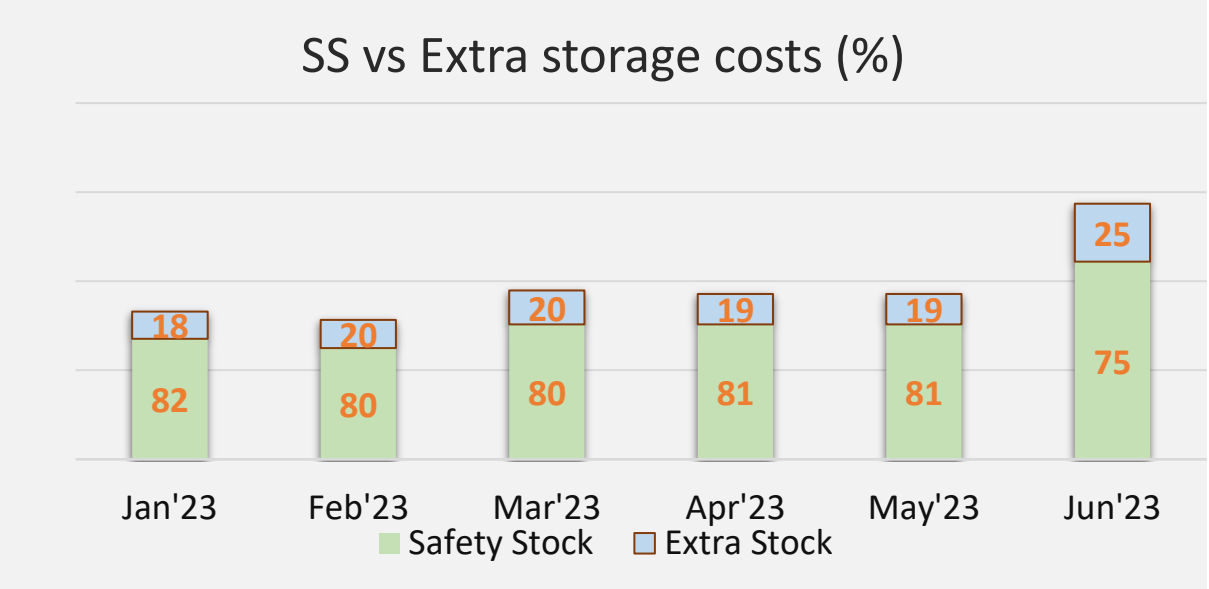


Figure 11 – Comparison between Safety Stock values and extra storage costs paid.

Given the magnitude of the problem and its financial implications, addressing the root causes, and bringing stock levels back within the agreed safety stock limits is essential. Optimizing the MOQ values and aligning the production planning with the FP demand requirements, reduce the excess stock, minimize the holding and opportunity costs, and enhance

the efficiency and agility of the supply chain. Such an improvement will reflect on financial performance and strengthen the ability to respond to demand fluctuations and market changes.

The severity of the situation this year was evident in terms of inefficiencies, marked by a multitude of issues, including IDE (Inventory Disposition Expense), Underperforming Inventory, Non-Performing Inventory, product scrapping, scrapping services, and even resale to cover production costs, representing a significant 15% of the total budget for external production, highlighting the urgent need for intervention and optimization. In Figure 12, the several stages of the Underperforming Inventory (UPI) and the respective characteristics are presented, based on P&G's proprietary tool named "Driving out Unhealthy Inventory Tool" or, as shown in Figure 12, DUITI - One of Inventory Actuals reports which allows the monitorization of the unhealthy portion of total inventory, in Days Forward Coverage (DFC).

[UPI] Unproductive Inventory	
[BR] Brown/Excess Safety	Non-negative amount by which safety appears to be too high based on the actual deadstock as a percent of safety compared to the expected deadstock as a percent of safety.
[YS] Short-Term Yellow/Excess Cycle	Excess inventory calculated according to DUIT from mat-locs with less than 2 weeks of DFC of Excess. Would be gone in < 2 weeks if there are no replenishments and the forecast materializes.
[YM] Moderate-Term Yellow/Excess Cycle	Excess inventory calculated according to DUIT from mat-locs with more than 2 weeks of DFC of Excess. The excess will take more than 2 weeks to be eliminated if without special action.
[AB] Amber/Slow	All MRP Available Inventory for very slow moving non-Anticipation, non-Orange/Remnant codes where MRP Available Inventory is greater than both 2 pallets and 180 DFC. Need special attention to eliminate.
[OR] Orange / Remnant	Orange/Remnant Inventory as calculated in DUIT
[RD] Red/Blocked	Red/Blocked Inventory as calculated in DUIT

Figure 12 – Under Performing inventory subcategories and details.

The problem evolved, in such a way, that at the beginning of the internship, the risk of the Non-Performing Inventory (NPI) and Under Performing inventory (NPI), shown as Total Risk in Figure 13, represented 12% of the total inventory of the CM-1, shown in Figure 14 as Total OBL, representing the totality of the Out-of-Book Liabilities. The situation reached a critical juncture when in week 6 of the internship, the Total Risk achieved a maximum value of 16% of the Total OBL. To face this circumstance, it was decided to give more support to the study being conducted in the ambit of this thesis. The analysis performed until that instant was presented to the ESS Supervisor, MSM, and the purchasing department. The result of this meeting was the implementation of the measures described in chapter 4.1 and the initiation of a new initiative, the study of the FMOQ, seen in Chapter 4.2, was lunched with the support of P&G's Planner and Site Leader responsible for CM-1.

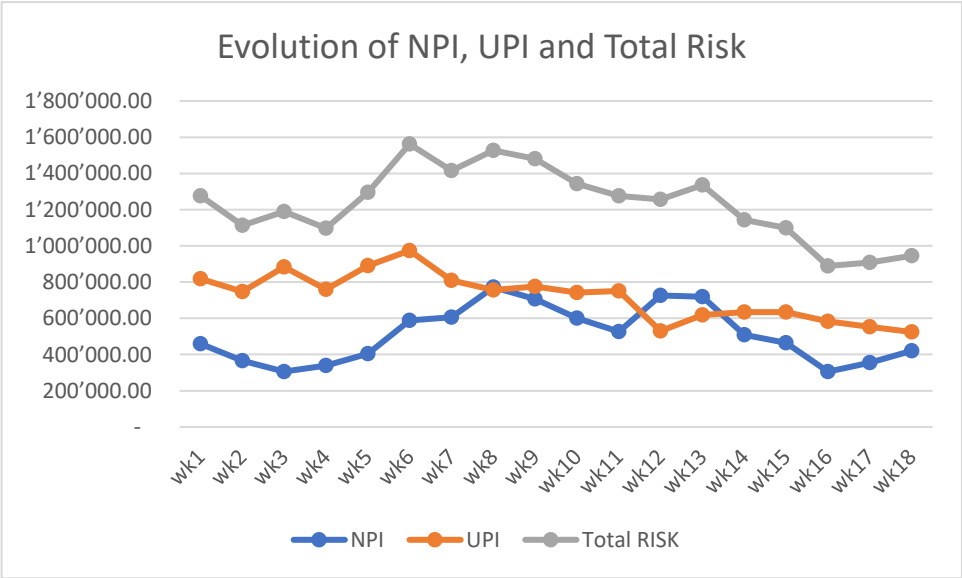


Figure 13 -Evolution of NPI, UPI, Total Risk during the internship

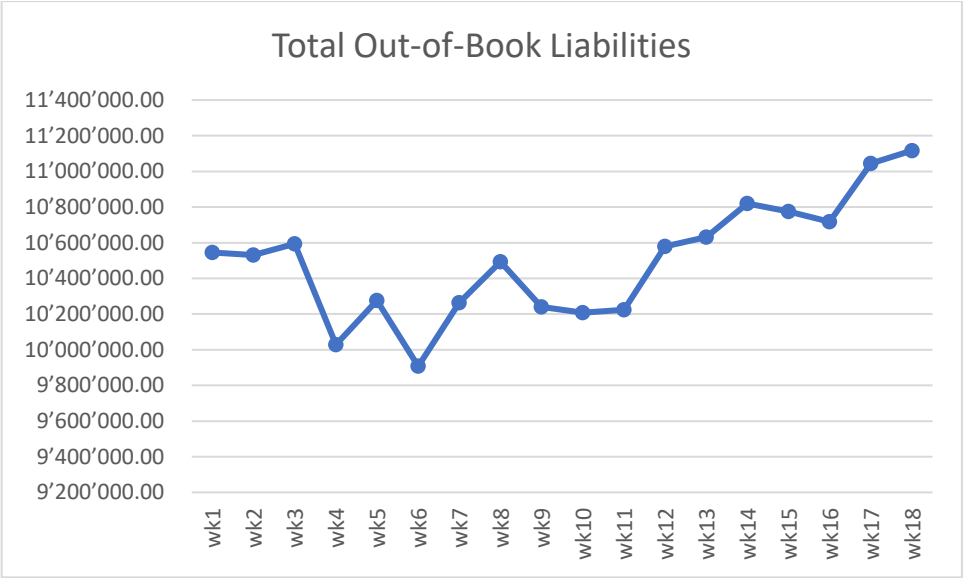


Figure 14 - Evolution of total out-of-books liabilities during the internship

4 Results of the performed analysis

The systematic and detailed analysis carried out throughout this project has culminated in identifying significant avenues for financial optimization within the supply chain operations. A notable finding of this investigation is the potential savings opportunity amounting to 1.5% of the total expenditure budget for the Contract Manufacturers (CMs). This discovery, derived from a diligent examination of the firm's inventory management and production strategies, reflects the efficacy of thorough analytical methods in unravelling tangible benefits.

The forthcoming sections in this chapter elucidate the intricate processes involved in uncovering this savings potential, segmenting it across three principal categories: Raw and Packaging Material (RPM) MOQ revision, Family MOQ revision, and Safety Stock and Storage Costs revision. Each category contributes distinctively towards the total potential savings, with 50% originating from the Family MOQ revision, 30% from the RPM MOQ revision, and the remaining 20% from the revision of Safety Stock and Storage Costs, as shown in Figure 15.

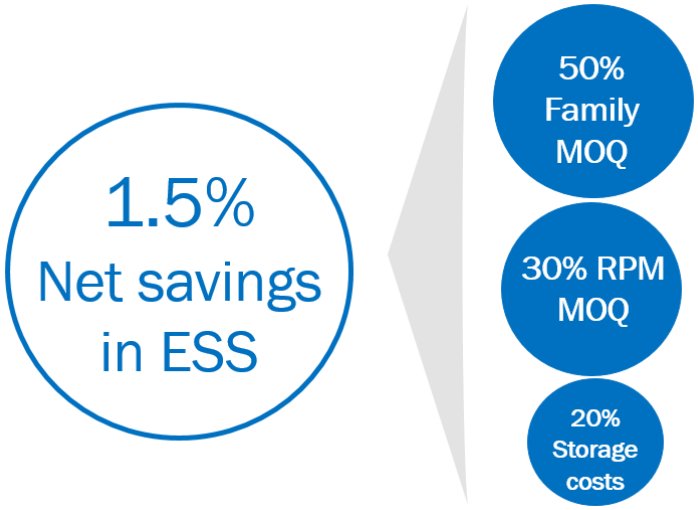


Figure 15 – Schematic demonstrating the distribution of the savings opportunities resulting from the analysis

The first focus of the discussion will be the analysis and revision of RPM MOQ. The extensive analysis identified optimization opportunities, including MOQ adjustments that align the ordering processes more closely with the Feed for Use (FFU) criteria, and ultimately driving significant cost savings.

4.1 Raw and Packing Material

The initial investigation focused on the RPM values, probing the current state of Minimum Order Quantity (MOQ) practices within the organization. A sizable proportion of non-efficient MOQ values were discovered, a consequence of the existing policy of revising MOQs only at contract renewal, typically a 1-year basis event, revealing very ineffective considering that the phase-in phase-out of a product is usually between 12 to 18 months, due the high values of customer demand and intense competition from other brands. This infrequent revision practice fails to account for the dynamic nature of demand, resulting in MOQs that often need to be aligned with the current demand patterns.

To address this issue, a comprehensive analysis was undertaken to find achievable improvements in the supply chain. However, the application of the empirical Economic Order Quantity (EOQ) formula was not always feasible due to certain constraints imposed by P&G. Due to the growing IDE values P&G had been liable of in the past years, it instituted a Feed for Use (FFU) criteria, which stipulates that the maximum quantity of products that can be ordered should not exceed the forecasted demand for the next 30 days. However, until now, this criterion was only applied to the Full-service business model, in which the batches of product are shipped from a P&G plant, and the CM only must pack the product. This is due to the previous contracts with the CM stating that, in the case of Free Issue and Direct Buy Business Model, if P&G supplied a forecasted demand of 6 months, the CM would be allowed to order the RPM for up to 6 months of coverage.

The FFU criterion serves as a cap designed to prevent excessive ordering and overstocking. While this criterion can help keep the inventory levels in check, it also introduces a limitation to applying the EOQ formula, which does not consider such demand caps in its basic form, and the calculated order quantity might exceed the FFU limit. Therefore, a modified EOQ approach or a different optimization method is required to determine the optimal MOQs under this constraint.

This scenario underscores the complexity of real-world inventory management and the need for more flexible and adaptable models that can accommodate various operational constraints and business rules. Despite the challenges, the redefined MOQ values, guided by data analysis and business constraints, are expected to better align with the current demand patterns and contribute to more efficient and cost-effective inventory management.

The PIPO (Phase In Phase Out) process presents a complex challenge in inventory management and supply chain forecasting due to the transitional periods of products. The extended duration of these periods further aggravates the difficulties inherent in managing products. During this time, both the phased-out and phased-in products must be addressed simultaneously in the production process, which can lead to complicated inventory dilemmas.

Balancing the demand and supply of phased-out and phased-in products is vital during the PIPO period to minimize the risk of overstock or stockout situations. Despite being on the verge of obsolescence, the phased-out products still require sufficient supply to meet existing demand, which gradually diminishes over time. The opposite happens for the phased-in products, which face an increase in production volume to meet the potential rise in demand. This delicate equilibrium requires wise and accurate forecasting, as the repercussions of underproduction or overproduction can significantly impact financial performance and customer satisfaction.

Given these complexities, applying advanced forecasting models and strategies that factor in PIPO periods can play a critical role in improving inventory control and production planning. Techniques such as probabilistic forecasting and quantifying uncertainty can be particularly effective.

The comprehensive examination of the Raw and Packaging Material (RPM) and the subsequent adjustments of Minimum Order Quantity (MOQ) values yielded both increases and decreases in the MOQ across different items. This variability reflects each item's unique characteristics and demand patterns, requiring individualized MOQ decisions rather than a one-size-fits-all approach to increase supply chain performance. In Figure 16, a trade-off between the value of the product MOQ, MOE and inventory cost is presented, demonstrating the principle of finding the total cost optimum value.

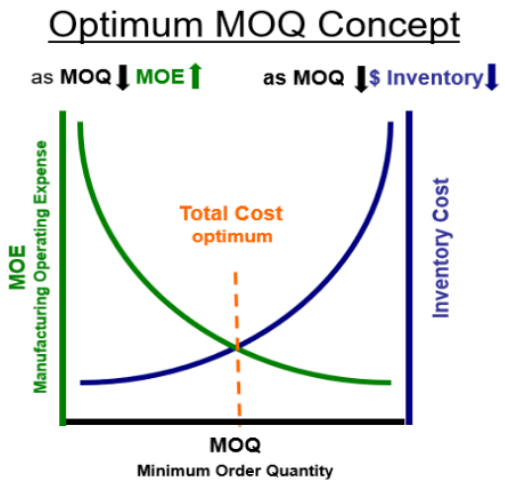


Figure 16 – Representation of the optimal point for ordering – Concept of MOQ [P&G]

The performed analysis was initially around the collection of vital master data from a variety of sources established within the supply chain, such as stakeholders, ranging from the Planner and Site leader to the Material Sourcing Manager (MSM), who provided insightful perspectives on the operational dynamics. In addition, critical data was extracted from weekly stock reports received from the Contracted Manufacture for materials of which P&G was liable and used in manufacturing the products.

Key focal areas during this analysis included comparing current Minimum Order Quantity (MOQ) values against future demand forecasts and the duration of their coverage in terms of days while also considering the lead time. Furthermore, it also considered the negotiated price list from several suppliers with the direct buy business model due to the possibility of influencing the ordering quantities in this model. Historical data was meticulously recovered from previously received stock reports, facilitating a comprehensive evaluation of demand variability and the MOQ's effectiveness in inventory coverage. This data collection span was essential to understand the historical patterns and the dynamic interplay between demand and supply over time.

Generally, the CMs will offer a better unit cost if the MOQs are bigger, since longer production runs imply better productivity for their production lines (given fewer line change overs and production runs). However, these cost-effective large MOQs can bring significant inventory hurts in the case of SKUs with low volume, i.e. the agreed MOQ can represent several months or even years of days of forward inventory coverage and consequently leading to underperforming inventory and IDE risks.

Collecting the mentioned data and analysis offered a rich, contextual understanding of the current supply chain operation. By cross-examining the current MOQ against future demand, inspecting the product coverage, and analysing pricing structures, it was possible to identify potential bottlenecks and opportunities for optimization.

The revisions to the Minimum Order Quantity values were done in close collaboration with the Material Sourcing Managers, who are responsible for ensuring the smooth functioning of the product supply chain. The revised MOQ's were validated by the purchasing department and site leader (P&G's employee responsible for overseeing CM-1), marking an important milestone in the ongoing negotiation and optimization process. In the most extreme cases, the MOQ, when compared to the monthly forecasted demand, was as low as two days of coverage. This short coverage period represented a significant opportunity for improvement, as it entailed frequent reordering, leading to additional costs. These costs included Manufacturing Order Expense (MOE) fees - costs associated with setting up and running the production process, transportation, and logistics costs, which are incurred in moving the products from the suppliers

to P&G´s facilities, and warehousing costs, which are associated with storing the products until they are needed.

The increase in MOQ for certain items resulted in notable cost benefits. Due to the economies of scale often associated with bulk purchasing, a larger order quantity often fetches a lower unit cost. The preliminary analysis found a potential unit cost reduction ranging between 3% and 12,5% for most items that experienced an MOQ increase. This cost-saving benefit can significantly contribute to the inventory system's overall cost efficiency and the business's profitability. Table 5 summarizes the savings obtained by increasing the current MOQ levels.

Table 5 - Results from the increase of MOQ

Product	SKUS	Old Coverage (days)	Average Increase	New Coverage (days)	Size of savings
Labels	40	18	x2	31	11%
Pumps	6	18	x4	30	3%
Cartons	10	16	x2	30	3%

Conversely, the reduction in MOQ for other items also offered its unique advantages. Although a smaller MOQ might lead to a higher unit cost due to the loss of economies of scale, it helps avoid the financial and operational burdens associated with excess inventory. Specifically, by reducing the MOQ, it was possible to diminish the Non-Performing Inventory and Under-Performing Inventory, in other words, inventory that is not generating value. Non-Performing Inventory typically refers to stock that remains unsold for an extended period, often due to low demand or obsolescence. On the other hand, Under-Performing Inventory denotes inventory that turns over at a slower rate than expected, tying up capital and storage space. A lower MOQ also helps mitigate the Inventory Disposition Expense (IDE), which encompasses the costs of disposing of unsold or obsolete inventory. These costs can be significant, particularly for perishable or hazardous materials that require unique disposal methods. Keeping the inventory level in line with the actual demand reduces the likelihood of scraping products and incurring the associated disposal costs.

Although the analysis proved useful and valuable, there was no mechanism in place to ensure the automatization of the update of the MOQ values or any factor that would enable the agility of the supply chain. With that in mind, a proposal arose to enhance the ordering process's flexibility and responsiveness instead of simply replacing the old MOQ values. Previously, the order quantity options were limited to the MOQ or MOQ plus a rounding value (RV). The RV is a residual value of the MOQ, that the supplier allows to order above the MOQ value without having to order another full MOQ. It is typically used to adjust the order quantity to a more manageable or convenient level, such as a round number or a full pallet.

Under the innovative approach, the order quantity options were expanded to include the old and new MOQ values and their respective RVs (Rounding Value). This developed set of options provides greater agility in responding to different demand scenarios and supplier conditions. For instance, it is possible to order the old MOQ plus RV when the demand is relatively low or uncertain or opt for the new, higher MOQ when the demand is solid and stable. Figure 16 shows an example for one of P&G’s products.

This increased flexibility allows us to exploit better the economies of scale associated with bulk purchasing. Instead of ordering multiple quantities of the old, smaller MOQ, P&G

can now order a single, larger MOQ that offers a more favourable unit price. This shift reduces the unit cost and simplifies the ordering and handling, leading to additional operational efficiencies.

This novel approach resulted in a significant improvement in P&G´s ability to meet the forecasted demand. While the previous MOQ values satisfied the historical demand in only 2 out of 12 months, opposing the revised MOQ values, which would fulfil the demand in 10 out of 12 months, as seen in Figure 17. The mentioned increase in flexibility and demand fulfilment capability enhances the service level and promotes the stability and sustainability of the supply chain.

In Figure 17, the forecasted demand could not be shared due to confidentiality reasons, so an average value, represented by the label 12MF, referring to the next 12 months forecast, was presented.

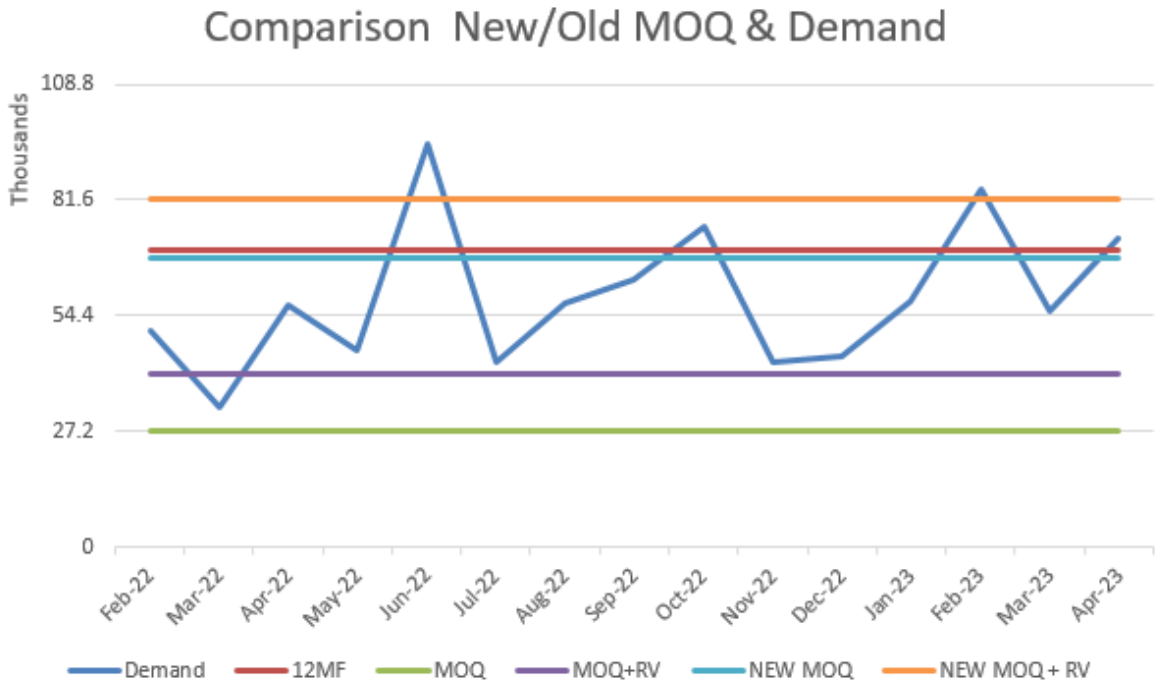


Figure 17 – Comparison in coverage between the in-use MOQ and the 4 levels MOQ strategy.

Adopting a more flexible and strategic MOQ policy, informed by a comprehensive analysis and validated by the MSMs (Material Sourcing Managers), promises to yield substantial benefits in cost efficiency, operational agility, and demand fulfilment performance. By aligning the ordering decisions with the current demand patterns and taking full advantage of the economies of scale, P&G can build a more robust and resilient supply chain that is well-equipped to navigate the dynamic business environment.

One of the significant challenges encountered during the execution of the dual-level Minimum Order Quantity (MOQ) system lies within the complexity of integrating it within existing systems, particularly concerning price reconciliation. This complexity becomes especially prominent in the direct buy business model, where P&G directly negotiates with the suppliers, thereby circumventing intermediary manufacturing contractors. While this business model generally brings about substantial cost savings and increased control over the raw material acquisition, it inherently adds an extra layer of complexity when implementing a dual-level MOQ system. The process will require an additional reconciliation procedure to verify that the cost reductions are effectively transmitted to P&G, representing increased manual overview and complexity associated with the process.

This reconciliation not only involves the numerical accuracy of the transferred savings but also requires an evaluation of the alignment of the contracted manufacturers' procurement and production processes with the new dual-level MOQ system. The intricacy of this reconciliation process requires comprehensive planning, robust system design, and meticulous implementation to maintain the integrity of the supply chain, guarantee accurate price transmission, and reap the benefits of the dual-level MOQ system.

4.2 Joint Lot Sizing

In alignment with the established theories in production engineering and inventory management, balancing batch production to optimize resource utilization is critical. Thus, this chapter seeks to delve deeper into the existing inefficiencies and offer potential solutions grounded in both academic knowledge and industry best practices to foster a more efficient production environment.

The analysis was initiated by adopting a methodology analogous to the one used for the Raw and Packaging Material (RPM) MOQ revision. This entailed gathering pertinent data from the individuals directly involved in the supply chain operations, including those in operational roles and decision-making capacities. After amassing and comprehending the scope of this data, a strategic meeting was arranged with the planner from P&G responsible for supervising the production scheduling for a vast array of SKUs manufactured at CM-1.

This collaborative meeting was a platform for shared ideation, employing brainstorming techniques to facilitate problem-solving. An underlying issue was unearthed during this engaging session, as outlined in Chapter 3.3. It was found that the management of the production of finished products belonging to the same 'family' sharing identical formula content but varying in their packaging – was not being optimized to its full potential. The consequence was a latent inefficiency that caused extra production costs that needed to be addressed. A disconnect between the finished products and their associated formula-containing bulks was the source of the problem. Specifically, the bulk quantity proved inadequate to fully satisfy the requirements of all associated finished products. This shortfall was not immediately apparent due to prevalent production practices that did not necessarily involve manufacturing all finished products linked to a particular formula 'family'.

However, upon deeper scrutiny, this approach was exposed as inefficient. The reason is twofold: firstly, while some finished products were bypassed during production, their demand remained unmet in the market, posing a challenge to P&G's stewardship policies. An entire bulk must be allocated to manufacture the unfinished products from the initial production run. Secondly, this led to a situation where certain finished products were being overproduced without corresponding demand, leading to underperforming inventory. This would escalate to Inventory Devaluation Exposure (IDE) in the most severe cases.

Post this revelatory meeting, a comprehensive analysis was undertaken to identify and understand the roots of this inefficiency. The subsequent steps aimed to conceptualize strategies for increasing production process efficiency by rectifying identified issues.

The detailed examination of the Joint Economic Lot Sizing, referred to within the company as "Family Production," shed light on the divergences in the two business models detailed in Chapters 3.1 and 3.3. Both models manifested their unique issues, contributing to systemic inefficiencies that warranted further exploration.

In the Free Issue business model context, the issue lies in the size of the bulk orders. On several occasions, these orders were disproportionally large compared to the demand for the finished products they contributed to. Such disparities led to a surplus of materials that may not

be utilized promptly or efficiently, tying up financial resources and leading to potential inventory management issues.

In contrast, the challenges posed by the Full Issue business model were tied to an inappropriate balance between the raw materials' minimum order quantities (MOQ) and the production requirements for the finished products. This mismatch was manifested in two distinct scenarios, each presenting its own set of complexities.

The first scenario is where the production requirements for the finished products surpass the capacity of the formula MOQ. In this case, the under-supply of raw materials leads to a production shortfall, potentially resulting in unfulfilled demand and lost sales.

Conversely, the second scenario presented the opposite issue, wherein the capacity of the formula MOQ outweighed the production requirements for the finished products. In this situation, the company is left grappling with excess raw materials and, consequently, overproduction of the finished products. This surplus, in turn, contributes to underperforming inventory and, in more severe instances, inventory designated for disposal (IDE).

It is evident from these findings that striking a delicate balance between order quantities and production requirements is essential. It is also critical to align these parameters with fluctuating market demands. More efficient inventory management practices can be employed through a nuanced understanding of these factors, minimizing instances of surplus or shortfall and promoting financial stability.

The rigorous examination of the interaction between formulas and finished products revealed significant imbalances in production capacities. A notable disparity was observed with 93 formulas linked to 370 finished products. 55% of the finished products had demand requirements that exceeded the production capacities of the corresponding formulas' minimum order quantities (FMOQ). Conversely, around 30% of cases demonstrated the opposite situation, with the formula's production capacity exceeding the demand requirements for the finished products.

The methodology underpinning this analysis involved collating forecasted demands for the upcoming 12 months and evaluating them against the production capacity embedded within the company's weekly production schedule. Since bulk and FMOQ were quantified in kilogram units, a conversion process was essential to align these figures with the forecasted demand, often expressed in units of finished products.

Notably, the company's commitment to stewardship, which underscores its operational ethos, significantly influences its production decisions. This orientation favours overproduction to mitigate the risk of failing to meet customer demand. While this conservative approach reduces the risk of stockouts, it does contribute to an ongoing issue of overproduction.

While acting as a buffer against unforeseen demand spikes, this overproduction has associated costs and risks. Excessive inventory leads to higher storage costs, potential obsolescence, and tied-up capital, negatively impacting the company's financial performance and operational efficiency. Thus, striking a delicate balance between fulfilling customer demand and maintaining a lean and cost-efficient production process remains a critical challenge. Therefore, a comprehensive understanding of these dynamics is crucial in informing efficient and effective inventory management practices.

The investigation into the distribution of manufactured products underscores the intricate nature of the supply chain under study, where products are dispatched to various markets across Europe. This geographical expanse adds a layer of complexity to demand forecasting due to the variation in consumption patterns across different markets. Moreover, within families of products sharing the same formula, a unique demand pattern becomes discernible: an apparent surge in demand during the summer months. This seasonal fluctuation

presents another dimension of complexity to the forecasting process, adding a predictable yet impactful variation to the demand pattern.

Figure 18 illustrates this phenomenon by presenting the forecasted demand for the ensuing 12 months for products within one family, all sharing the same formula. This visual representation brings into sharp relief the cyclical surge in demand during the summer period, demonstrating the seasonality embedded in the demand pattern for these products. The units on this graph could not be disclosed due to confidentiality reasons.

This discovery enlightens the need for demand forecasting techniques to accurately capture and predict variations and seasonal trends in demand. Understanding these dual aspects of demand is crucial for optimizing inventory decisions. Incorporating seasonality into inventory management models can improve demand forecasting accuracy, leading to more efficient inventory practices. This, in turn, would allow for better synchronization of supply with demand, contributing to minimized holding costs and improved customer service levels.

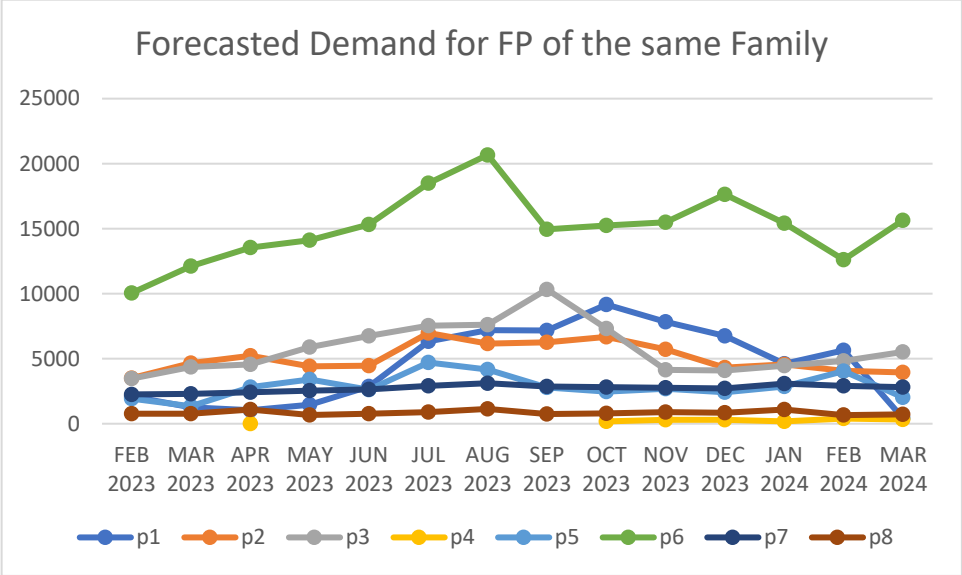


Figure 18 - Representation of forecasted demand for families of finished products grouped by formula

The comprehensive analysis of the gathered data and a survey of the technical limitations imposed by CM-1 regarding its production was performed. With P&G's prevailing concerns about IDE and the substantial costs incurred within the present fiscal year, it became swiftly apparent that recommendations for amplifying Formula Minimum Order Quantity (FMOQ) were not feasible. The possibility of IDE generation posed a substantial risk, instigating apprehension among the individuals responsible for budgetary oversight.

Nonetheless, despite these challenges, there was still room for enhancing efficiency. A trade-off value was determined through meticulous examination involving estimates of surcharges and discounts that could result from quantities variations. This value, representing an average reduction of 30% in FMOQ, struck a balance between the unit cost escalation driven by the decrease in FMOQ, the savings accrued by averting overproduction and the need for supplementary packaging materials, and transportation and warehousing costs.

This reduction in FMOQ of, on average, 30% effectively addressed the two problem cases identified earlier, as shown in Table 4. In scenarios where the Finished Product (FP) requirements surpassed the FMOQ capacities, double production runs were initially employed.

The performed approach maintains the two production runs (in the cases where it was necessary, due to the FP requirements being superior to the FMOQ capacity) and eliminates the production of excess finished products, that would lack demand, decreasing the risk of the stock

becoming underperforming or evolving into IDE. Furthermore, this approach also led to the removal of associated transportation, warehousing, and MOE costs.

In Table 6, the proposal is explained with the two examples presented on Table 4. In the first line, the excess of FP reduces from 60% to 5%. Observing the second line of Table 6, it's possible to see that the FP requirements vs FMOQ increases from 45% to 70%, decreasing by 25% the production of excess FP.

Table 6 – Numeric demonstration of the proposed change to the FMOQ levels.

Problem	Type	FP (M IT)	FMOQ (M IT)	FP vs FMOQ	Excess FP	FMOQ (M IT) (30% Reduction)	FP vs FMOQ (30% reduction)	Excess FP (30% reduction)	Savings ($M)
FP Requirements > FMOQ	300ml bottle	39	28	140%	60%	20	195%	5%	-17
FP Requirements < FMOQ	680 ml bottle	4	9	45%	55%	6	70%	30%	-8

For the other case, wherein the FMOQ exceeded FP requirements, the 30% reduction of FMOQ resulted in a considerable decrease in the production of FP lacking demand and thus, resolved the issue of potential waste. Considering that excessive stock production was incurring a substantial cost, equivalent to 0.8% of the total budget allocated to ESS. These operational inefficiencies in inventory management presented a significant opportunity for cost savings, mainly if addressed strategically.

Through the implementation of the proposed strategy, which involves a 30% reduction in the Formula Minimum Order Quantity (FMOQ), it is anticipated that the inventory levels will decrease significantly. Based on the analysis, this reduction could lead to a 60% decrease in the current excessive inventory levels.

The recommendations derived from the exhaustive analysis were subsequently conveyed to the entity overseeing the End-to-End Supply Chain (ESS). This entity expressed approval for the proposed initiative, consequently allocating further resources to explore the implications of its implementation.

A dedicated team was assembled to facilitate a more thorough exploration of this initiative, encompassing individuals with critical roles within the company. This team included the Site Leader, Planner, and Master Scheduler Manager (MSM). Additionally, the Purchasing Department, tasked with negotiating manufacturing processes' quantities and prices, was incorporated into the team.

At the end of the internship, the recommendations had yet to yield measurable results. Nevertheless, the initiative presented a potential opportunity for cost reduction, amounting to 0.75% of the total ESS spend for the Joint Economic Lot Size production, as seen in Figure 19, where PM represents the Packaging Material, IDE represents the Inventory Disposition Expenses and NPI represents the Non-Performing Inventory. In Figure 19, the cost help refers to the savings conducted, and the cash help refers to the avoidance of expenses. The proposed changes promise considerable savings by reducing the incidence of Idle and Excess Stock (IDE), the need for extra packaging material, and transportation and warehousing (T&W) costs.

The collaboration of various departments in this initiative illustrates the importance of interdisciplinary efforts in operational efficiency. It also underscores the potential benefits of a proactive approach to inventory management, with the goal of realizing cost savings and improving sustainability. By actively seeking opportunities for improvement, the organization

can strive to minimize wastage and inefficiency, creating a more streamlined and cost-effective supply chain.

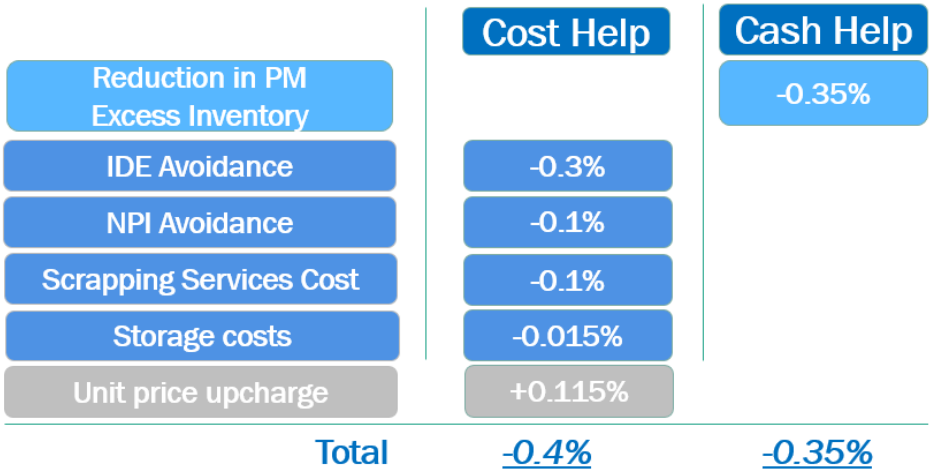


Figure 19 - Drivers of savings in the Joint Economic lot production

These findings illustrate the substantial impact that inventory management strategies can have on an organization's bottom line. By efficiently managing production schedules and order quantities, companies can reduce the excess stock levels, thereby diminishing the holding costs and potential for waste. Such steps not only enhance operational efficiency but also improve the financial performance and sustainability of the organization. It also underscores the importance of an integrated approach to supply chain management, where strategic decision-making can lead to improved operational and financial outcomes.

This strategic solution emphasizes the potential of astute decision-making in inventory management, reconciling the competing interests of cost reduction and efficient production. The findings contribute to cost savings and promote sustainability by minimizing waste and excess inventory.

4.3 Safety and storage stock

This chapter details the process of redefining the safety stock levels for improved efficiency and significant cost reductions.

The emphasis on safety stock arises from its role as a buffer against demand variability and supply disruptions. Establishing optimal safety stock levels was conducted with a clear focus on reducing storage costs without compromising the reliability of meeting consumer demand.

Simultaneously, storage costs are considered as they represent a significant portion of the total inventory carrying costs. Reducing these costs contributes to the overall efficiency of the inventory management process.

The analytical process applied in this Chapter involved the meticulous study of past demand patterns, forecasted demands, and the establishment of new safety stock levels by applying a novel company-owned tool. These efforts towards efficient inventory management manifest themselves in the reduction of Total Risk, observed as a significant decrease in non-performing and underperforming inventory, especially over the last four weeks of the internship in Figure 13.

The benefits of this comprehensive approach extended beyond inventory efficiency to significantly reduce IDE, shifting from a semi-annual revision of safety stock levels to a more dynamic, bi-monthly revision.

Examining the Raw and Pack Material (RPM) and the Family Minimum Order Quantity (FMOQ) frameworks revealed a vital link between these elements and storage costs. As the comprehensive analysis of these areas unveiled opportunities for a more efficient alignment with the forecasted demand, there is projected to be a consequential decrease in excess storage costs.

This inference stems from the enhanced efficiency that the revised RPM and FMOQ strategies bring to the production process. By attuning production more closely to forecasted demand, excessive production and the resultant storage costs can be significantly diminished.

The performed analysis on RPM and FMOQ, and their subsequent revision, is anticipated to engender a more demand-responsive production paradigm. This expected shift not only ensures the better utilization of resources but also directly impacts reducing storage costs, further enhancing the overall efficiency of the company's operations.

The company had recently developed a novel safety stock management tool for the ESS. However, it had not yet been implemented due to the decentralization of the data from the CM’s. For the tool to be used, manual labour was required to collect the stock reports from each CM, filter the reports from the CM’s external systems, and manually insert the data on the tool. Although the tool is of high importance and utility, the process before the utilization is very time-consuming.

Considering these constraints, a meeting was set up with the key users of the tool to understand if the data collection would be automated and what degree of difficulty it would imply. After the meeting, it was discovered that it wouldn’t be that complicated to arrange an automatic data collection system that would also be able to transform the data to the desired format, eliminating the effort required to have the tool in place. The result of this meeting was the recommendation to the higher management to program an additional tool to collect and pre-process the data.

By integrating historical demand data with forward-looking demand forecasts, this tool enables comprehensive end-to-end supply chain visibility, potentially driving significant reductions in storage costs and allowing P&G to decrease further its Total Risk, constituted by the non-performing and underperforming inventory. As shown in Figure 13, the Total Risk metric achieved a remarkable low of 8% during the final four weeks of the research period, when some of the RPM MOQ recommendations were already in place, indicating a promising trend towards enhanced inventory management efficiency.

By facilitating the data collecting and transformation process, it allowed the scheduling of bi-monthly safety stock revisions, rather than the previously established six-month interval, translating to a more rapid response to changes in demand or supply. This agility will likely yield a notable reduction in IDE, contributing further to the organization's operational efficiency.

In essence, the strategic revisions suggested and the new tool's deployment promise to improve the current inventory management in the ESS for the Hair Care Europe business unit.

5 Conclusions and Recommendations

This dissertation has comprehensively investigated various supply chain management strategies, focusing on inventory control methodologies and their application in the fast-moving consumer goods (FMCG) sector. The global disruptions caused by the COVID-19 pandemic underscored the need for resilient supply chain strategies, emphasizing geographical and supplier diversification, optimized capacity, and landscape assessments. In the face of such challenges, this work also scrutinized inventory management models, particularly static, dynamic, stationary, and non-stationary ones, shedding light on their applicability under different scenarios.

Applying these principles and models to the context of P&G resulted in invaluable insights. Through detailed analyses, this work identified potential areas for optimization in raw and packaging material (RPM) management, Joint Economic Lot Sizing (JELS), and safety stock and storage costs. The research revealed a potential saving opportunity amounting to 1.5% of the total spend budget at the 9 Contract Manufacturers (CMs), where these savings were distributed across Family Minimum Order Quantities (FMOQ) revision (50%), RPM Minimum Order Quantity (MOQ) revision (30%), and revisions to safety stock and storage costs (20%).

These findings have significant implications for stock management paradigms. Implementing the proprietary safety stock level determination tool demonstrated a marked decrease in total risk and Inventory Disposition Expenses (IDE). Additionally, a shift from semi-annual to bi-monthly safety stock level revisions led to improvements in resource allocation, bringing it closer to actual demand.

The lot sizing models, including Wagner-Whitin and Silver-Meal, proved crucial in supporting decisions on order replenishment sizes and timings. Their application underscored the importance of aligning production schedules with forecasted demand to minimize inefficiencies and the financial implications of overproduction.

In the broader picture, this dissertation contributed to understanding supply chain resilience strategies in the FMCG industry, elucidating the nuances of inventory management models and their influence on efficiency, cost savings, and risk minimization.

Yet, like any research endeavour, this work has limitations. The exclusive focus on P&G's Hair Care business unit and its specific supply chain challenges may limit the generalizability of the findings. Future research may expand this investigation to other business units inside P&G to test the strategies' robustness. Additionally, while this research provides substantial evidence for short-term adjustments and improvements, the long-term impacts of these changes remain an avenue for further exploration.

These findings have important implications for the P&G's external supply chain management practices. By tackling and improving the problems found during the analysis, P&G can potentially reduce inventory costs and improve customer service levels by adjusting the MOQ of raw materials, packaging materials, and the family MOQ. Similarly, by improving safety stock levels, the company can mitigate the risk of stockouts, lost sales or extra storage costs.

This study provides valuable insights on P&G's external production logistics, identifying improvement opportunities, and offering a range of recommendations to enhance operational efficiency in inventory management. The recommendations resulting from the analysis performed during the internship were the following:

1. Holistic Inventory Management: Balancing raw materials, finished goods, and safety stocks requires fine-tuned synchronization of supply and demand. Therefore, the company should implement robust inventory management systems that provide real-time visibility of the entire supply chain, enabling data-driven decision-making.

2. Regular Revaluation of MOQ: Periodic reviews and potential revisions of the minimum order quantities (MOQs) should be conducted. This should account for changes in market demand, supplier reliability, product lifecycle stages, and other relevant factors. This approach can help avoid overstocking and understocking situations.

3. Comprehensive Supply Chain Diversification: The company should diversify its supply chain further. While it has made strides in geographical and supplier diversification, it can extend this principle to product sourcing, transportation routes, and manufacturing processes. Diversification can act as a safety net during unexpected disruptions.

4. Streamline Production Planning: P&G should refine its production planning process to efficiently utilize bulk formulas for finished products. This can help avoid overproduction and underutilization of formulas, reducing the risk of underperforming inventory and inventory days of exposure (IDE). P&G should also create a system of shared materials between the P&G owned plant and CM-1, to give use the materials without forecasted demand, and create a smaller MOQ for the batches sent to CM-1, to avoid waste and scrapping costs.

5. Implementation of the Safety Stock level Tool: The proprietary safety stock determination tool that the company has developed shows promise in reducing total risk and IDE. This tool should be rolled out wider and incorporated into standard operating procedures in the CMs. The automatization of the process represents a valuable opportunity which can easily be implemented with P&G's resources and generate significant resources.

6. Increased Frequency of Safety Stock Revision: Moving from semi-annual to bi-monthly safety stock level revisions can bring stock levels closer to actual demand and avoid unnecessary storage costs.

7. Invest in Advanced Analytics and AI (Artificial Intelligence): Advanced analytics and artificial intelligence (AI) tools can accurately forecast demand, optimize inventory levels, identify potential disruptions, and suggest optimal responses. Investing in such technologies could drive significant efficiency and resilience in the supply chain.

By implementing these recommendations, P&G can enhance its supply chain efficiency, reduce costs, and improve its resilience against future disruptions. These steps require a combined effort from multiple stakeholders, including supply chain managers, procurement officers, production planners, and top management, underscoring the need for a holistic, integrated approach to supply chain management.

This dissertation underlines the significance of thoughtful, data-informed decision-making in inventory management and the broader supply chain context. As global markets continue to evolve and face unprecedented challenges, resilience and efficiency in supply chain management will only grow in importance, underscoring the value of the findings presented in this work.

Future Work

This thesis' study and conclusions provide a number of possibilities for further research. The research done in this project was focused on the raw and packaging material management, joint economic lot sizing, and safety stock and storage costs in the context of the external production in Procter & Gamble. Building on this, future research could broaden the scope of this study in the following ways:

1. By expanding the Scope to remaining Contract Manufacturers (CMs): While this thesis was focused on a specific CM (CM-1), future work should extend the analysis to other CMs within P&G's network or even compare practices across different companies in the fast-moving consumer goods industry. This may provide additional insight into the common challenges and potential solutions in managing supply chains with external manufacturers.

2. Performing a comprehensive analysis of the Supply Chain Network: This study has focused mainly on inventory management practices. In order to provide a more comprehensive picture of the supply chain operations, future studies should examine additional aspects of P&G's supply chain, such as supplier selection, supplier relationship management, logistics, and distribution.

3. Launch a longitudinal Study on the Impact of Implementing Recommendations: Once all the recommendations of this thesis have been implemented, a follow-up study could assess the impact of these changes on the performance indicators over a more extended period. This could validate the effectiveness of the proposed changes and possibly uncover additional areas for improvement.

4. Further exploration of Technological Solutions: This study discovered that effective data analysis is crucial for inventory management. Future work should investigate the role of emerging technologies such as AI (Artificial Intelligence), machine learning, and blockchain in enhancing inventory management and the overall efficiency of the supply chain.

5. Analyse the sustainability of the Supply Chain: Given the growing importance of sustainability inside and outside of P&G’s business practices, future research could also delve into the environmental and social impacts of P&G's supply chain practices, particularly in relation to inventory management.

This thesis has laid a foundation for understanding the challenges and opportunities in managing inventories in an external manufacturing setting. Future work in these suggested areas can build on this understanding and continue to drive improvements in supply chain management in the fast-moving consumer goods industry.

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