Lisbon School of Economics & Management
Universidade de Lisboa

MASTER

MANAGEMENT & INDUSTRIAL STRATEGY

MASTER´S FINAL WORK

DISSERTATION

STOCK MANAGEMENT OPTIMIZATION IN A MATTRESS COMPANY

CRISTIANA SOFIA SANTOS DOMINGOS

OCTOBER – 2023

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SUPERVISION:

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Abstract

Nowadays, to optimize the operations in a company and the related costs, it's crucial to have an efficient supply chain, and consequently, an optimized stock management.

This work studies the stock management optimization in a mattress company, reducing the total operational costs while the service quality remains. To deploy the research and design conclusions, it was compared the total cost with, and without optimization in different scenarios. To calculate the total optimized cost, it was conducted the Economic Order Quantity model and the Re-order Point method to generate the optimal quantities to order and to compare the academic model of stock management with the current model used by the company.

Besides the stock management optimization, a comparison between 3 different scenarios that the company can adopt in their network design was conducted, to understand the best option for the company while they apply an optimized stock management strategy.

In a primary phase, the ABC analysis was applied to identify the categories and items that represent the higher financial value for the company, and that would generate the greatest impact in the savings after applied the proposed stock management strategy.

Secondly, with the results it was proved that by comparing scenarios and simulating different total costs with, and without academic stock management models, can provide guidance about the best strategy to adopt.

Lastly, by applying a sensitive analysis it was proved that the total cost can highly be dependent on the carrying cost, impacting the strategy adopted by the company.

Keywords: Stock management, ABC analysis, EOQ model, Re-order point method, Sensitivity analysis, Total stock costs.

Resumo

Para otimizar as operações e os custos associados numa empresa, torna-se crucial ter uma cadeia de abastecimento, e consequentemente, uma gestão de stock, ambas eficientes.

Neste sentido, o presente trabalho estuda a otimização da gestão de stocks numa empresa de colchões – reduzindo os custos totais operacionais, assegurando ao mesmo tempo, a qualidade do serviço prestado. Para o desenvolvimento da investigação aqui realizada, foi comparado o custo total com e sem otimização em diferentes cenários. Para calcular o custo total otimizado, foi utilizado o modelo de Quantidade Económica de Encomenda e o método de *Re-order Point*, os quais geram as quantidades ótimas a encomendar. Posteriormente, foi comparado o modelo académico para a gestão de stocks com o modelo atual utilizado pela empresa.

Para além da otimização da gestão de stocks, foi feita uma comparação entre três cenários diferentes que a empresa pode utilizar no *design* da sua rede de operações, tendo em vista o estudo da melhor solução que a empresa deverá aplicar, com vista a otimização dos respetivos stocks.

Deste modo, e numa fase preliminar, foi aplicada uma análise ABC, com vista a identificar as categorias e produtos que representam um maior peso financeiro para empresa, possibilitando assim gerar um melhor impacto nas poupanças geradas, através da aplicação da estratégia de gestão de stocks aqui proposta.

Posteriormente, e através da análise dos resultados obtidos, verificou-se ser possível conceber novas estratégias tendo em vista a otimização dos stocks a existirem na empresa.

Por último, e efetuando uma análise de sensibilidade, comprovou-se a existência de uma forte influência nos custos totais por parte dos custos de manutenção, impactando deste modo, as decisões futuras a serem tomadas neste âmbito.

Palavras-chave: Gestão de stocks, ABC análise, modelo QEE, método *Re-order point*, Análise de sensibilidade, Custo total de stocks

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Abbreviations and terms

EOQ – Economic Order Quantity

IM – inventory management

KSRM – key supplier relationship management

ROP – re-order point

SCM – supply chain management

SRM – supplier relationship management

SS – safety stock

TC – total costs

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To everyone, my biggest thank you!

1. Introduction

Nowadays, the capacity of a company to compete in the market while ensuring service quality and low costs is one of the biggest challenges. The challenge is even higher in online retail businesses, where they need to build a brand and trust in customers´ mind. To achieve a good service to the customer, the supply chain and the operations need to be designed to provide the best possible service, being cost cautious. Having an optimized stock management strategy is the key to improving the relationship between service and operational costs.

This work will be a case study in a mattress company, aiming to decrease the total logistic cost. Operating worldwide in the sleep market, the company uses e-commerce as the main channel to sell their products. The focus of the study will be on the Iberian market where it´s used two different modalities to send the products to the final client: warehousing and dropshipping.

The objective of this research is to improve the stock management in the studied company by defining and comparing different possible scenarios to optimize stock management and the related costs.

The research will include stock management models such as EOQ, ABC analysis, ROP models, sensitivity analysis, and total cost comparisons.

The data used in the paper refers to the year 2023 - being past and forecasted sales included - in the Portuguese and Spanish markets.

The dissertation aims to adjust the academic models for stock management to the operational reality of the business in the Iberian market, minimizing the total operational costs and keeping the same or better service level.

The research paper is divided into 5 chapters: Introduction, Literature Review, Methodology, Presentation of Results and Discussion, and Conclusion.

In the introduction, a short approach to the theme of research and the objectives are presented.

The Literature review supports all the research and presents concepts included in diverse topics throughout the paper. The concepts used in the study are linked to supply chain management, stock management and order fulfilment strategies. The models used in stock management will be defined.

In the methodology, the type of research, process and data collection will be defined, as well as the logic used in the results analysis.

In the presentation of results and discussion, it will be compared the results with and without the Economic Order Quantity model in the company´s reality, through different scenarios defined in the methodology. Additionally, a sensitivity analysis of a variable in the EOQ model is presented.

In the last section, conclusions, limitations, and recommendations will be presented.

2. Literature Review

2.1 Logistics and Supply Chain Management (SCM)

2.1.1 Supply Chain

The definition of Supply Chain Management (SCM) is not consensual and there are different theories defined by different authors. However, the creators of the concept Oliver and Webber (1982) defend that "Supply Chain Management (SCM) is the process of planning, implementing and controlling the operations of the supply chain with the purpose to satisfy customer requirements as efficiently as possible". Each part of the SCM is linked to a flow of products, information and cash that are transacted by two or more agents.

Ellram (1991) defines SCM as a network of firm's interaction to deliver products or services to the end customer, linking flows from raw material supply to final delivery.

SCM can also be defined as the management of processes and relationships with suppliers and clients that add value and minimize costs or as a "network of connected and interdependent organizations mutually and co-operatively working together to control, manage and improve the flow of materials and information from suppliers to end users" (Christopher, 2005).

One of the main challenges for SCM and logistics is that a company is focused on having a cost leadership position or a service excellence position. So, the companies try to seek out strategies to add more value and create competitive advantages while they manage the supply chain.

While SCM covers all the coordination of the company´s network from the initial partners to the final client, including sourcing, manufacturing, transporting, storing, and selling, logistics focuses on the movement and storage of the items within the supply chain.

According to Christopher (2005) "The scope of logistics spans the organization, from the management of raw materials through to the delivery of the final product", and the goal is to reach desired levels of delivered service and quality having the lowest possible cost. The process starts with suppliers and ends in customer management, going through procurement, operations, and distribution during the flow. (Figure 1).

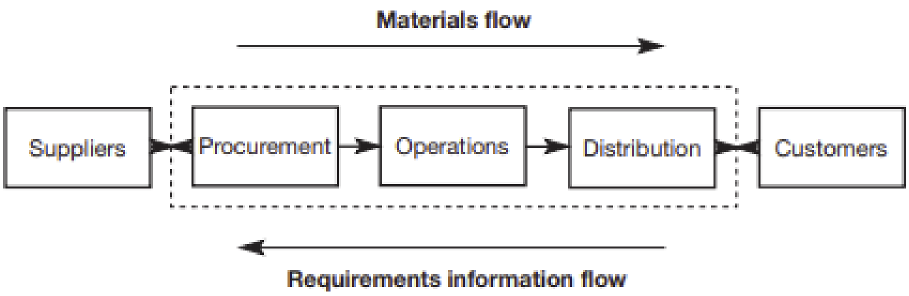

Figure 1- Logistics Management Process (Christopher, 2005)

Logistic costs include all the costs allocated to SCM such as costs of procurement, transportation, and storage of all materials between the manufacturing and selling process, being shipping and storage costs the highest logistic costs. Logistic costs have a huge weight in the total costs of the company, so there´s a need to reduce these costs while promoting efficiency in the supply chain.

Carvalho and Guedes (2017), defined three dimensions in logistics. On one side, the authors defended that time and cost prioritization provides more agility to the supply chain network, allowing it to satisfy the needs at the lowest cost possible. On the other side, focus on time and service level quality power the responsiveness through good service quality, and fastness at the same time. Lastly, the authors combine cost and quality of service which gives leanness to the supply chain through a higher efficiency in used resources, lowering the costs. (Figure 2)

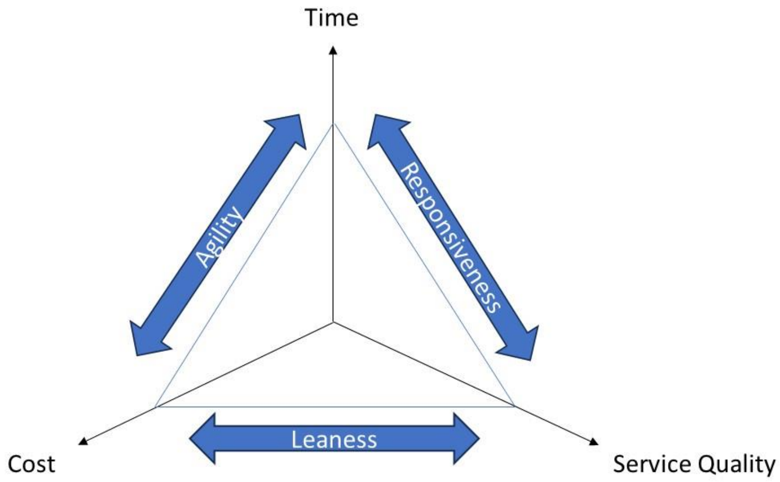

Figure 2 - Triangle of logistic dimensions (Carvalho & Guedes, 2017)

2.1.2 Supplier Relationship Management (SRM)

Supplier relationship management (SRM) is defined as a practice of planning, implementing, developing, and monitoring relationships with a company´s suppliers, according to Akamp and Müller (2013).

SRM's main goal is to ensure the provision of standard products and services within the supply chain (Olorunniwo *et al.*, 2011). It consists of a commitment process that includes starting, developing, establishing, and finishing relationships with suppliers. It also includes out-suppliers observation so companies can compare and enhance the value in their relationships (Moeller *et al.*, 2006).

A supply chain can include upstream and downstream relations with customers and suppliers, so the company and SCM team should decide strategically which ones they want to work with and define the optimal degree of exchange with these partners. (Giannakis and Louis, 2011).

Having a consistent SRM with current and potential suppliers have advantages for the company as a better supplier base, tackling and solving significant problems easily, working in a coordinated and consistent way and increasing value creation for customers (Moeller *et al*., 2006). SRM also works on cooperation, coordination and communication between a company and its suppliers. It means they can increase their business relationship level, process level, and information system level, using the knowledge acquired already by the supplier (Mettler and Rohner, 2009).

Besides SRM exists key supplier relationship management (KSRM) which involves two parties with high involvement relationships, that view themselves as an extension of their firms and have a significant level of business integration. (Lambert *et al.* 1996). With KSRM the company can have higher advantages as being responsive, agile, fast, and profitable (Doyle *et al*., 2006).

2.1.3 Inventory Management

Inventory management is included within SCM and refers to the whole process of managing inventories from raw materials to finished products. The process includes ordering, storing, using, and selling the inventory. Streamlining inventories efficiently and avoiding gluts and shortages are the main purposes of inventory management.

Different types of inventories are used by companies depending on the needs of their business. According to David Simshi-Levi *et al.* (2008) and Sunil Chopra *et al.* (2012), the types of inventories can be divided into:

1- Buffer inventory - used to protect against uncertainties in demand and supply. It can also be nominated as safety stock.
2- Cycle inventory – the average quantity of inventory used to satisfy demand between replenishments.
3- Decoupling inventory – used to separate different stages of the supply chain or production processes.
4- Anticipation inventory – stock built for future needs, often used when the company faces high lead times or seasonal demand patterns.
5- Pipeline inventory – inventory in transit between stages of the supply chain, as raw materials transported between manufacturing facilities or finished goods being transported to distribution centers.

Each company has their way of managing and tracking stocks, according to their size, portfolio, strategy, and supply chain. Usually, smaller companies control stocks manually, medium businesses prefer specialized Enterprise Resource Planning (ERP) and large organizations have their own highly customized Software as a Service (SaaS) application.

According to Zermati (1987), the demand planning quality and the processes involved in that strongly impact the performance of stock management. Zermati (2017) and Carvalho and Guedes (2017) also define stock as articles that have the purpose of being sold, allowing satisfying client needs at the minimum cost and maximum efficiency possible.

Zermati (1987) classifies stocks accordingly with their functionalities, which can be:

- Raw materials – products that need to be transformed.

- Consumable materials – products used during production that will get wasted.
- Semi-products
- Final products – products done and ready to sell.
- Packages
- Waste

Zermati (1987) defends that building stock levels has advantages such as: avoiding stock ruptures, speculation (buying products at lower cost), quantity discounts, scale economies, cost advantage in transportation for higher quantities and having a buffer in case of the wrong sales forecast.

However, it also has risks and disadvantages as the risk of obsolescence, capital invested with no recurrent profit, space constraints and costs.

Safety stocks are important to satisfy customers' needs when any part of the supply chain fails, avoiding longer lead times. (Zermati (1987))

The costs with stock can have different typologies: (Zermati (1987))

- Possession costs – cost of capital, storage, risk, and maintenance
- Acquisition cost – production cost, transportation cost, order processing cost
- Cost stock rupture – sales lost, lower customer satisfaction.

2.1.4 Dropshipping

The dropshipping distribution model is a strategy used to ship products within the supply chain. Considered as an order fulfilment process includes 3 parties: consumer, retailer and dropshipper. The consumer buys the goods from the retailer. The retailer transmits orders to the dropshipper and the dropshipper produces and ensures that the goods are being delivered.

Dropshipping is one of the most effective and simple ways to do e-commerce business. It allows e-commerce businesses to sell products without dealing with order fulfilment operations. (Jian, Chen, *et al.*, 2011)

The model has a lot of advantages and disadvantages. Most of the advantages are for the retailer by optimizing the supply chain processes. Usually, the dropshipping method is adopted by e-commerce companies that do not need to have the products physically in a store (Bon, Abdul, *et al.*, 2020). Dropshipping is an easy and cheap method for beginners since the retailers do not have inventory costs, and don´t have to handle a warehouse including all the operations involved. Even bigger companies when they want to enter new markets or launch new products minimizing investment and risk, can take advantage of dropshipping in specific products, even though they have ongoing operations with warehouses and distribution centers.

Besides the advantages, the model has an important disadvantage since it creates a dependence on the supplier because they control all the production time, order preparation and the delivery to the end customer.

2.2 ABC Method

Activity-based costing (ABC) method is based on the theory that all inventory does not have an equal value. The technique ABC is used for assigning the direct and indirect costs to activities that consume resources from an organization. According to Kaplan (1998), the ACB technique facilitates the tracing of the cost of performing activities for a specific product, client, or distribution channel.

The ABC analysis is frequently used by inventory management to identify the most important stock items in the portfolio and to control them (Nallusamy *et al.*, 2017; Muller, 2019; Abdolazimi *et al*., 2021). Traditionally, the inventory is divided into three categories: A (most important), B (fairly important) and C (least important). Following the logic in the ABC theory, most of the management efforts are invested in category A items. The annual financial volume used in ABC analysis is determined by the annual demand of each SKU multiplied by the unit cost of the SKU. (Heizer *et al*., 2017)

The ABC analysis follows the Pareto Principle that determines which items should get priority in company´s inventory management. The Pareto Principle defends that 20% of the stocks (Category A) generate 80% of the cost and the remaining 80% (category B and C) of the stocks generate the remaining 20% of the costs. (Muller, 2019; Abdolazimi *et al*., 2021). According to Heizer *et al*. (2017), assuming the Pareto Principle hypothesis (only a few critical products and many trivial ones) companies should focus on establishing politics to allocate the monitoring resources to critical and impacting products instead of focusing on cheap products that will not add that much value.

The ABC analysis should be defined in the bellow rules: (Krajewski *et al*.,2013; Nallusamy *et al*., 2017; Heizer *et al*., 2017; Muchaendepi *et al.*, 2019):

- Class A: items that represent between 70% and 80% of the financial value and between 10% and 20% of the total stock. They have an important role for the company and are reviewed regularly to ensure deliveries are on time.
- Class B: intermediate items with a financial value between 15% and 25% and a weight of 30% in the total stock. The Class B items require an intermediate control to ensure the safety stocks.
- Class C: low-value items for the company, usually represent less than 5% of the annual demand and have 50% of the total stock. The Class C items have flexible control because usually their value and holding costs are low.

2.3 Stock Management control – Models

Stock management models highly depend on supply and demand, requiring different control modes to adapt efficiently to the business while minimizing the total cost and satisfying the clients.

According to Krajewski *et al.* (2013), the control models used in stock management aim to define the quantity to order and when.

Vidal, Germán (2022) refers to different authors distinguishing the control modes in Deterministic models and Probabilistic models. Being deterministic models used in regular and predictable demand like the Economic Order Quantity (EOQ) model, and probabilistic models used in uncertain and irregular demand. (Carvalho, 2020).

2.3.1 EOQ – Economic Order Quantity

Developed by Ford Whitman Harris, the Economic Order Quantity Model (EOQ) was first published in an article in 1913, to balance the ordering and holding costs (Alfares & Turnadi, 2018). The model is currently used to optimize and minimize the cost between holding costs and re-ordering costs. Excess stock is one of the main factors that limit efficiency in the supply chain (Godichaud & Amodeo, 2018) and the EOQ model is used to obtain the best option between the supply and the demand, so that the company achieves a balance.

The model aims to answer the question “How many units should the company order?” and the goal is maximize the profit and minimize the main costs such as: holding "carrying" costs, ordering costs, and shortage costs (Nemtajela & Mbohwa, 2017; Soares, Mendes & Santos, 2019; Liao &Li, 2021). Nemtajela & Mbohwa (2017) also described the costs as:

- Holding (or carrying) costs – costs linked with storing stocks, possible damage insurance, obsolescence, and depreciation of stocked items.
- Setup costs – commonly named as production change costs, define the costs of acquiring the material needed and the machinery for setting up a new batch of production.
- Ordering costs – administrative costs linked with creating a manufacturing or procurement order. Includes the cost of all the order information (including delivery, system and tracking of the order).
- Shortage Costs – the cost of not meeting the demand because of a stock out and the client needs to cancel the order. It also includes the costs and troubles that Waiting for stock situation causes.

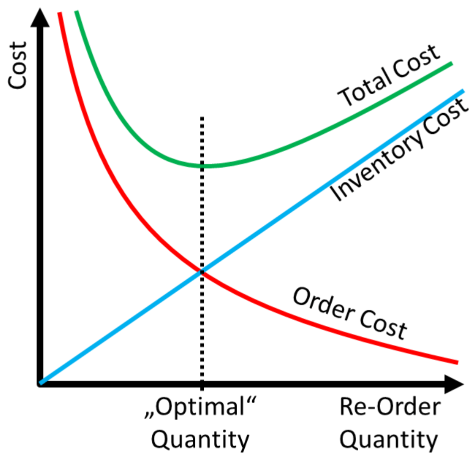

Figure 3-Economic Order Quantity model; Heizer *et al*. (2017)

To calculate the basic EOQ, Lucey (1992) made the following assumptions:

- Demand is uniform, constant, and continuous over time.
- The lead time is constant.
- There is no limit on order size.
- The cost of placing an order is independent of the size of the order.
- The cost of holding a unit of stock does not depend on the quantity in stock.

According to Krajewski *et al*. (2013), supply chain managers deal constantly with the challenge of keeping the correct stock volume without excess or lack of stock, so they can optimize the inventory costs and provide the service level required. With the economic order quantity (EOQ), supply chain managers can calculate the minimum quantity to balance the stock needed and the total inventory costs.

The EOQ formula determines the optimal quantity of each product to order, minimizing total costs:

$$\boldsymbol{EOQ = Q^{*} = \sqrt{\frac{2DS}{IC}}} \qquad (1)$$

D = item annual demand (units/year)

S = procurement cost (cost/unit)

C = item value carrier in inventory (per unit)

I = carrying cost as a percentage of item value (percentage/year)

2.3.2 Total Cost

The EOQ model aims to minimize the annual total cost calculated by using the formula (Ballou, 2004):

Total Cost = (Procurement / Ordering Cost) + (Carrying / Holding Cost)

$$\boldsymbol{TC = \left(\frac{D}{Q}\right) * S + (I * C) * (\frac{Q}{2})} \qquad (2)$$

Where:

TC = total annual inventory cost (€/year)

Q = order size to replenish inventory (units)

D = item annual demand (units/year)

S = procurement cost (cost/unit)

C = item value carrier in inventory (per unit)

I = carrying cost as a percentage of item value (percentage/year)

D/Q = number of times it´s needed to place a replenishment order per year

Q/2 = average amount of inventory on hand

2.3.3 ROP – Re-order Point

The re-order point method (ROP method) allows identifying the quantity and the moment the company should place a new order with the supplier to minimize the total cost (Reis, 2016). According to Heizer *et al.* (2017), the ROP is the level of inventory that requires an action to replenish a particular inventory stock. A new order is usually created regularly every time the stock levels reach a determined quantity, named order point.

The two factors that determine and have an influence on the ROP are the lead time per order and the safety stock (Heizer *et al.*, 2017).

To calculate the ROP and discover the best timing to order stocks efficiently, it´s needed the N (total number of orders per year), T (ideal time between orders) and LT (lead time per order) (Heizer *et al.*, 2017; Muller, 2019).

$$\boldsymbol{N = \frac{D}{Q}} \qquad (3)$$

$$\boldsymbol{T = \frac{Q}{D}} \qquad (4)$$

Q = order size to replenish inventory (units)

D = item annual demand (units/year)

ROP – Re-order point formula

$$\boldsymbol{ROP = d * LT} \qquad (5)$$

d= demand per day (units)

LT = lead time (days)

d and LT need to have the same temporal horizon

ROP – Re-order point with safety stock

$$\boldsymbol{ROP = d * LT + SS} \qquad (6)$$

$$\boldsymbol{SS = d * 7\ days} \qquad (7)$$

2.3.4 Safety Stock

To prevent the shortages in stock that can happen due to unpredictable high demand, companies should invest in safety stocks. According to Gonçalves, J.N.C *et al*. (2020) "safety stocks are one of the most robust strategies to soften supply and demand uncertainty".

Creating safety stock (SS) enables the company to provide a better service, but it also increases the logistics costs, so the SS calculation should be optimized (Jung, Blau, Pekny, Reklaitis & Eversdyk, 2008). To calculate SS quantity, the daily demand is multiplied by the necessary time needed to recover the stock levels.

3. Methodology

3.1 Research Strategy Adopted

To develop the research, it will be used a case study of an international mattress company operating in the Iberian market, with suppliers in Portugal.

The research will be exploratory, bibliographic, and documental, focused on a case study. The exploratory methodology aims to explain the causes and consequences of certain questions. The methodology will also be bibliographic and documental because theoretical concepts about stock management models were applied during the study, and data and documents provided by the company were used as base for data collection. Due to the different questions tested and validated, the research is deductive.

"A case study strategy can generate insights from intensive and in-depth research into the study of a phenomenon in its real-life context, leading to rich, empirical descriptions and the development of theory" (Dubois and Gadde (2002); Eisenhardt (1989); Eisenhardt and Graebner (2007)); Yin (2018).

The company studied is a worldwide company that started in the mattress market as a startup and nowadays operates in the sleep industry as one of the biggest companies.

In the case, the phenomenon analyzed is the comparison of total cost for stock management in different scenarios. It will compare current and adopted models by the company to calculate the total cost of ordering mattresses from the supplier with academic models. The used models were designed to optimize inventory management and to reduce the total costs.

It will be a longitudinal study since the research will cover a time interval of 12 months, during the year 2023, where past data and forecasted sales were used to generate the results.

3.2 Data Collection Methods

To be precise data collection should be divided into 3 stages in the process: planning, data collection and data analysis, according to Kumar (2015); Ghauri, Grønhaug & Strange (2020).

In the planning stage, the research questions and how the research will be conducted are defined. The method and the concepts applied will be also defined.

In the second stage, the data collection refers to the period and methods applied to find proper data for the analysis. In this study, a quantitative approach is used, extracting primary data through observation and an interview with an operations manager.

In the last stage, a data analysis is conducted to conclude the study with valid results.

3.3 Research Questions

To proceed with the analysis, 3 different scenarios for the stock management setup were defined. The goal is to determine the feasibility of the 3 scenarios and define the best option for the mattress company.

The research questions studied are:

- Is the current model of stock management and order fulfilment used by the company "XPTO" for the mattresses category the best option when compared to academic models of stock management? If not, what is the difference between the current situation and the academic models?
- Which scenario should the company use to reduce the total costs of mattresses? The scenario should be based on stock management model and order fulfilment strategy.
- Which methodology should the company adopt (quantity and periodicity of order) to reduce the total costs in 2023?

Answering the questions and defining the scenario the company should implement is the main objective of the research. The final option should decrease the logistics costs linked to the stock management of mattresses, keeping the same or less level of complexity in the company.

3.4 Introduction to Case Study

3.4.1 The Mattress Company

Started in 2013 the mattress company is one of the fastest-growing providers of mattresses and sleeping products.

The company had fast growth due to their capacity to revolutionize the mattress market with an easy buying process for the end customer. In the first year, the company achieved a revenue of 5.3 thousand euros with only 7 members. However, the huge growth started when clients understood the concept and the product innovation, allowing the company to end 2021 with 645 million euros of revenue. With more than 700 workers the multinational has offices in 5 countries and operates in 33 countries.

Being a well-known sleep brand, the company adopted an omnichannel strategy through several partnerships with retailers and marketplaces and selling their products online. Having a pondered relational approach in the business network and exploring the digital path led the company to a differentiated position from other companies.

As part of the mattress industry, its biggest revenue comes from the sale of mattresses. However, the portfolio includes beds, pillows, bed linen and other accessories. The company sells mattresses in a box which facilitates transportation to clients´ houses and reduces the complexity and costs of distribution.

3.4.2 Supply chain and logistics at Company "XPTO"

The company has suppliers worldwide, mainly in South Europe and Asia. They have raw material providers and producers that transform raw materials into final products.

As a company that sells in more than 33 countries, the logistics and operations are dispersed in various locations. In this research, the focus will be on Iberia, in Spanish and Portuguese markets.

In Iberia, the operations are divided through one warehouse in Madrid and two dropshipping locations in Portugal that follow the below processes:

Central Warehouse:

1 The supplier produces the product in Portugal.

2 Stock transfer from the supplier to the central warehouse in Spain in a truck.

3 Goods are inbounded and stored in the central warehouse.

4 Outbound and product shipping through a last-mile carrier.

5 Product delivery in the client´s house is done by a carrier.

Dropshipping directly from the supplier:

1 The supplier produces and stores the product in their facilities in Portugal.

2 Outbound and product shipping through a last-mile carrier.

3 Product delivery in the client´s house is done by a carrier.

4. Results and discussion

4.1 Scenario Description

The main goal of this study is to analyze the possible scenarios to optimize the stock management for products produced in Portugal and shipped for the whole of Iberia in a mattress company. The database presented is dated 2023.

The company sells products from different categories, such as mattresses, beds, and accessories. The products analyzed in this study are included in the Mattresses category and represent 74% of total sales in Portugal and Spain.

In this analyze were considered all the logistic costs linked to storing, order processing and shipment of an order, and the demand considered were the sales in Portugal and Spain.

During the analyze it´s calculated the ABC analyze to determine the most important categories and products in the company and an EOQ model is designed to calculate the optimal quantity to order, allowing to determine and compare the total cost for each scenario.

The study includes 3 different scenarios that will be compared.

Possible Scenarios:

- **Scenario 1** – Ship all orders with all products from the central warehouse.
- **Scenario 2** – Company "XPTO" dropships all products produced by Portuguese suppliers (Mattress 2, Mattress 4, and Mattress 5) from the supplier facilities in Portugal. If the order includes other products from another supplier, the remaining products will be shipped from the central warehouse.
- **Scenario 3** – Company "XPTO" dropships only orders that only include: Mattress 2, Mattress 4, and Mattress 5 - from the supplier facilities in Portugal. Orders with other products are fully fulfilled by the central warehouse.

Table I - % orders per fulfilment location

	Scenario 1		Scenario 2		Scenario 3	
Product	Central Warehouse	Dropshipper	Central Warehouse	Dropshipper	Central Warehouse	Dropshipper
Mattress 1	100%	0%	100%	0%	100%	0%
Mattress 2	100%	0%	0%	100%	60%	40%
Mattress 3	100%	0%	100%	0%	100%	0%
Mattress 4	100%	0%	0%	100%	60%	40%
Mattress 5	100%	0%	0%	100%	60%	40%

4.2 ABC Deployment

To determine the products that have the biggest impact on the company's financial value, it was used the ABC analysis. The method allows the classification of all the products included in stock, comparing their importance to the company.

The products with higher value for the company are classified as A products, the products with medium value as B products and the ones with lower value are classified as C products.

Table II demonstrates the product categories sold in the company "XPTO" and the classification of each category according to their financial value and Table III calculates the ABC classification for each product inside the mattress category.

Table II - ABC model per category

#	Product Category	# SKUs	Average logistic cost per unit (€)	Demand 2023 (#)	Total Cost 2023 (€)	% Value	% Cumulative Value	Class
1	Mattresses	46	23,04 €	89,953	2, 072, 517.12 €	58%	58%	A
3	Accessories	140	8,11 €	123,992	1, 005, 575.12 €	28%	86%	B
2	Beds	149	26,60 €	18,787	499, 734.20 €	14%	100%	C
Total		335		232,732	3, 577, 826.44 €			

The result shows that in total in 2023 the company will sell 232,732 units with a total logistic cost of 3,577,826.44€. Mattresses and accessories are the categories with the highest costs and the ones that require more attention from the stock management team.

Table III - ABC model per product (mattress category)

#	Product Category	# SKUs	Average logistic cost per unit (€)	Demand 2023 (#)	Total Cost 2023 (€)	% Value	% Cumulative Value	Class
1	Mattress 1	10	33.50 €	32,488	1, 088, 348 €	47%	47%	A
2	Mattress 2	10	20.62 €	28,739	592, 598.18 €	26%	73%	A
3	Mattress 3	9	22.81 €	20,224	461, 309.44 €	20%	93%	B
4	Mattress 4	9	21.39 €	3,860	82, 565.40 €	4%	97%	C
5	Mattress 5	8	16.88 €	4,642	78, 356.96 €	3%	100%	C
Total		46		89,953	2, 303, 177.98 €			

The detailed analysis (Table III) demonstrates that the demand expected in the mattress category until the end of 2023 is 89,953 units, with a total logistic cost of 2,303,177. 98€. Mattress 1 and Mattress 2 are the mattresses with the highest weight in the total costs of the mattress category.

Table IV - ABC model per product (mattress category) - %

Class	Number of products	% Products	% Value
Class A	20	43%	73%
Class B	9	20%	20%
Class C	17	37%	7%

The result of ABC analysis for mattresses shows that 73% of the value invested in logistic costs by the company is allocated to Class A products, 20% to Class B and 7% to Class C, meaning that inside the mattress category, the company mostly invest in Mattress 1 and Mattress 2.

4.3 Total Logistic Cost in 2023

4.3.1 Non-optimized total cost

To analyze and compare the different scenarios it´s necessary to compute the total cost for each logistic option.

With the information for 2023 shared by the company, it´s possible to define the different variables for each product as shown in Table V, which represents the case of scenario 1.

In the non-optimized model, the company uses Q = 276 units as a maximum order quantity because of the average truck capacity. The maximum truck capacity varies with the quantities of each model and each size of mattress transported.

Table V - Total cost non-optimized - scenario 1

Product	D (units)	Q (not optimized)	N (orders)	I	C (€)	S (€)	TC not optimized
Mattress 1	32,488	276	118	0,1	103.57 €	603.24 €	72,436.73 €
Mattress 2	28,739	276	104	0,1	145.98 €	603.24 €	64,827.98 €
Mattress 3	20,224	276	73	0,1	178.17 €	603.24 €	46,661.38 €
Mattress 4	3,860	276	14	0,1	104.59 €	603.24 €	9,879.96 €
Mattress 5	4,642	276	17	0,1	104.59 €	603.24 €	11,589.14 €
Total	**89,953**		**326**				**205,395.19 €**

N (number of orders) is calculated by dividing the Demand per Quantity. The company shared the % of the annual carrying cost of stocks is 10%. To calculate the cost of each product (C), it was taken as a reference the mattress size 160x200 - the most sold size in the Iberian market. The ordering cost (S) was calculated by summing the material handling and the cost of administrative work (1 hour per purchase order and truck).

With the previous details, it´s possible to calculate the Total Cost (TC) of stock management during 2023 for mattresses in the Iberian Market. To demonstrate the calculations done, it was used Mattress 1, as an example:

$$\boldsymbol{TC = \left(\frac{D}{Q}\right) * S + (I * C) * (\frac{Q}{2})} \qquad (8)$$

D = 32,488 units

Q = 276 units

S = 603.24 €

I = 10%

C = 103.57 €

$$\boldsymbol{TC = \left(\frac{32,488}{276}\right) * 603.24 + (0.10 * 103.57) * \left(\frac{276}{2}\right) = 72,436.73\ €}$$

Using this logic is shown that the total cost of stock management for Mattress 1 in 2023 was 72,426.73€. It´s possible to conclude that the total cost non-optimized of stock management for all mattresses in Portugal and Spain in 2023 is forecasted as 205,395.19 € (Table V).

Similar calculations were conducted for all the scenarios having the result presented in the Annex.

4.3.2 Economic Order Quantity Model

To determine the best quantity of each product to order, by minimizing total costs, the Economic Order Quantity (EOQ) Model was used, where for example, the optimal quantity to order for Mattress 1 in scenario 1 is determined by:

D = 32,488 units

S = 603.24 €

I = 10%

C = 103.57 €

$$\boldsymbol{EOQ = Q^* = \sqrt{\frac{2 * 32,488 * 603.24}{0.10 * 103.57}} = 1,946\ units}$$

The optimal economic order quantity for each type of mattress in 2023 in scenario 1 is: (Table VI)

Table VI - EOQ model - scenario 1

Product	D (units)	N (orders)	I	C (€)	S (€)	EOQ (units)	EOQ corrected
Mattress 1	32,488	118	0.1	103.57 €	603.64 €	1,946.03	1,946 units
Mattress 2	28,739	104	0.1	145.98 €	603.64 €	1,541.68	1,542 units
Mattress 3	20,224	73	0.1	178.17 €	603.64 €	1,170.63	1,171 units
Mattress 4	3,860	14	0.1	104.59 €	603.64 €	667.50	668 units
Mattress 5	4,642	17	0.1	104.59 €	603.64 €	732.00	732 units
Total	**89,953**					**6,057.85**	**6,059 units**

To calculate the Re-order Point (ROP) and discover the best timing to order stocks efficiently, it´s needed the N (total number of orders per year), T (ideal time between orders) and LT (lead time per order). The Lead Time shared by the operations team of the company for mattresses is 3 weeks, 21 days.

Mattress 1 was used as an example to demonstrate the calculations, where:

EOQ = 1,946 units

D = 32,488 units

$$N = \frac{32,488}{1,946} = 16.7 \cong 17 \; orders \; in \; 2023$$

$$T = \frac{1,946}{32,488} * 365 = 21.9 \; days \cong 21 \; days$$

$$d = \frac{D}{365} = \frac{32,488}{365} = 89.01 \cong 89 \; units \; per \; day$$

$$ROP = 89 * 21 = 1,869 \; units$$

Table VII - N, T, d, ROP calculation - scenario 1

Product	D (units)	EOQ corrected	T (days)	N (orders)	d (units)	LT (days)	ROP (units)
Mattress 1	32,488	1,947	21.9	16.7	89.01	21	1,869
Mattress 2	28,739	1,542	19.6	18.6	78.74	21	1,653
Mattress 3	20,224	1,171	21.1	17.3	55.41	21	1,164
Mattress 4	3,860	668	63.2	5.8	10.58	21	222
Mattress 5	4,642	733	57.6	6.3	12.72	21	267
Total	**89,953**	**6,061**		**64.71**	**246**		**5,175**

in the Mattress 1 example, as the daily demand on average is 89 units and the lead time is 21 days, the Re-order point for this product is 1,869 units, which means when the stock level is equal or below 1,869 units the company should place a new purchase order to the supplier. The company should place 17 orders (N calculation) in 2023 every 21 days (T calculation).

4.3.3 Safety Stock

Besides ROP determines that the company only needs to place a new order when it has 1,869 units of Mattress 1 in stock, there´s a need to ensure that the company don´t stock out. For that, it´s taken into consideration a safety stock of 7 days. The total safety stock is calculated by multiplying the daily demand by the coverage days.

$$\boldsymbol{SS = d * 7\ days}$$
$$\boldsymbol{SS = 89 * 7 = 623.06\ \cong 623\ units}$$

$$\boldsymbol{ROP = d * LT + SS} \qquad (9)$$

$$\boldsymbol{ROP = 1869 + 624 = 2493\ units}$$

Table VIII - Safety stock and ROP with SS - scenario 1

Product	D (units)	d (units)	LT (days)	ROP (units)	SS (units)	SS corrected (units)	ROP with SS (units)
Mattress 1	32,488	89	21	1,869.17	623.06	624	2,493
Mattress 2	28,739	78.74	21	1,653.48	551.16	552	2,205
Mattress 3	20,224	55.41	21	1,163.57	387.86	388	1,552
Mattress 4	3,860	10.58	21	222.08	74.03	75	297
Mattress 5	4,642	12.72	21	267.07	89.02	90	357
Total	**89,953**	**246**		**5,175**		**1,729**	**6,904**

With the final analysis for ROP including safety stock can be concluded that the company need to order more stock of Mattress 1 when the stock level achieves 2,493 units to not run out of stock and keep the safety levels.

4.3.4 Total Cost with EOQ

As defined in the case study description there are 3 different scenarios and, in each case, can be or not be applied the EOQ model. So, all the calculations explained before were applied for all the scenarios that result in Table IX. The detailed version of each scenario is presented in the Annex.

Table IX - Total cost comparison between scenarios

	Scenario 1		Scenario 2		Scenario 3	
Product	**EOQ Model**	**No model**	**EOQ Model**	**No model**	**EOQ Model**	**No model**
Mattress 1	20,148.31 €	72,436.73 €	20,148.31 €	72,436.73 €	20,148.31 €	72,436.73 €
Mattress 2	22,497.93 €	64,827.98 €	86,217.00 €	86,217.00 €	51,913.62 €	74,189.40 €
Mattress 3	20,850.24 €	46,661.38 €	20,850.24 €	46,661.38 €	20,850.24 €	46,661.38 €
Mattress 4	6,979.09 €	9,879.96 €	11,580.00 €	11,580.00 €	10,037.98 €	11,137.31 €
Mattress 5	7,653.46 €	11,589.14 €	13,926.00 €	13,926.00 €	11,498.74 €	13,101.22 €
Total	**78,129.03 €**	**205,395.19 €**	**152,721.54 €**	**230,821.11 €**	**114,448.89 €**	**217,526.04 €**
% difference with the current scenario	**-66%**	**-11%**	**-34%**	**0%**	**-50%**	**-6%**

In Scenario 1, the stock management of all mattresses is done in the main warehouse with and without the EOQ model. Scenarios 2 and 3 include some mattresses managed in the main warehouse and 3 mattresses (Mattress 2, Mattress 4 and Mattress 5) managed in the supplier facilities in the dropshipping modality. In scenario 2, all the orders that include a mattress model managed by the dropshipping are shipped from there. In scenario 3, only orders that include Mattress 2, Mattress 4 or Mattress 5, and no other products are shipped by dropshipping. For the calculation in scenario 3 was assumed that 40% of the orders go to the dropshipping and 60% to the main warehouse, according to the data shared by the operations team in the company.

The actual set-up that company “XPTO” is using is scenario 2. So, when answering the first research question about whether the current model used by the company should be replaced by the academic model EOQ using the current scenario, the answer is that by applying EOQ in scenario 2 the company can save 34% of the total cost, equivalent to 78,099.57€.

As suggested by the second research question, when comparing the 3 scenarios (with and without the EOQ model) with the current set-up used in the company (scenario 2 without the model) it´s visible that using scenario 1 with the EOQ model is the best option for the company in terms of total cost allocated to the stock management. This option generates savings of 152,692.08€ corresponding to a decrease of 66% in the total cost compared to the actual model.

When comparing the savings in each scenario allowed by the EOQ model application it´s perceptible that there´s a huge decrease in the total cost in all the scenarios, reaching the -61% of the total cost in scenario 1.

In conclusion, and according to the analysis made and presented in Table IX, the company should concentrate all the stocks in the main warehouse.

Despite the conclusions already discussed, the company has some restrictions such as the maximum transportation capacity per order and the maximum warehouse capacity. Assuming the company wants to implement scenario 1 using the EOQ plus the safety stock the company would need 1,150 pallets of space (Table X). The operations manager shared the company has 3,000 pallets of space in the central warehouse, so warehouse capacity is not a restriction to implement the academic model. Regarding the transportation capacity, mattresses have big boxes so the maximum quantity per FTL is 396 units.

Table X - Pallet usage in EOQ model - scenario 1

Product	ROP (units)	SS (units)	SS corrected (units)	ROP with SS (units)	# Pallets
Mattress 1	1,869.17	623.06	624	2,492	417
Mattress 2	1,653.48	551.16	552	2,205	367
Mattress 3	1,163.57	387.86	388	1,551	259
Mattress 4	222.08	74.03	75	296	49
Mattress 5	267.07	89.02	90	356	59
Total	**5,175**	**1,725**	**1,729**	**6,904**	**1,150**

Table XI - Total cost and EOQ model with restrictions - scenario 1

Product	D (units)	I	C (€)	EOQ (units)	Q max per truck (units)	N trucks with EOQ	S (€) with truck restriction	TC with truck restriction (max 396)
Mattress 1	32,488	0.1	103.57 €	1,946	396	5	3,016.20 €	60,432.09 €
Mattress 2	28,739	0.1	145.98 €	1,542	396	4	2,412.96 €	56,226.56 €
Mattress 3	20,224	0.1	178.17 €	1,171	396	3	1,809.72 €	41,687.00 €
Mattress 4	3,860	0.1	104.59 €	668	396	2	1,206.48 €	10,464.88 €
Mattress 5	4,642	0.1	104.59 €	732	396	2	1,206.48 €	11,478.92 €
Total	**89,953**							**180,289.46€**

Assuming scenario 1 with the transportation restriction, even though the quantity ordered remains, the number of trucks needed will increase as well as the setup costs (S). (Table XI). When comparing the total costs, using the EOQ model with the transportation restrictions, the most advantageous scenario is scenario 1 and the company will keep saving 22% of the total cost versus the current set-up (Table XII).

Table XII - Total Cost comparison between scenarios – including restrictions.

	Scenario 1		Scenario 2		Scenario 3	
Product	**EOQ Model with restrictions**	**No model**	**EOQ Model with restrictions**	**No model**	**EOQ Model with restrictions**	**No model**
Mattress 1	60,43.09 €	72,436.73 €	60,432.09 €	72,436.73 €	60,432.09 €	72,436.73 €
Mattress 2	56,226.56 €	64,827.98 €	86,217.00 €	86,217.00 €	78,049.07 €	74,189.40 €
Mattress 3	41,687.00 €	46,661.38 €	41,687.00 €	46,661.38 €	41,687.00 €	46,661.38 €
Mattress 4	10,464.88 €	9,879.96 €	11,580.00 €	11,580.00 €	12,740.31 €	11,137.31 €
Mattress 5	11,478.92 €	11,589.14 €	13,926.00 €	13,926.00 €	14,461.96 €	13,101.22 €
Total	**180,289.46 €**	**205,395.19 €**	**213,842.09 €**	**230,821.11 €**	**207,370.43 €**	**217,526.04 €**
% difference with the current scenario	**-22%**	**-11%**	**-7%**	**0%**	**-10%**	**-6%**

Answering the third question about the quantities the company should order and when, if the company adopts the optimal scenario (Scenario 1 applying EOQ with restrictions) they should place 65 orders in 2023. The quantity per order is the EOQ and the frequency the company should place orders is detailed in Table (VII) for scenario 1. For the remaining scenarios, the details are in the Annex.

Besides the total cost calculations presented, it was verified the carrying costs used can change the overall total costs, being able to change the best decision the company can take.

Assuming the company chose to operate in scenario 1, a sensitivity analysis (Figure 4) was performed. Process a sensitivity analysis is important because evaluate if the company should keep the same stock management strategy even if the annual carrying cost % change.

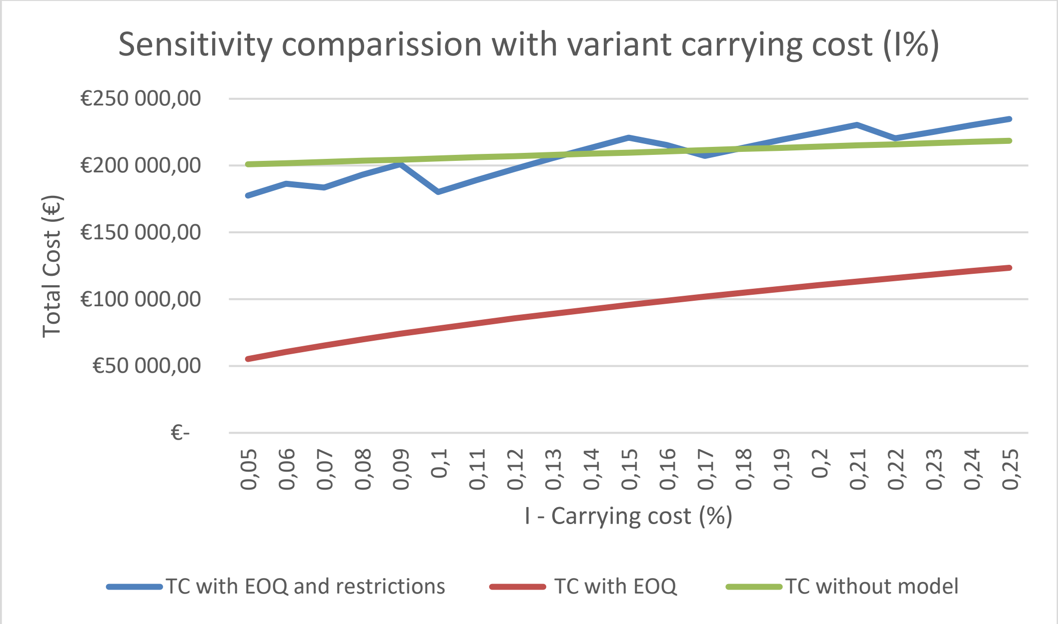

Figure 4 - Sensitivity analysis - scenario 1

The result proved that the decision to use the EOQ model with restrictions or no model change depends on the % used in I (carrying costs). Being an EOQ model with restrictions is more advantageous until I < 13% and after I > 18%. Overall, if all the options were feasible the EOQ model without restrictions is the optimal option.

5. Conclusions, limitations, and recommendations for future research

This research was developed to compare and evaluate the best logistic solution for the company to optimize stock management and reduce the total costs linked to mattress storage and order fulfilment.

To calculate the results that will support and answer the research questions were applied models such as ABC and Economic Order Quantity and it was calculated the total costs for each scenario using the reality of the company in 2023.

Through the application of the academic model ABC, it was possible to identify the category with higher financial value for the company, mattresses in the case, and inside the category where the company invests more money in terms of stock it was applied a new ABC analysis to determine the product with higher financial value in 2023.

To properly assess the results in the optimization of the stock management in the mattress company it was studied 3 research questions in the Methodology:

- Is the current model of stock management and order fulfilment used by the company in the mattresses category the best option when compared to academic models of stock management? If not, what is the difference between the current and the academic models?
- Which scenario should the company use to reduce the total costs of mattress stock management and order fulfilment?
- Which methodology should the company adopt (quantity and periodicity of order) to reduce the total costs in 2023?

In the first question, it was possible to observe that the current model (scenario 2) the company is using, to calculate the quantity and timing to order is not ideal and that the company should use the EOQ model with restrictions, allowing them to reduce the costs in 7,36%, meaning 16,979.02€ of savings in 2023.

As an answer to the second research question, all the scenarios were compared, and the result shows the company should use scenario 1 and apply the EOQ model to have the lowest cost possible. When comparing this option with the current setup it allows to decrease the total cost by 22% (Table XI). Scenario 1 is also less complex in terms of supply chain design since all the orders, independent of the product, follow the same flow.

Regarding the methodology the company should adopt, mentioned in the third research question, the company should use the quantities presented in Table VII.

The application of the models presented and defined as the ideal option has some limitations such as the transportation capacity and holding stock costs. The EOQ model doesn´t consider that since mattresses are bulky products, the maximum quantity that can be transported is 396 units per purchase order. However, to calculate the TC, the setup costs (S) were adjusted to meet the maximum transportation capacity. A possible solution for the company to reduce the set-up costs and the total cost could be to increase the maximum capacity per truck by reducing the size of the boxes or changing the transportation mode to other alternatives such as trains.

Also, the result only refers to the ordering, first-mile transportation and warehousing, not including the distribution costs to the final client. This limits the result so when including last mile costs, the best scenario for the company can be different.

In future analysis is recommended to consider more costs and volumes end-to-end, including last-mile costs to deliver the goods to the customer´s house, so it´s possible to have a complete overview of stock management, warehousing, and last mile. To reduce the total costs even more, in future research the same logic can also be applied to other categories of products so that the portfolio is included in the study and can generate a more complete strategy to optimize stock management and reduce total logistic costs.

It is also recommended to consider the seasonality during the year, and the variations in demand according to the week and the month.

For future research it can be interesting process similar analysis applying academic models to optimize stock management costs in other categories of products sold by the company as Beds, Bed Linen, and Accessories. By applying the academic models, it can be interesting to compare the different scenarios, as conducted with the Mattress category, to define the best model for each category. To finalize the achievement if having the best network design that maximizes service and minimizes costs, measuring the total costs for the company of all the products in the portfolio can be a good future research.

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ANNEX

ANNEX 1- analyze with the method used by the company – TC not optimized

Table XIII - TC non-optimized - without model

	Product	D (units)	Q (not optimized)	N (orders) not optimized	I	C (€)	S (€)	TC not optimized
Scenario 1	Mattress 1	32,488	276	118	0.1	103.57 €	603.24 €	72,436.73€
	Mattress 2	28,739	276	104	0.1	145.98 €	603.24 €	64,827.98€
	Mattress 3	20,224	276	73	0.1	178.17 €	603.24 €	46,661.39€
	Mattress 4	3,860	276	14	0.1	104.59 €	603.24 €	9,879.96€
	Mattress 5	4,642	276	17	0.1	104.59 €	603.24 €	11,589.14€
	Total	**89,953**		**326**				**205,395.19€**
Scenario 2	**Product**	**D (units)**	**Q (not optimized)**	**N (orders) not optimized**	**I**	**C (€)**	**S (€)**	**TC not optimized**
	Mattress 1	32,488	276	118	0.1	103.57 €	603.24 €	72,436.73€
	Mattress 2	28,739	1	28,739	0	145.98 €	3.00 €	86,217.00€
	Mattress 3	20,224	276	73	0.1	178.17 €	603.24 €	46,661.38€
	Mattress 4	3,860	1	3,860	0	104.59 €	3.00 €	11,580.00€
	Mattress 5	4,642	1	4,642	0	104.59 €	3.00 €	13,926.00€
	Total	**89,953**		**37,432**				**230,821.11€**
Scenario 3	**Product**	**D (units)**	**Q (not optimized)**	**N (orders) not optimized**	**I**	**C (€)**	**S (€)**	**TC not optimized**
	Mattress 1	32,488	276	118	0.1	103.57 €	603.24 €	72,436.73€
	Mattress 2	17,243.4	276	62	0.1	145.98 €	603.24 €	39,702.60€
	Mattress 2	11,495.6	1	11,496	0	145.98 €	3.00 €	34,486.80€
	Mattress 3	20,224	276	73	0.1	178.17 €	603.24 €	46,661.38€
	Mattress 4	2,316	276	8	0.1	104.59 €	603.24 €	6,505.31€
	Mattress 4	1,544	1	1,544	0	104.59 €	3.00 €	4,632.00€
	Mattress 5	2,785.2	276	10	0.1	104.59 €	603.24 €	7,530.82€
	Mattress 5	1,856.8	1	1,857	0	104.59 €	3.00 €	5,570.40€
	Total	**89,953**		**15,168**				**217,526.04€**

ANNEX 2- analyze EOQ with unlimited resources – TC with EOQ without restrictions

Table XIV - TC with EOQ without restrictions

	Product	D (units)	Q (not optimized)	N (orders) not optimized	I	C (€)	S (€)	EOQ	TC with unlimited EOQ
Scenario 1	Mattress 1	32,488	276	118	0.1	103.57 €	603.24 €	1,946	20,148.31 €
	Mattress 2	28,739	276	104	0.1	145.98 €	603.24 €	1,542	22,497.93 €
	Mattress 3	20,224	276	73	0.1	178.17 €	603.24 €	1,171	20,850.24 €
	Mattress 4	3,860	276	14	0.1	104.59 €	603.24 €	668	6,979.09 €
	Mattress 5	4,642	276	17	0.1	104.59 €	603.24 €	732	7,653.46 €
	Total	**89,953**		**326**					78,129.03 €
Scenario 2	**Product**	**D (units)**	**Q (not optimized)**	**N (orders) not optimized**	**I**	**C (€)**	**S (€)**	**EOQ**	**TC with unlimited EOQ**
	Mattress 1	32,488	276	118	0.1	103.57 €	603.24 €	1,946	20,148.31 €
	Mattress 2	28,739	1	28,739	0	145.98 €	3.00 €	1	86,217.00 €
	Mattress 3	20,224	276	73	0.1	178.17 €	603.24 €	1,171	20,850.24 €
	Mattress 4	3,860	1	3,860	0	104.59 €	3.00 €	1	11,580.00 €
	Mattress 5	4,642	1	4,642	0	104.59 €	3.00 €	1	13,926.00 €
	Total	**89,953**		**37,432**					152,721.54 €
Scenario 3	**Product**	**D (units)**	**Q (not optimized)**	**N (orders) not optimized**	**I**	**C (€)**	**S (€)**	**EOQ**	**TC with unlimited EOQ**
	Mattress 1	32,488	276	118	0.1	103.57 €	603.24 €	1,946	20,148.31 €
	Mattress 2	17,243.4	276	62	0.1	145.98 €	603.24 €	1,194	17,426.82 €
	Mattress 2	11,495.6	1	11,496	0	145.98 €	3.00 €	1	34,486.80 €
	Mattress 3	20,224	276	73	0.1	178.17 €	603.24 €	1,171	20,850.24 €
	Mattress 4	2,316	276	8	0.1	104.59 €	603.24 €	517	5,405.98 €
	Mattress 4	1,544	1	1,544	0	104.59 €	3.00 €	1	4,632.00 €
	Mattress 5	2,785.2	276	10	0.1	104.59 €	603.24 €	567	5,928.34 €
	Mattress 5	1,856.8	1	1,857	0	104.59 €	3.00 €	1	5,570.40 €
	Total	**89,953**		**15,168**					114,448.89 €

ANNEX 3- analyze EOQ and TC with EOQ with transport restrictions

Table XV - EOQ model - TC with truck restrictions

	Product	D (units)	I	C (€)	EOQ	Q max per truck	N trucks with EOQ	S (€) with truck restriction	TC with truck restriction (max 396)
Scenario 1	Mattress 1	32,488	0.1	103.57 €	1,946	396	5	3,016.20 €	60,432.09 €
	Mattress 2	28,739	0.1	145.98 €	1,542	396	4	2,412.96 €	56,226.56 €
	Mattress 3	20,224	0.1	178.17 €	1,171	396	3	1,809.72 €	41,687.00 €
	Mattress 4	3,860	0.1	104.59 €	668	396	2	1,206.48 €	10,464.88 €
	Mattress 5	4,642	0.1	104.59 €	732	396	2	1,206.48 €	11,478.92 €
	Total	**89,953**							180,289.46 €
Scenario 2	**Product**	**D (units)**	**I**	**C (€)**	**EOQ**	**Q max per truck**	**N trucks with EOQ**	**S (€) with truck restriction**	**TC with truck restriction (max 396)**
	Mattress 1	32,488	0.1	103.57 €	1,946	396	5	3,016.20 €	60,432.09 €
	Mattress 2	28,739	0	145.98 €	1		0	- €	86,217.00 €
	Mattress 3	20,224	0.1	178.17 €	1,171	396	3	1,809.72 €	41,687.00 €
	Mattress 4	3,860	0	104.59 €	1		0	- €	11,580.00 €
	Mattress 5	4,642	0	104.59 €	1		0	- €	13,926.00 €
	Total	**89,953**							213,842.09 €
Scenario 3	**Product**	**D (units)**	**I**	**C (€)**	**EOQ**	**Q max per truck**	**N trucks with EOQ**	**S (€) with truck restriction**	**TC with truck restriction (max 396)**
	Mattress 1	32,488	0.1	103.57 €	1,946	396	5	3,016.20 €	60,432.09 €
	Mattress 2	17,243.4	0.1	145.98 €	1,194	396	4	2,412.96 €	43,562.27 €
	Mattress 2	11,495.6	0	145.98 €	1	396	1	3.00 €	34,486.80 €
	Mattress 3	20,224	0.1	178.17 €	1,171	396	3	1,809.72 €	41,687.00 €
	Mattress 4	2,316	0.1	104.59 €	517	396	2	1,206.48 €	8,108.31 €
	Mattress 4	1,544	0	104.59 €	1	396	1	3.00 €	4,632.00 €
	Mattress 5	2,785.2	0.1	104.59 €	567	396	2	1,206.48 €	8,891.56 €
	Mattress 5	1,856.8	0	104.59 €	1	396	1	3.00 €	5,570.40 €
	Total	**89,953**							207,370.43 €

ANNEX 4- analyze EOQ, T, N, ROP, and SS

Table XVI - T, N, ROP, and SS

	Product	EOQ (units)	T (days)	N (orders)	d (days)	LT (days)	ROP (units)	SS (units)	ROP with SS (units)
Scenario 1	Mattress 1	1,946	22	17	89	21	1,869	623	2,492
	Mattress 2	1,542	20	19	79	21	1,653	551	2,205
	Mattress 3	1,171	21	17	55	21	1,164	388	1,551
	Mattress 4	668	63	6	11	21	222	74	296
	Mattress 5	732	58	6	13	21	267	89	356
Scenario 2	Product	EOQ (units)	T (days)	N (orders)	d (days)	LT (days)	ROP (units)	SS (units)	ROP with SS (units)
	Mattress 1	1,946	22	17	89	21	1,869	623	2,492
	Mattress 2	1	0	28,739	79	0	0	551	551
	Mattress 3	1,171	21	17	55	21	1,164	388	1,551
	Mattress 4	1	0	3,860	11	0	0	74	74
	Mattress 5	1	0	4,642	13	0	0	89	89
Scenario 3	Product	EOQ (units)	T (days)	N (orders)	d (days)	LT (days)	ROP (units)	SS (units)	ROP with SS (units)
	Mattress 1	1,946	22	17	89	21	1,869	623	2,492
	Mattress 2	1,194	25	14	47	21	992	331	1,323
	Mattress 2	1	0	11,496	31	21	661	220	882
	Mattress 3	1,171	21	17	55	21	1,164	388	1,551
	Mattress 4	517	81	4	6	21	133	44	178
	Mattress 4	1	0	1,544	4	21	89	30	118
	Mattress 5	567	74	5	8	21	160	53	214
	Mattress 5	1	0	1,857	5	21	107	36	142