Logistics Distribution Model for Worten's Own Brands on European Marketplaces

The Case Study of Worten

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Thesis to obtain the Master of Science Degree in

Industrial Engineering and Management

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December 2024

Declaration

I declare that this document is an original work of my own authorship and that it fulfills all the requirements of the Code of Conduct and Good Practices of the Universidade de Lisboa.

Acknowledgments

In the first place, I would like to thank both my supervisors, Professor Diana Jorge and Professor Susana Relvas, for the opportunity to develop this master thesis and for the guidance they gave me throughout its completion.

I would like to thank my parents and my sister for their constant support, love and affection, for trusting in me and motivating me to always do my best.

To my friends, for always being there and understanding my absences, and for making my lowest moments, high.

A special thanks to Madalena, for her company throughout this journey, for being my ”fairy god-mother”, always available and with an optimistic outlook, to offer me the most colourful side of an IST student.

To Joaninha, thank you for your joyful presence and good humour, which gave me the best laughs.

I would like to thank my cousin Inês for all her patience and availability.

Finally, thanks to all the friends I've made along the way, with a special thanks to Nuno.

Abstract

Advances in technology have led consumers to increasingly demand quick access to information, products and services, which forces companies to constantly adapt and optimise their operations in order to meet growing demand. This growing demand for speed and accessibility pushes companies toward internationalisation, allowing them to expand their reach and meet consumer expectations globally, while maintain a competitive edge. In this context, Worten, a Portuguese retailer of consumer electronics, household appliances, and entertainment, is seeking to expand its presence in international markets, particularly in Germany and France, through e-commerce platforms. This thesis explores a logistics distribution model for a company aiming to internationalise via European marketplaces, with a focus on the Amazon platform. Given the steady growth of e-commerce and the pivotal role of marketplace platforms, this research analyses different internationalisation strategies. Two different scenarios are studied: using the fulfilment services offered by the Marketplace, and subcontracting their own Distribution Centres. The methodology adopted includes mathematical modelling to optimise the location of Distribution Centres, which minimises total costs. The results offer valuable insights for companies looking to expand their operations into new markets via e-commerce platforms, contributing to more informed strategic decisions.

Keywords

Distribution Model; Facility Location Problem; Internationalisation; Marketplace

Resumo

O avanço da tecnologia tem levado os consumidores a exigir cada vez mais um acesso rápido a informações, produtos e serviços, o que força as empresas a adaptarem-se constantemente e a otimizarem as suas operações, de modo a responder à procura crescente.Esta crescente procura incentiva as empresas a internacionalizarem-se, permitindo-as expandirem o seu alcance e satisfazer as expectativas dos clientes de uma forma global, mantendo simultaneamente uma vantagem competitiva. É neste contexto que a Worten, uma empresa portuguesa de retalho de bens eletrónicos de consumo, eletrodomésticos e entretenimento, pretende expandir a sua presença no mercado internacional, especialmente na Alemanha e França, através de plataformas de e-commerce. Desta forma, este estudo explora um modelo de distribuição logística para uma empresa que se queira internacionalizar através de marketplaces europeus, com foco específico na plataforma Amazon. Dado o crescimento contínuo do comércio eletrónico, e a importância das plataformas de marketplace, este trabalho procura analisar as diferentes estratégias de internacionalização disponíveis.Dois cenários distintos são estudados: a utilização dos serviços de fulfillment oferecidos pelo Marketplace, e a subcontratação de Centros de Distribuição próprios. A metodologia adotada inclui a modelagem matemática para otimizar a localização dos Centros de Distribuição, que minimize os custos totais. Os resultados oferecem insights valiosos para empresas que procurem expandir as suas operações para novos mercados por meio de plataformas de e-commerce, contribuindo para decisões estratégicas mais informadas.

Palavras Chave

Modelo de Distribuição; *Facility Location Problem*; Internacionalização; Marketplace;

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Acronyms

1P	First-Party Sellers
3P	Third-Party Sellers
ASC	Amazon Seller Central
AVC	Amazon Vendor Central
B2C	Business-to-Consumer
B2B	Business-to-Business
CFLP	Capacity Facility Location Problem
DC	Distribution Centre
EOQ	Economic Order Quantity
FBA	Fulfillment By Amazon
FBM	Fulfillment By Merchant
FC	Fulfillment Centre
FLP	Facility Location Problem
FTL	Full Truck Load
GDP	Gross Domestic Product
LIP	Location Inventory Problem
LIRP	Location Inventory and Routing Problem
LRP	Location Routing Problem
LTL	Less than Truck Load
LTSF	Long Term Storage Fee
MC	Multi-Channel
MILP	Mixed Integer Linear Programming
OC	Omni-Channel

SC	Supply Chain
SFP	Seller Fulfilled Prime
SLA	Service Level Agreement

1

Introduction

Contents

This chapter introduces the context and motivation of the dissertation. Subchapter 1.1 provides an overview of the problem and its importance, and how it emerged, based on its contextualisation. Subchapter 1.2 presents the objectives that this thesis aims to achieve and analyse throughout this work and, finally, Subchapter 1.3 describes the Dissertation's Structure.

1.1 Contextualisation

The continuous evolution of the world's population and the globalisation of markets stimulates constant consumption of goods, and the consequent need for them to be distributed throughout the world. Given the fast pace of global trade, there is a need to keep up with market trends, looking for new ways to grow and expand.

COVID-19 had a major impact on society around the world, when in March 2020, in order to contain the spread of the virus, countries were forced to implement restrictive measures, leading to the closure of physical shops. Thus, the share of e-commerce took on, in 2020 proportions never seen before, as it encouraged people to still shop, in a different, but more convenient way, even for mature and well-established markets, such as the United Kingdom, reaching an impressive 31.3%, before stabilising in subsequent periods [2].

Given the increase in online demand, companies have had to adapt their strategies in order to strengthen their online presence, integrating the various sales channels (from physical shops to websites and apps) in order to provide a better consumer experience, and consistent across all points of contact. Verhoef et al. defines omnichannel as the synergistic management of the different available channels and points of contact with the customer, with the aim of optimising the customer experience and the performance of the chain across all channels [3]. The emergence of omnichannel has completely revolutionised traditional e-commerce, combining all points of contact with the customer into an integrated holistic experience.

Another concept that has revolutionised the way people shop today, is the Marketplace concept. A Marketplace is a platform that acts as an intermediary between sellers and buyers, involving an online transaction process [4]. In this way, Marketplaces aggregate the offers of numerous sellers, providing consumers with a wide selection of items from which they can choose, according to their preferences and needs. By providing great convenience and accessibility for consumers, allowing them to shop for a huge variety of products, anytime, anywhere, these platforms are becoming increasingly popular. Additionally, digital channels enable companies to leverage data-driven insights to refine marketing strategies, personalise the shopping experience, optimise inventory management, enhance operational efficiency, and drive growth.

As such, in today's connected society, the emergence of marketplaces and e-commerce platforms has transformed the way business is done, with a major impact on both sellers and consumers. Due to their power to reach a wide audience without physical limitations, these digital channels have become essential for companies. As these platforms facilitate global trade and expand business across borders, efficient and effective logistics operations play a crucial role in ensuring a positive customer experience, and maintaining competitiveness in the market. ”The key to achieving international e-commerce success lies in understanding one simple fact: customers everywhere want better selection, more convenience, and better service. After recognizing this fact, online retailers will soon understand that the major challenge to international expansion is the ability to bring these universal benefits to customers around the world while honoring local customs” [5].

It is in this context that this study, prompted by Worten, arises. With stabilised domestic markets and consistent customer demand, retail companies, such as Worten, must explore new markets and adopt innovative distribution models to maintain growth and drive expansion. As Europe is one of the largest markets in the world, establishing a strong presence in the main European countries can significantly increase Worten’s market reach and competitiveness. For those seeking to enter major e-commerce platforms like Amazon, recognised as a world leader in the e-commerce market, the emphasis lies on developing a strategic approach to ensure a successful market entry. Thus, the main objective of this study is to explore and analyse how Worten can expand into the rest of Europe, in particular to France and Germany, taking into account Amazon and the options it offers businesses to enter, that best fits the company’s long-term strategy and objectives, with a view to maximising reach, visibility and sales potential in new territories. The decision analysis will focus on the best way to satisfy customer orders efficiently and effectively, designing a network distribution to satisfy customer orders, while minimising the total cost of delivery.

1.2 Objectives

The main objective of this thesis is to develop a model to be a useful and practical tool for companies considering the potential use of marketplaces to expand to other countries, helping them to make informed decisions. This tool will be tested using Worten, a leading company in the retail sector in Portugal, as a real case study.

In order to achieve this general objective, the dissertation establishes the following specific objectives:

- Defining the problem, identifying the main challenges and opportunities associated to it.
- Select and review the relevant scientific literature to develop a robust knowledge base and an appropriate methodology for the topic under investigation.
- Design and implement a methodology that supports the main objective of this thesis.

- Understand and get to know the marketplace to be analysed and the services it offers.
- Develop possible and useful scenarios to evaluate the internationalisation system, according to the methodology developed. These scenarios will help to simulate different strategies and predict possible outcomes.
- Make recommendations about the most suitable scenario, based on the detailed assessment of the scenarios developed.

1.3 Dissertation Structure

This master's thesis is organised into seven chapters, as detailed below:

- **Chapter 1 - Introduction:** This chapter introduces the context and motivation of the study, presenting an overview of the problem and its importance. In addition, the objectives that the dissertation aims to achieve are defined.
- **Chapter 2 - Problem Definition:** This chapter presents the general concepts related to the retail sector and its evolution, which are important for providing a comprehensive understanding of the environment in question. It then describes the specific problem that will be studied.
- **Chapter 3 - Literature Review:** The third chapter analyses the scientific literature relevant to understanding the issues that constitute the problem, which are fundamental to the development of the proposed methodology.
- **Chapter 4 - Methodology:** This chapter presents the characterisation of the model developed to solve the different logistics and distribution scenarios proposed.
- **Chapter 5 - Case Study:** This chapter describes the case study, through a more detailed context of the scenarios involved, as well as the assumptions made to study the problem.
- **Chapter 6 - Results and Discussion:** This chapter discusses some simplifications of the model, and presents the results obtained from applying the methodology to the proposed scenarios.
- **Chapter 7 - Conclusions, Limitations and Future Work:** The last chapter presents the conclusions of the study, the limitations found and indications for future research that could expand on this work.

2

Problem Definition

Contents

The main objective of this chapter is to present the generic problem that will be discussed. Subchapter 2.1 will cover fundamental concepts such as e-commerce, omnichannel, marketplaces and order fulfilment, highlighting how the technological revolution has driven the creation of these concepts and transformed the retail landscape, while Subchapter 2.2 describes the generic problem that will be studied.

2.1 General Concepts in Retail and their evolution

The motivation for this chapter stems from a retail company's need to understand the challenges involved in e-commerce and the potential advantages of using marketplaces for internationalisation. Therefore, it is essential to explore these concepts and understand the current context of e-commerce and the significance of marketplaces.

2.1.1 The Impact of Technological Advances

The rapid digitalisation of markets and communication channels has had a significant impact on global competition, extending the reach of companies to a global audience without physical presence. Autio defined digitalisation as "the application of digital technologies and infrastructures in business, economy, and society", and added that digitalisation shapes business opportunities by transforming best practices and utilizing technologies like e-commerce, big data analytics, and machine learning [6].

Technological advances have enabled the development of smaller, faster and more efficient devices, such as smartphones, and tablets, among others. These innovations allow people to access the internet and take advantage of all its features from anywhere. The popularisation, ease and affordability of these mobile devices is driving the growth of mobile commerce, given the accessibility and convenience with which people can shop today [7]. This shift towards mobile commerce has led to a significant increase in e-commerce, as customers expect excellent and consistent service, whenever and wherever they are, regardless of the channel they are using [8]. Although digitalisation may not have a direct impact on competitive advantage, by allowing companies to adapt to market changes, reach a wider audience, personalise consumer experiences and improve customer service, it indirectly ends up allowing companies to differentiate themselves in the market [9].

Innovation in the digital economy focuses on improving efficiency by simplifying, optimising and automating processes. By taking advantage of these technologies, companies can improve workflow and reduce costs [10].

2.1.2 E-commerce

With the appearance of the internet and its rise, until it was easily accessible, at the end of the 1990s, e-commerce was introduced and formed. The rapid development of technological information, allowed this new concept to evolve rapidly in the last 20 years, transforming the way businesses operate and how customers engage with companies. E-commerce is a consequence of the improvement of the internet, which in 1995 allowed Amazon and other companies to start exchanging products electronically. Moreover, emerging technologies, such as social media, Cloud computing, Big Data, and Artificial Intelligence (AI), have also scaled up e-commerce development [11].

The concept of the digital economy has evolved significantly since it was first conceptualised by Don Tapscott in 1995. Initially, Tapscott described the digital economy as the ”new economy based on the networking of human intelligence” [12]. The digital economy, linked to e-commerce and the online transactions it involves, has transformed the way companies interact with customers, leading to new ways of creating value.

E-commerce, or electronic commerce, is the trading of goods and services on the internet, and it was around 40 years ago that one of the first transactions took place over the Internet. Zwass describes e-commerce as “the sharing of business information, maintaining of business relationships, and conducting of business transactions by means of telecommunications networks” [13].

Companies compete in diverse online channel formats today, including electronic, mobile commerce, and social media. These channels have become essential for businesses to engage with customers, market their products or services, and drive sales in the digital age. As defined by Qin et al., ”E-commerce is the process by which people use electronic means to do business or to do other economic activities. It is the process whereby traditional trade is carried out by electronic methods” and, as described by Fraser, ”includes the exchange of information of value, in the form of products and services as well as payments, using web-based technologies” [14] [15]. In Qin’s words, e-commerce ”breaks through limits of time and space, alters trade patterns, improves the circulation of merchandise, capital and information, and makes enterprises more competitive by effectively reducing the cost of production” [14].

As Qin et al., also said, E-commerce is “the most significant industrial revolution since the first industrial revolution” [14]. In this way, in the coming years, sales through e-commerce are projected to overtake sales through traditional channels [16]. This situation creates pressure for companies to rethink their strategies, improve their presence on these platforms, and effectively plan their global operations to remain competitive in the evolving digital landscape [17] [18].

With this growth and expansion, retailers have adopted a Multi-Channel (MC) approach, a strategy that involves using several communication and distribution channels to reach customers, including physical and online shops. The integration of social media into e-commerce has enabled companies to offer customers a seamless experience, allowing them to interact with brands through various touchpoints and channels, creating a new concept: the Omni-Channel (OC). Initially, these channels operated separately and independently, which hindered the convenient experience they were intended to offer consumers. However, with the necessary evolution imposed by the rapid advance of e-commerce, there is no longer a clear distinction between online and physical channels, giving rise to the concept of OC. OC is a sales strategy that integrates different communication and sales channels in order to provide an unified, integrated and consistent shopping experience for the customer. This includes channels such as physical shops, websites, mobile applications and social media [19]. This concept is facilitated by technology, as it allows retailers to unify their online and offline operations, providing a seamless experience for consumers, regardless of the channel used, strengthening the relationship between the brand and the consumer, and promoting brand loyalty [20].

There are many different types of e-commerce business models to choose from. Among these, the Business-to-Consumer (B2C) sales model stands as the most common and used model. Within this framework, merchants interact directly with end-users, facilitating transactions and delivering products or services directly to consumers. While the Business-to-Business (B2B) sales model revolves around businesses selling their offerings to other businesses. Here, the buyer may sometimes serve as the end-user, but often acts as a reseller, distributing the acquired goods or services to the ultimate consumer [21].

2.1.3 Marketplaces

A platform, according to Gawer, is not just a physical structure, but also includes digital interfaces, standards and protocols that enable interactions and transactions between different groups of users, serving as a basis for the creation and exchange of value, facilitating the integration of complementary products and services [22]. Platforms are not static entities, but evolve over time, adapting to changing market conditions, technological advances and user preferences [22]. As can be seen, the concept of platform evolved over time, refining into the concept of marketplace, as the underlying principles and considerations of a platform align closely with the core concepts of a marketplace.

The digital marketplace was described by Ghazawneh and Henfridsson as “a platform component that offers a venue for exchanging applications between developers and end-users belonging to a single or multiple ecosystems” [23]. According to Andersson et al., “Marketplaces facilitate the exchange of products and services, the transfer of information and payments, and the creation of economic value for parties such as buyers, sellers, and market intermediaries”, and are nowadays the main delivery channel and interaction point between digital service providers and users [24]. As such, marketplaces function as essential ecosystems for the distribution, promotion and interaction of services, where service providers must learn to navigate the complex dynamics of these markets, in order to effectively provide their services, interact with users, and succeed in the digital services world. Thus, both historically and today, it serves as an intermediary for economic transactions, social interactions and the exchange of goods and services, and is behind the creation of value through economic activities. By empowering consumers, it makes information accessible and available to everyone, influencing consumer behaviour and market trends [25].

E-marketplaces, also known as electronic marketplaces or online marketplaces, are digital platforms that facilitate transactions between buyers and sellers, acting as intermediaries in the distribution channel. These platforms connect customers with suppliers, enabling the exchange of goods and services. The main characteristics of e-marketplaces include acting as two-sided platforms, i.e. platforms that match customers with sellers, where ownership and control of the goods is generally with the sellers [26].

With the constant evolution of markets, it is essential to design them to efficiently meet the specific needs of different market types, address failures, and provide the necessary support to foster ongoing innovation. Market Design, by shaping the infrastructure, rules and customs of markets, plays an important role in facilitating efficient transactions, improving market outcomes, and creating platforms of trust for buyers and sellers to interact effectively [27].

2.1.4 Order Fulfillment

Order fulfilment involves a variety of operations, from network design to inventory management to the operations that take place in warehouses [28]. Important factors to consider regarding the impact of order fulfilment on customer satisfaction include optimizing warehouse capacity, maintaining adequate stock levels, managing demand seasonality fluctuations, and delivering products to the customer quickly [29]. The main challenges associated with order fulfilment are operational and logistical matters, especially in the last mile delivery process, due to the importance of delivering a good quality service to the customer quickly. It is crucial to guarantee an efficient planning route that minimises delivery times, as well as transport costs. To do this, it is necessary to manage the different levels of customer density, distributed over the geographical areas to be taken into account, which has a major impact on the efficiency of the route. Technology can be a great ally in this whole process, both in the inventory management process and in the optimisation of the transport route allowing for a real-time tracking [30].

As such, determining suitable hub locations can lead to reduced transportation costs and faster delivery times for goods, by strategically locating them in order to optimise delivery routes and improve distribution efficiency. This also minimises last-mile distances, reduces operational expenses, and increases flexibility in managing inventory and adapting to changing demands [31].

One of the main objectives of this study is, by analysing scenarios with different types of order fulfilment, to find the optimal scenario that allows a company to fulfil orders from the most cost-effective location, in the context of marketplaces. This optimisation will enable faster order processing, reduce shipping costs, and improve customer satisfaction.

2.2 Problem Description

With the development of technology and increased connectivity, access to a wide range of products for consumers anywhere in the world has become easier. Globalisation has eliminated physical barriers, allowing companies to explore new markets and new opportunities outside national borders, thus facilitating access to international markets in a very affordable way. As companies seek to expand globally, internationalisation through marketplaces becomes a crucial strategy to increase their presence and reach.

Calof and Beamisht's defined internationalisation as "the process of adapting firms' operations (strategy, structure, resources, etc.) to international environments" [32]. And in this way, in well-established companies with growth objectives, the main strategies involve looking for new markets, as it allows them to reach a larger network of clients and accessing new growth opportunities. Among the main factors that lead companies to internationalise, are the characteristics of the markets in which they operate. If these markets are mature, companies tend to seek investments in other countries, as a way of diversifying and managing their exposure to risk [33]. The possibility of achieving economies of scale is also very attractive when deciding to internationalise, as mass production allows companies to achieve a higher profit margin by reducing production costs. Through digitalisation and the ease of entering other markets that it has brought, internationalisation has become a very attractive strategy.

As such, internationalisation plays a crucial role in business expansion, allowing companies to reach a global audience and position themselves in international markets. Verhoef et al. recognise the importance of e-commerce channels and online marketplaces in internationalisation, because of the way they shape consumer behaviour, influence purchasing decisions and drive the evolution of retail strategies towards Omnichannel Retailing [3].

Marketplaces are an easy entry platform for companies, allowing them to expand internationally with guaranteed visibility and global reach, enabling them to grow rapidly. Therefore, the use of e-commerce platforms such as Amazon provides access to a vast network of potential customers, facilitating penetration into these markets.

E-commerce has not only transformed the way consumers shop, it has also revolutionised the entire retail process, from order fulfilment to stock management. As such, efficient distribution and logistics have emerged as essential to guaranteeing order fulfilment and improving the overall customer experience. The promise to offer the consumer a seamless experience, creates expectations for the service the company delivers. This has a significant impact on the logistics, due to the complexity it introduces to integrate the various channels by managing inventory, orders and their delivery across all channels, requiring a robust, fast-acting distribution logistics network.

Although the internationalisation process is facilitated by marketplaces, the strategy and logistics associated with the process can be quite challenging. These challenges range from the strategic choice of how to enter the marketplace, taking into account the place of origin, the adaptation of products and marketing strategies to reach more consumers, to the efficient management of the distribution chain to guarantee fast and reliable deliveries of orders.

This thesis will develop a model to help retail companies on how to expand, by entering other countries through marketplaces. This study is therefore designed for any company with its own brand products, that wants to expand its presence in any market other than its own, by using a marketplace platform as a distribution channel. The main focus of the work is to help companies regarding logistical decisions, by exploring different scenarios, to identify the best approach for expanding its international operation.

Two different scenarios will be explored. In the first scenario, companies may take advantage of the fulfilment services already offered by the marketplace, in a two-level supply chain network. Whereas in the second scenario, a three-level supply chain network is considered, which can be made up of the Warehouse, the Distribution Centre (DC)s, and the end customers. In this scenario, the company must decide whether to subcontract one or more DC, with the aim of guaranteeing a certain lead time, to satisfy the demand. In this way, the distribution network will cover the product flow from the Warehouse to the marketplace's Fulfillment Centre, or from the Warehouse to the DC, and from the DC to the end customer it is assigned to. It is not a single item product case, but of products aggregated by families, with exogenous demand.

The aim is therefore to identify the best locations for DCs, considering different fulfilment strategies, whether through marketplace services, or direct supply to the end customer. The decisions involved in this problem are which scenario to use, the quantity of products to send from the main warehouse to each Fulfillment Centre (FC) of the marketplace or DC, the assignment of which DCs will serve each demand node, and the determination of the ideal number of DCs to open, as well as their locations, in order to minimise the total costs.

Decisions will take into account various factors, including DC costs, which cover variable costs associated with operating the DCs; transport costs, which involve shipping products from the main warehouse to the DCs, and from the DCs to the end customers; and marketplace fees, which include the fees for using the fulfilment services offered by the marketplace, and the fees of using the marketplace. Another factor that will be considered in the decision, is the service level agreement that the company aims to ensure.

By focusing on a case study of a retail company that wants to internationalise through marketplaces, the study aims to contribute not only theoretically, but also by providing practical and applicable insights for companies facing similar challenges.

3

Literature Review

Contents

This chapter will focus on the literature related to the problem this thesis aims to solve, with an emphasis on facility location problem.Section 3.1 introduces the Facility Location Design Problems, delving into the various decisions critical to Supply Chain (SC) functioning, outlining various optimisation models and methodologies used to resolve these issues. Section 3.2 focuses on Order Fulfillment, addressing how modern e-commerce logistics demand swift, efficient order processing, and transport to meet customer expectations, and reviewing different fulfillment strategies. Section 3.3 summarises the research gaps identified in previous studies, and positions this work as an attempt to fill the gap by integrating marketplace-related challenges into the facility location study framework.

3.1 Supply Chain Design Problems

There are several decisions that can impact SC functioning positively or negatively, such as facility location decisions, inventory allocation, distribution of products between more than one level, and capacity planning, among others. Businesses can adapt their SC strategies to meet the growing demand for online consumption by enhancing inventory management, ensuring efficient order fulfilment, optimizing the distribution network, integrating technology, and adopting a customer-centric approach [34].

In order to optimise the implementation of the distribution network, factors such as the strategic positioning of the inventory, the delivery scheme, the incoming flow pattern, the uncertainty of demand and capacity, and the delivery time restriction must be taken into account, with the main objective being to minimise costs.

In supply chain management, strategic decisions regarding the DC location, inventory and routing decisions are crucial to the operational efficiency and competitiveness of companies. These problems, known as the Facility Location Problem (FLP), the Location Inventory Problem (LIP) and the Location Inventory and Routing Problem (LIRP), are interconnected and address different aspects of supply chain management. The interconnectedness of these three problems is evident, when the complexity and interdependencies of supply chain decisions are taken into account. This is necessary not only because of the location of the facilities, but also because of how these locations affect the movement and storage of inventory in a network.

Perl and Sirisoponsilp studied the interconnection between these three major themes: facility location, inventory decisions and transport [1]. The following diagram 3.1 aims to elucidate the interdependency between the Subchapters that will be presented below.

Problem	Main Decisions
Facility Location Problem - FLP	• Number of installations: How many facilities should be opened • Location of facilities: Where each facility should be located • Client Assignment: Which clients will be served by which facilities • Facility Capacity: Determining the required capacity of each installation (in some models - CFLP)
Location Inventory Problem - LIP	• Number of installations: How many facilities should be opened • Location of facilities: Where each facility should be located • Client Assignment: Which clients will be served by which facilities • Facility Capacity: Determining the required capacity of each installation (in some models - CFLP) • Stock levels: How much inventory should be kept at each facility. • Replenishment Policy: How often and how much inventory should be replenished.
Location Routing Problem - LRP	• Number of installations: How many facilities should be opened • Location of facilities: Where each facility should be located • Client Assignment: Which clients will be served by which facilities • Vehicle routing: Planning vehicle delivery routes
Location Inventory Routing Problem - LIRP	• Number of installations: How many facilities should be opened • Location of facilities: Where each facility should be located • Client Assignment: Which clients will be served by which facilities • Facility Capacity: Determining the required capacity of each installation (in some models - CFLP) • Stock levels: How much inventory should be kept at each facility. • Replenishment Policy: How often and how much inventory should be replenished. • Vehicle routing: Planning vehicle delivery routes.

Figure 3.1: Literature Main Problems adapted from [1]

As summarised in the figure 3.1, the FLP is the starting point for optimising the distribution network. This problem involves critical decisions about the number of facilities that should be opened, the location of these facilities, the assignment of customers to each facility and the required capacity of each facility, its main objective being to minimise establishment and allocation costs, while ensuring that customers are allocated efficiently to each DC. The choice of locations is crucial, as it directly affects operating costs, delivery times and customer satisfaction. However, given the complexity of SC systems, LIP comes into play, which adds the inventory dimension to location decisions. In addition to the decisions made in FLP, LIP involves determining the stock levels to be kept in each facility and the replenishment policies, since effective inventory management can significantly reduce maintenance costs and improve responsiveness to fluctuations in demand. Furthermore, the Location Routing Problem (LRP) adds another layer by incorporating vehicle routing into the mix, as it simultaneously addresses the location of facilities, the assignment of customers, and the routing of delivery vehicles. With the aim of reducing transport costs and increasing delivery efficiency, as well as customer satisfaction, taking into account the inventory, the LIRP emerges. This problem adds to LIP decisions, the need to plan vehicle delivery routes, and adds to the LRP decisions, the inventory dimension.

The interconnection of location, inventory and routing decisions is fundamental to achieving a truly efficient SC, since location decisions directly affect the required inventory levels and transport routes, while inventory policies influence the efficiency of transport operations and customer satisfaction. The main objective of these problems is ultimately the same: to achieve a more efficient supply chain network that significantly reduces costs (operational - FLP -, inventory and stock management - LIP -, and transport - LIRP and LRP) and improve customer response.

Although not all of the topics will be properly deepened, as they do not fully fit into the problem to be approached, it would be difficult to address one problem without addressing the others. As such, the FLP, LIP, LRP and LIRP problems will be addressed in the following Subchapters 3.1.1, 3.1.2, 3.1.3 and 3.1.4 respectively, with greater detail on the FLP, since it is the problem to be studied in this dissertation.

These problems that will now be described are considered NP-hard problems. This means that there is no deterministic algorithm known that solves the problem in polynomial time, that is, there is no efficient solution to solve the problem in a reasonable amount of time, especially for large-scale cases [35]. Ways around large-scale problems, especially NP-hard problems, are Lagrangian heuristics, which are used to generate approximate solutions with manageable computational demands [36].

3.1.1 Facility Location Problem

The strategic decision on where to locate facilities plays a very important role in the design of the SC network, as there are a number of decisions involved in determining where products are stored, the amount of products in inventory, and the transport to and from which facility, to the end customer, that are critical to the efficient and effective movement of products [37]. The quality of delivery services is compromised by the location of the facility, in relation to the point of origin and the end customers, as choosing the optimum location may improve operational efficiency, reduce costs and deliver orders quickly, while offering the consumer the best experience [38]. The strategic placement of DCs plays a crucial role in optimising inventory holding costs, transportation costs, service levels, and supply chain responsiveness. Inadequate locations can lead to excessive and unnecessary costs, whereas strategically placing DCs closer to demand points can reduce inventory holding costs and minimise transportation costs. As such, strategic DC locations enable companies to meet customer demand efficiently, enhance service levels, and improve supply chain responsiveness.

The study of FLP can be traced back to Alfred Weber, who in 1909 began research into this subject, developing the first model for locating just one factory, by minimising the total distance between the depot and the customers [39]. The elementary FLP consists of an optimisation model that minimised total costs, which included the sum of distribution and opening costs. This approach to the problem included making decisions on two levels: a first, a more stratigical one, which consisted of determining an optimal subset, from a given set of candidate facility locations; and in a second step, that concerned the determining of which facility each end customer would be assigned to, in a given region of the plan [40]. In this way, the FLP aims to determine the optimum trade-off between the minimum possible distribution costs and the costs associated with the facility (fixed and operating costs), resulting in the optimum number of warehouse locations. However, the increasing complexity of real problems has meant that the problem has also had to be adapted from its original form, evolving to include parameters such as capacity, inventory allocation, among others.

In this way, associated with the FLP, is the capacity of the facilities, since the ones chosen must be able to serve all the demand assigned to them. While the classical FLP problem assumes that there are no restrictions on the capacity of the facilities, the more advanced models of this problem, which tend to be closer to real problems where these limitations do exist, take these conditions into account by incorporating them into the restrictions. This gives rise to the Capacity Facility Location Problem (CFLP), a problem first formulated by Kuehn and Hamburger in 1963, to which restrictions based on the capacity limitations of facilities are added to the classic FLP problem [41]. The original CFLP is based on a heuristic method that focuses on the location of the facility, based on the benefits that can be gained from economies of scale in transport to the facility, and on improving lead times, by having facilities closer to demand. The capacity restriction is assigned when allocating the demand points to the facilities, taking into account the capacity of each one, to ensure acceptable service level and spatial equity. This problem, while minimising the total costs associated with transporting the goods and operating the DCs, only adds the limitations of the capacities of the different facilities [41].

One of biggest influences considered by Verter in relation to the CFLP, was the study developed by Geoffrion and Graves in 1974 [42] [43]. This study addresses the problem of the optimal location of intermediate distribution facilities, with capacity limitations, in a distribution system, by applying a Mixed Integer Linear Programming (MILP). The approach used to tackle the problem is based on Benders Decomposition, an optimisation technique used to solve large-scale, complex MILP problems, which divides the original problem into smaller, simpler sub-problems. In this way, the model managed to minimise the costs of transportation and warehousing, over a distribution network comprising three echelons: warehouses, DCs, and the final customer. However, despite having been a major driver for the evolution of the CFLP, with technological advances today, this is not the best approach, since it can generate more than one optimal solution to minimise the location and costs, not necessarily resulting in the global optimum [43].

Akinc and Khumawala, in 1977 developed branch-and-bound procedures, in order to asses this problem through linnear programming, and Nauss, in 1978 used the Langrangean relaxation [44] [45]. According to Verter, the cross-decomposition algorithm developed by Van Roy, in 1986 and the Lagrangean-based approach of Beasley in 1988 are two of the most effective techniques for solving the CFLP [42]

[46] [47].

These problems studied throughout these articles involve at least two echelons, meaning that the distribution system they address can have two levels, consisting of the factory and the DCs; three levels, where the first level concerns the factory, a second one, concerns the DCs, and a third involves the end customer; or a multi-echelon, consisting of more than three levels. Kaufman et al., in 1998, were responsible for formulating the first multi-echelon study, which involved determining the location for sets of facilities and warehouses simultaneously [48].

Gill and Bhatti in 2007, developed an optimisation heuristic model for the location-allocation problem [49]. This model is based on two levels, the first of which aims to minimise the number of warehouse locations, for a maximum load distance between the last two levels of the SC. This step helps in narrowing down the possible warehouse locations, that can efficiently satisfy the demand. In the second step, the final client is allocated to the selected warehouse locations, in a way that minimises the load distance between each retailer, and its assigned warehouse [49].

Also Liao and Guo, in 2008 developed an optimisation model using clustering, with the aim of integrating demand allocation with capacity constraints. This model optimises the locations of facilities iteratively, taking into account not only the proximity of the demand points, but also the capacities of the facilities, through a holistic approach, allowing for an efficient allocation of DCs to end customers [50].

Still in the context of FLP, Tang et al. 2020 studied a MILP model that extends the capacitated fixed-charge location model to a multi-objective optimisation framework. This model aims to minimise the total costs, which include transport costs, and the costs of operating the DCs, trying to obtain a trade-off between economic efficiency and environmental sustainability (by also minimising carbon emissions). The model takes into account practical considerations, such as shipping costs, distances between facilities, their capacities, ensuring that each customer is assigned to exactly one facility, limiting the capacity of facilities based on demand [51].

Gert Wolf, in 2022, addressed the gap in the literature regarding the disappearance of publications related to facility location from geographic journals, and the evolution of the concepts within this problem [52]. In his review, Wolf structured the articles based on the FLP problems, organising them by topic, which was very helpful for this section. It is also worth highlighting the contribution of the study conducted by Wolf, in relation to the model developed because, in a simple way, it approaches the FLP by means of professional optimisation software such as CPLEX, explaining how the model is structured to deal with more complex and realistic planning scenarios, going beyond the capabilities of traditional GIS modules, the modulation system used until then [52].

All these problems related to the location of facilities and the allocation of clients to facilities have a common objective: to minimise total costs, which include transport costs, facility costs, service costs, etc., all of which are based on the assumption that desirable facilities are as close as possible to the demand centre. However, these problem formulations ignore tactical decisions such as lead times and service levels. It should also be emphasised, that all these problems involving the allocation of products to demand nodes, from an intermediate facility, assume a policy in which each demand point is assigned exclusively to a single DC.

The objective function of a basic FLP aims to minimise the total cost, which is the sum of the fixed costs of operating the facilities and the variable transport costs, weighted by demand. As formulated by Tang et al. 2020, the generic mathematical expression for an FLP objective function is [51]:

$$Minimise \ \ \sum_{j} f_j \times z_j + \sum_{j} \sum_{k} c_{jk} \times d_{jk} \times dm_k \times w_{jk} \tag{3.1}$$

Expression 3.1 adds up to the fixed costs, f_j, of facilities *j* that are being used, the transport costs from facility *j* to demand node *k*, calculated as the product of the unit transport cost c_{jk}, the distance d_{jk}, the demand dm_k and the binary variable w_{jk} that indicates whether the facility *j* serves the *k* demand node. Variable z_j is a binary variable that indicates whether the facility *j* in question is being used. The objective function 3.1 is subject to the following constraints:

$$S.t. \ \ \sum_{j} w_{jk} = 1 \ \ \forall k \tag{3.2}$$

$$w_{jk} \leq z_j \ \ \forall j, k \tag{3.3}$$

$$\sum_{k} dm_k \times w_{jk} \leq cap_j \times z_j \quad \forall j \tag{3.4}$$

$$z_j, \ w_{jk} \ \ \epsilon \{0, 1\} \ \ \forall j, k \tag{3.5}$$

Constraints 3.2 ensure that each demand node *k* is served by exactly one facility *j*; constraints 3.3 assures that allocations of facilities *j* to demand nodes *k* are only possible if the facility *j* is active; constraints 3.4 ensure that the capacity limit of each facility *j* cannot be violated; and finally constraints 3.5 define the domain of the decision variables z_j and w_{jk}, imposing they are binary.

3.1.2 Location Inventory Problem

By incorporating lead time and safety stock considerations into network design models, allows the decisions at a strategic level regarding the location of facilities and the placement of inventory to be optimised, in order to be agile and respond to variations in customer demand [36].

”A typical LIP assumes the predetermined location of suppliers and aims to determine the optimal number and the location of DCs, allocate customers to DCs and optimise the inventory service level at each DC" [53]. Whereas FLP concentrates on allocating demand to facilities, LIP concentrates more on stock management and the costs that this entails. In this way, the LIP integrates strategic decisions regarding the design of the SC, with more operational decisions regarding inventory management, and tactical decisions, which include factors, such as lead times and service level. Although it may not be the main problem, the inventory problem is critical to the optimisation of logistics networks, as "tactical planning decisions and operational planning decisions (...) are reliant on transportation and storage costs and capacities, which in turn, are highly influenced by strategic decisions" [53]. As such, LIP extends the determination of optimal warehouse locations, by also focusing on the efficient management of inventory levels at these locations, with the aim of minimising total operating costs and improving service levels.

LIP is a complex problem that involves choosing optimal locations for facilities and the coverage of each facility, considering various aspects such as how many facilities to open, the planning horizon, order size, facility capacity and customer demand. In addition, models can be developed to consider different types of products and demand, as well as different cost functions, such as location costs, operating costs, inventory costs and transport costs. LIP models can also consider different cost functions, such as safety stock costs, which refer to the cost of keeping extra items, to cope with variations in demand, shortage costs, i.e. the cost of not meeting demand, and lost sales costs [54].

Shen et al., in 2003, proposed a similar version of the FLP model, adding inventory control decisions through a non-linear integer programming model [55]. This model also incorporates decisions about the level of safety stock to maintain, in a LIP, for a two-echelon network. In this way, the ordering decisions are based on the Economic Order Quantity (EOQ) model, where the inventory control strategy is an approximation to the (Q,R) model, which considers the lot size as a decision variable. The objective of this article was to minimise the cost of transportation, location and safety stock, using a Lagrange method [55].

Ozsen et al. stands out in the integration of lead time and safety stock levels in location-allocation inventory problems, through a heuristic Lagrangian model they developed, in an approach to managing uncertainties and optimising service levels [36]. It is based on a network design model for a single product, applying specific details for inventory management and product distribution. Ozsen et al. assume time-stationary demand distribution at the demand points, although they consider demand to be stochastic. In this model, the DC functions as a cross-docking system, meaning that replenishment lead time is divided into three components: load make-up time, replenishment time, and congestion time. [36].

Miranda and Garrido, solved in 2008 the problem of locating a set of facilities, with restrictions on their capacity, to satisfy a stochastic demand, knowing the fixed points of the space over which the customers are distributed, which must be satisfied to a given level of service, based on Lagrangian relaxation in conjunction with a complex heuristic [56]. The model developed by Miranda and Garrido also takes into account the EOQ's cost structure, resulting in an analysis of the savings from inventory control. As in FLP models, restrictions on the capacity of facilities tend to limit the demand they can satisfy, Miranda and Garrido replaced the typical restrictions on capacity in FLP models, with restrictions on the size of the order. In this way, their model located DCs, and assigned them to the demand point, having also defined policies of inventory to adopt in each DC, regarding its capacity. [56]

Farahani et al., in their study on the evolution of the literature review on LIP, show how the literature on this problem has grown and evolved in order to adapt to the most modern needs, integrating the updates that have been developed in this field [53]. This review helps to contextualise the trends, challenges and research opportunities surrounding LIP. It also introduces new problems that have emerged from this principal, such as: the Dynamic-Location-Inventory Problem (DLIP), the LIRP and the Inventory-Transportation problem (ITP). Other constraints that can be added as complementary to the LIP are: capacitated warehouse space and transshipment modes. In addition to the extensive literature review, Farahani et al. also present a mathematical model that aims to provide an answer to the inventory problem. This optimisation formulation has room for continuity and adaptations to different real-world scenarios, aiming to minimise costs, maximise operational efficiency, but also meet other specific SC performance requirements [53].

Vahdani et al., in their article discussed LIP, through an extensive literature review, addressing several key challenges related to the problem [57]. Among them, the main challenges include considering correlated demand among retailers, incorporating allowed shortages, implementing a periodic review system, optimising location-inventory decisions in a supply chain network, integrating strategic and operational issues, and minimising costs associated with maintenance, ordering, transportation, inventory, and construction. These challenges underscore the complexity of managing joint location-inventory decisions, and emphasise the importance of optimisation techniques in order to address them effectively [57].

3.1.3 Location Routing Problem

The LRP is a problem that combines two classic aspects of logistics: the FLP and the Vehicle Routing Problem (VRP). The aim of the LRP is to simultaneously determine the optimum location of facilities, and the routes of vehicles, in order to minimise total costs.

Transport is recognised as one of the most important activities, when it comes to the physical distribution of a SC network, where it is necessary to balance the costs of transport, storage and distribution. The transport problem was originally proposed by Hitchcock in 1941, where he introduced a mathematical model to address the efficient distribution of products from multiple sources to multiple destinations [58]. The transportation problem is a special case of linear programming, and aims to minimise total transportation costs, by meeting the demand of different destination locations from various supply sources. Since then, this problem has been discussed all over the world, with the aim of improving and developing methods to solve the transport problem more efficiently and effectively.

In this combination between vehicle route planning, and customer allocation, the LRP takes into account constraints such as vehicle capacity and time windows for deliveries, in order to minimise, not only transport costs, but also the total distance travelled, adding decisions on which customers will be served by which facilities, in an attempt to balance the workload. To do this, it takes into account fixed installation costs, proximity to customers and accessibility. This problem aims to reduce cost savings by improving operational efficiency, with a direct impact on customer service [59].

Prodhon, in 2014, carried out a detailed analysis of the new LRP variants, classifying them and discussing the most effective methodologies to solve them [60]. Through a study that compares the best algorithms, highlighting those that have obtained the best results in terms of efficiency and effectiveness, addressing the new trends in LRP research.

3.1.4 Location Inventory Routing Problem

Another problem that is also part of this set of problems, but which will not be studied, is the LIRP. However, due to its importance, this Subchapter will present a brief summary of its study and importance. This problem considers not only location and inventory decisions, but also the transport routes in a SC, since these have a direct impact on the costs and efficiency of the service. In this way, LIRP aims to optimise vehicle routes in order to reduce the distance travelled and the delivery time [61].

The LIRP has evolved to include more complex decision-making. It now involves identifying optimal locations for new facilities, by considering not only transportation costs, but also factors such as fixed costs, service capacity, and the challenges of the vehicle routing problem. This expanded approach considers not only transport between multiple sources and destinations, but also optimises vehicle routes, to minimise costs and travel times. This is a problem that goes beyond product distribution, being present in various sectors, highlighting its importance in optimising all kinds of logistics processes.

Different methodologies have been developed and adopted to solve problems related to FLP and LIP. The following table 3.1 presents a classification of the literature analysed, summarising it according to the solution techniques used and the parameters and decision variables used.

Table 3.1: Literature Review and Research Contributions

									Decisions			Objective function		Formulation Approach	
Article	Year	Location allocation	Facility capacity	Marketplace	Inventory Level	Lead time	SLA	Real Case	Facility location	Facility Allocation	Volume Transported	Minimise cost	Other objective	Formulation Type	Solution Method
Jayaraman	1998	✓	✓			✓			✓		✓	✓		MILP	Exact Optimisation
Erlebacher and Meller	2000	✓	✓					✓	✓	✓	✓	✓		MINLP	Heuristic
Shen et al.	2003	✓			✓	✓	✓	✓	✓	✓		✓		MINLP	Lagrangian Relaxation
Ozsen et al.	2006	✓	✓		✓	✓	✓		✓	✓		✓		SPLS	Lagrangian Relaxation
Bhatti and Gill	2007	✓								✓			✓	MILP	Heuristic
Miranda and Garrido	2008	✓	✓		✓	✓	✓		✓	✓	✓	✓		MINLP	Lagrangian Relaxation
Liao and Guo	2008	✓	✓							✓			✓	MILP	Genetic Algorithm
Farahani et al.	2015	✓			✓	✓	✓		✓	✓		✓		MILP	Exact Optimisation
Vahdani et al.	2017	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		MINLP	Genetic Algorithm
Tang et al.	2020	✓	✓					✓	✓	✓		✓		MILP	Exact Optimisation
Chandra et al.	2021	✓	✓					✓	✓	✓	✓	✓		MINLP	Meta-heuristic
Gert Wolf	2022	✓	✓						✓	✓		✓		MILP	Exact Optimisation
This thesis	2024	✓		✓		✓	✓	✓	✓	✓	✓	✓		MILP	Exact Optimisation

3.2 Order fulfillment

The SC infrastructure has a major impact on order fulfilment, which includes everything from the way retailers manage their inventory ordering systems, establish business rules for order fulfilment and guarantee last-mile delivery [62]. Order fulfillment includes stages such as order processing, inventory management, picking, packing, transport and delivery [28]. In this way, the process of fulfilling a customer's order can be divided into four stages: order processing, planning, execution and delivery, with each stage interacting with the previous one, by using the output of the latter and sending feedback to the next, collaborating together, in order to achieve customer satisfaction, considering costs and delivery time [63].

The increase in online shopping, driven mainly by millennials who value speed and low delivery costs, requires retailers to adjust their distribution strategies to meet consumer expectations. These consumers' sensitivity to delivery time and cost, forces companies to optimise their order fulfilment processes, ensuring fast and cost-effective delivery [64]. The main issues of order fulfillment involve how to deliver products from the premises to meet online customer demand, and how many products to keep in stock, to satisfy face-to-face requests. As such, the design of the distribution network significantly impacts order fulfillment performance, and plays a crucial role in controlling business costs [65].

Optimising the order fulfilment process, in other words, improving delivery times and reducing costs, while increasing customer satisfaction, can be achieved by understanding lead times in such a way as to find the optimum location for DCs, so that products are always available and can be delivered quickly. Integrated planning of facility location and capacity sizing, allows companies to achieve adequate order fulfilment, especially when significant variations in demand are expected over time, enabling them to adjust quickly to market changes, and maintain optimum service levels [66] [67].

By applying FLP in a model that contemplates fulfilment networks, it is possible to determine the ideal allocation of orders, allowing companies to ensure that orders are processed efficiently, and executed in an agile and economical manner, as it optimises the location of facilities, resulting in more efficient operations and reduced operating costs. In highly competitive markets such as e-commerce, the ability to reduce delivery times can be a decisive factor in customer satisfaction and loyalty. In addition, a well-localised fulfilment network allows for a faster response to market demands, adjusting better to seasonal variations and peaks in demand.

3.3 Literature Review Summary and Discussion

As can be seen in the table 3.1, there is a gap in the literature, when it comes to articles that have studied order fulfillment problems in the context of marketplaces. In this way, the aim of this study is to fill this gap, by integrating marketplace concepts into FLP study problems.

Although the LIP's importance is clear and recognised in the literature, the additional complexity introduced to the problem by the integration of location and inventory decisions makes solving the problem significantly more challenging. In the context of the real problem being addressed, focusing on the FLP will allow a more manageable analysis, enabling strategic location decisions to be made. In addition, many inventory-related operational decisions, such as service levels, lead times and reorder levels, could be addressed in a further analysis to the case study, once the optimal DC locations have been defined. This phased approach will allow the problem to be solved more efficiently, reducing complexity without overlooking the importance of inventory decisions.

This study thus aims to offer a detailed and practical analysis of a real case of internationalisation of a retail company, by integrating marketplace concepts into the FLP.

Following the literature review, which covered the different decisions and problems addressed, this study will focus on location-allocation problem, integrating the marketplace, the delivery times it requires, and Service Level Agreement (SLA). The decision variables will include the location of the facilities, the allocation of customers to the facilities and the volume transported. The objective function will be formulated to minimise costs, using an optimisation model based on MILP.

4

Methodology

Contents

This chapter explains the approach and methodology used to tackle the problem at hand. Section 4.1 explains the structure and design of the model used to analyse the problem. Section 4.2 details the mathematical model, and tools applied to develop the model.

4.1 Problem Representation

The network of the problem to be addressed involves a set of warehouses that provide a set of products to the DCs, which will then be ready to fulfill the product at multiple demand points, the final clients. This problem has three main costs that trade-off with each other: the cost of transporting the products, the cost of having a DC open, and the cost associated with the services that the marketplace offers. Having this said, it will answer the questions of how many hubs to open, where these hubs will be located, and how the flow of products along the system will work.

The problem, therefore, is based on determining how many DCs to locate, where to locate them, which search nodes to assign to each DC, in order to minimise the total costs of location and dispatch, while ensuring a specified service level.

Before presenting the model, it is important to note that it is developed to solve two different fulfillment options, which differ in terms of intermediate facilities, and floes (represented by the variables used), as shown in 4.1:

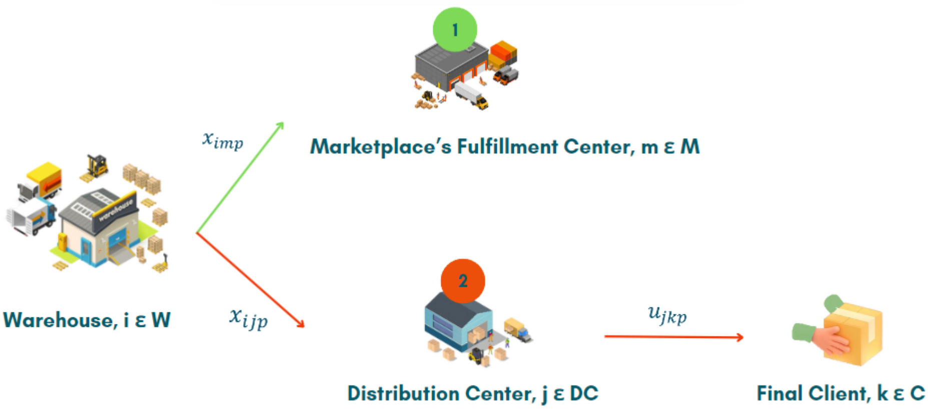

Figure 4.1: Problem Representation

The figure illustrates a multi-tier logistics network for distributing products from a warehouse to final clients, via an online marketplace, indicating two different routes products can take through the network. The logistics network starts with a warehouse, from where the products can:

1. be sent directly to a FC operated by the marketplace, which then handles distribution to end customers. This scenario takes advantage of the marketplace's logistics network and its capabilities for efficient order fulfilment.

2. be sent to an intermediate DC, which acts as a temporary storage point, before being dispatched to the end customers. This scenario requires the company to manage its own logistics operations, and sales are made through the marketplace, but not by the marketplace.

4.2 Mathematical Formulation

In this Subchapter, the mathematical formulation of the optimisation model is presented.

The notation used in the model, as well as it description, are presented in tables 4.1, 4.2, 4.4, and 4.3.

Table 4.1: Sets

Sets	Description
C	Set of nodes representing the potential Clients
DC	Set of nodes representing the potential Distribution Centres
M	Set of nodes representing the Marketplace's Fulfillment Centres
P	Set representing the Products Families
W	Set of nodes representing the Warehouses

Table 4.2: Parameters

Parameters	Description
$adjd_{jk}$	Adjusted distance between Distribution Centre *j* and Client *k* (km)
$bigM$	A sufficiently large number
ckm	Cost per kilometer, for the direct shipment between the Distribution Centre and the final Client (€)
$comm_p$	Marketplace's Commission Fee for Product *p* (€)
dem_{kp}	Demand of Client *k* for Product *p* ($units$)
dcf	The factor used to adjust the distance, reflecting actual traveling conditions
exp_{jp}	Expedition Cost at Distribution Centre *j* for Product *p* (€)
fee_p	Marketplace's Fee regarding the Fulfillment Service for Product *p* (€)
$ifee$	Insurance fee associated with the transportation of goods from Distribution Centre *j* to Client *k* (€)
$irate$	Insurance rate applied to the value of the goods transported from the Warehouse to the Distribution Centre (%)
max	Maximum number of units per trip, for the direct transport from the Distribution Centre to the final Client ($units$)
pc	Pallet capacity per truck, in order to get a Full Truck Load (FTL) ($pallets$)
pv	Pallet volume (m^3)
pp_p	Product *p* price (€)
$recept_{jp}$	Reception Cost at Distribution Centre *j* for Product *p* (€)
$stor_{jp}$	Storage cost of Distribution Centre *j* for Product *p* (€)
sl	Desired Service Level (%)
tc_{idN}	Cost of transport from Warehouse *i* to Destination $d \in \{DC,\ M\}$, given the number of pallets, $Npallets_{idt}$ (€)
tw	Time window for the delivery (h)
vel	Average Speed (km/h)
vol_p	Volume of Product *p* (m^3)
zip	Zip code's coordinates ($lat, long$)
$zipC_k$	Customer's *k* zip codes
$zipDC_j$	Distribution Centres' *j* zip codes
$zipFC_m$	Marketplace's FC *m* zip codes

Table 4.3: Auxiliary Variables

Variables	Description
$addp_{id}$	Number of additional pallets that do not fill a complete trip from Warehouse *i* to Destination $d \in \{DC,\ M\}$
$commc_{jkp}$	Total Cost of the commission associated with the demand (€)
$ctrip_{id}$	Number of complete trips required for the transport from Warehouse *i* to Destination $d \in \{DC,\ M\}$, based on pallet capacity per truck
$feec_{imp}$	Total cost of using the Fulfillment Service for the demand (€)
$FTLc_{id}$	Total transportation cost for a FTL between Warehouse *i* and Destination $d \in \{DC,\ M\}$ (€)
$LTLc_{id}$	Total transportation cost for additional pallets that do not fill a complete truck Less than Truck Load (LTL) between Warehouse *i* and Destination $d \in \{DC,\ M\}$ (€)
$ins1_{id}$	Insurance cost for the transport of goods from Warehouse *i* to Destination $d \in \{DC,\ M\}$, based on the value of the goods and the insurance rate (€)
$ins2_{jk}$	Insurance cost for the transport of goods from Distribution Centre *j* to Client *k*, based on the insurance fee (€)
N_{id}	Number of pallets required to transport goods from Warehouse *i* to Destination $d \in \{DC,\ M\}$, based on the total volume of the products
$ntrip_{jk}$	Total number of trips required to transport products from Distribution Centre *j* to Client *k*, based on the maximum capacity of units per trip
opc_{ijkp}	Total Operating Cost associated with receiving and shipping the products (€)
$ship1_{id}$	Total shipment cost from Warehouse *i* to Destination $d \in \{DC,\ M\}$, combining complete trips, additional pallets, and insurance (€)
$ship2_{jk}$	Total shipment cost from Distribution Centre *j* to Client *k*, based on the adjusted distance and the number of trips (€)
stc_{jp}	Total Storage Costs associated with the demand (€)
vog_{id}	Total value of the goods transported from Warehouse *i* to Destination $d \in \{DC,\ M\}$ (€)

Table 4.4: Decision Variables

Variables	Description
a_{imp}	Total quantity of Product *p* sent from Warehouse *i* to Marketplace's Fulfillment Centre *m* (Flow, in $units$)
I_{jp}	Inventory level of Product *p* at Distribution Centre *j* ($units$)
w_{jkp}	Binary variable that indicates whether Distribution Centre *j* is assigned to satisfy the demand of Product *p* for Client *k* (1 if yes, 0 otherwise)
x_{ijp}	Total quantity of Product *p* sent from Warehouse *i* to Distribution Centre *j* (Flow, in $units$)
u_{jkp}	Total quantity of Product *p* sent from Distribution Centre *j* to Client *k* (Flow, in $units$)
z_j	Binary variable that indicates whether Distribution Centre *j* is in operation (1 if yes, 0 otherwise)

Given the different scenarios, an objective function is needed to define each of the scenarios. Considering the notation above, the objective function model of scenario 1 is formulated as follows, on equation 4.1:

$$Min\ (ship1_{im} + feec_{imp}) \tag{4.1}$$

In this scenario, the objective function corresponds to minimise the transport costs associated with shipping from the Warehouse *i* to the Marketplace's FCs, *m*, and the fee associated with using the Marketplace's fulfilment services.

The transportation cost is presented in equation 4.2, and refers to the costs between the Warehouse *i* and the Marketplace's FCs *m*.

$$ship1_{im} = \sum_{i \in W} \sum_{m \in M} (FTLc_{im} + LTLc_{im} + ins1_{im}) \tag{4.2}$$

The cost of the Marketplace's fee for using the Fulfillment Service for Product *p*, is given by the following equation 4.3:

$$feec_{imp} = \sum_{i \in W} \sum_{m \in M} \sum_{p \in P} (fee_p \times a_{imp}) \tag{4.3}$$

For scenario 2, the objective function is described by equation 4.4.

$$Min\ (ship1_{ij} + ship2_{jk} + stc_{jp} + opc_{ijkp} + commc_{jkp}) \tag{4.4}$$

The objective function corresponds to minimise total costs. It includes transport costs, and all the variable costs of operating the distribution centres, including storage, expedition and reception costs, and the commission fee associated with using the Marketplace. The different terms of the objective function are shown in equations 4.5 to 4.9.

The transportation cost is presented in equation 4.5, and refers to the costs between the Warehouse *i* and DC *j*.

$$ship1_{ij} = \sum_{i \in W} \sum_{j \in DC} (FTLc_{ij} + LTLc_{ij} + ins1_{ij}) \tag{4.5}$$

The Transportation Cost between the DC *j* and the Client *k* can be given by the equation 4.6:

$$ship2_{jk} = \sum_{j \in DC} \sum_{k \in C} ((adjd_{jk} \times ckm \times ntrip_{jk}) + ins2_{jk}) \tag{4.6}$$

The Storage cost of the Product *p* at the DC *j* is given by equation 4.7:

$$stc_{jp} = \sum_{j \in DC} \sum_{p \in P} (stor_{jp} \times I_{jp}) \tag{4.7}$$

In addition to the cost of storing the products, there are other operating costs, such as the costs of receiving and shipping the products. These costs can be seen in the equation 4.8:

$$opc_{ijkp} = \sum_{j \in DC} \sum_{p \in P} (\sum_{i \in W} (recept_{jp} \times x_{ijp}) + \sum_{k \in C} (exp_{jp} \times u_{jkp})) \tag{4.8}$$

The cost of using the Marketplace's customers, in other words, the cost of selling the products through the Marketplace, is represented through a commision by product, and can be represented by equation 4.9.

$$commc_{jkp} = \sum_{j \in DC} \sum_{k \in C} \sum_{p \in P} comm_p \times u_{jkp} \tag{4.9}$$

To obtain the main equations, it was necessary to do some intermediate calculations, described from equation 4.10 to 4.16.

Given that the transport data from the Warehouse, *i* to the Destination, $d \in \{DC,\ M\}$, depends on the number of pallets transported and the zip code of the destination, it is necessary to convert the number of product units into the number of pallets to be shipped. Thus, the model converts the quantity of products, in units, to a number of pallets, taking into account the average volume of the products, vol_p, and the fixed capacity of a pallet, pv. This process is essential for optimising transport efficiency, since the number of pallets determines the number of journeys required and, consequently, the cost of transport.

The first equation (4.10) calculates the total number of pallets to be transported from Warehouse, *i*, to Destination, $d \in \{DC,\ M\}$, which can be the DC, ***DC***, or the FC of the Marketplace, ***M***. The number of pallets is obtained by adding up the total volume of all the products transported, and dividing by the capacity of a pallet:

$$N_{id} = \frac{\sum_{p\ inP}(x_{idp} \times vol_p)}{pv} \quad \forall i \in W,\ \ \forall d \in \{DC,\ M\} \tag{4.10}$$

Once the number of pallets is known, it is necessary to determine how many complete journeys are needed to transport these pallets. The maximum capacity of a truck for a FTL is 33 pallets [68]. Therefore, to calculate the number of full trips, equation 4.11 divides the total number of pallets, N_{id}, by the maximum pallet capacity per trip, pc (in this case, 33 pallets):

$$ctrip_{id} = \frac{N_{id}}{pc} \quad \forall i \in W,\ \ \forall d \in \{DC,\ M\} \tag{4.11}$$

This equation shows the number of full trucks a given demand corresponds to. The next step is to calculate the total cost of transport for a FTL. Equation 4.12 uses the number of journeys with a full truck, considering the cost of a journey with a full load of 33 pallets ($pc\ =\ 33$), from Warehouse *i*, to Destination, $d \in \{DC,\ M\}$, whether this is the DC or the FC of the Marketplace, as shown below:

$$FTLc_{id} = ctrip_{id} \times tc_{idN} \ \text{ with } \ N = pc, \quad \forall i \in W,\ \ \forall d \in \{DC,\ M\} \tag{4.12}$$

On the other hand, there are still some pallets left over that are not enough to completely fill a truck. These additional pallets, known as LTL, do not reach the maximum capacity of 33 pallets, and therefore need to be dealt with separately. Equation 4.13 calculates the number of remaining pallets, which are not being accounted for in the complete journeys.

$$addp_{id} = N_{id} - (ctrip_{id} \times pc) \quad \forall i \in W, \ \ \forall d \in \{DC, \ M\} \tag{4.13}$$

This equation is needed to identify the number of pallets that do not complete a full journey. After determining the number of additional pallets, the transport cost for these pallets is calculated using equation 4.14. This calculation is given by the cost of transport from Warehouse *i*, to Destination, $d \in \{DC, \ M\}$, applied to the number of additional pallets, which represents the pallets transported on incomplete journeys:

$$LTLc_{id} = tc_{idN} \text{ with } N = addp_{id}, \quad \forall i \in W, \ \ \forall d \in \{DC, \ M\} \tag{4.14}$$

Bearing in mind that transport insurance cost, from the Warehouse *i*, to any Destination, $d \in \{DC, \ M\}$, is given by the value of the total goods to be transported, it is necessary to first calculate the value of the commodities (4.15) in order to then, calculate the value of the insurance (4.16):

$$vog_{id} = \sum_{p \in P} (x_{idp} \times pp_p) \quad \forall i \in W, \ \ \forall d \in \{DC, \ M\} \tag{4.15}$$

$$ins1_{id} = vog_{id} \times irate \quad \forall i \in W, \ \ \forall d \in \{DC, \ M\} \tag{4.16}$$

Once the costs for complete journeys and for additional pallets have been calculated, the next step is to add up these costs and add the cost of insurance, in order to obtain the total cost of transport, from Warehouse *i*, to Destination, $d \in \{DC, \ M\}$. The total cost of transport is represented by equation 4.17.

$$ship1_{id} = \sum_{i \in W} \sum_{d \in \{DC, M\}} (FTLc_{id} + LTLc_{id} + ins1_{id}) \tag{4.17}$$

This is a generic formula, which covers the various destinations to which goods can leave from the Warehouse, depending on the scenario being used. Since the products leave from the same place, the warehouse, differing only in their destination, $d \in \{DC, \ M\}$, either the DC or the FC of the Marketplace, the calculations of this journey are based on the same approach.

Given that the value of the transport costs between the DCs and the end customers is given by km, and the data on the latitude and longitude of the DCs and the end customer is available, it is necessary to calculate the distance between two points on the surface of the Earth. To do this, the Haversine formula is used. This formula 4.18, takes into account the curvature of the planet, offering a more accurate measure of geodesic distance.

$$haversine_{jk} = 2r \cdot \arcsin\left(\sqrt{\sin^2\left(\frac{\Delta\varphi}{2}\right) + \cos\varphi_1 \cdot \cos\varphi_2 \cdot \sin^2\left(\frac{\Delta\lambda}{2}\right)}\right) \quad \forall j \in DC, \ \forall k \in C \qquad (4.18)$$

where:

- r is the radius of the Earth (approximately 6371 km)
- φ_1 and φ_2 are the latitudes of the two points in radians (Distribution Centre *j* and Client *k*, respectively)
- λ_1 and λ_2 are the longitudes of the two points in radians (Distribution Centre *j* and Client *k*, respectively)
- $\Delta\varphi = \varphi_2 - \varphi_1$ is the difference between the latitudes of the two points
- $\Delta\lambda = \lambda_2 - \lambda_1$ is the difference between the longitudes of the two points.

Since the Haversine formula only accounts for straight-line distances, the Distance Conversion Factor, dcf, is used in order to adjust the calculated distances between two geographical points, so as to reflect actual traveling conditions. This factor is used in order to obtain a more realistic estimate of the journey distance, as it incorporates variables such as traffic, bends, climbs, descents and detours, which can significantly increase the distance travelled compared to a straight line. This adjusted distance, whose calculation is represented in equation 4.19, is then used to accurately calculate transport costs, ensuring that the model faithfully reflects real transport costs and times.

$$adjd_{jk} = haversine_{jk} \times dcf \quad \forall j \in DC, \ \forall k \in C \qquad (4.19)$$

As the demand is being analysed over a relatively long period of time, the reality of the logistics process requires that products be delivered in several orders rather than a single journey. To reflect this reality, it was necessary to limit the quantity of products that can be sent on each journey, using max, which represents the maximum capacity of units per journey, from the DC *j* to the end client *k*, in order to space demand deliveries over this period of time. Equation 4.20 calculates the number of journeys required to transport all the products.

$$ntrip_{jk} = \frac{\sum_{p \in P} u_{jkp}}{max} \quad \forall j \in DC, \ \forall k \in C \qquad (4.20)$$

In the case of transport between the DC and the end customer, insurance is a fee charged for each journey. Thus, equation 4.21 calculates the total cost of insurance, associated with the number of journeys.

$$ins2_{jk} = ntrip_{jk} \times ifee \quad \forall j \in DC, \ \forall k \in C \qquad (4.21)$$

Equation 4.22 calculates the total transport cost between DC *j* and the end customer *k*, including both the transport cost and the insurance cost.

$$ship2_{jk} = \sum_{j \in DC} \sum_{k \in C} ((adjd_{jk} \times ckm \times ntrip_{jk}) + ins2_{jk}) \tag{4.22}$$

Constraints for the model

Scenario 1 only needs a restriction that ensures that the total demand is met, and sent to the Marketplace's FCs, and is given by constraints 4.23.

$$\sum_{i \in W} x_{imp} \geq dem_{kp} \quad \forall m \in M, \quad \forall k \in C, \quad \forall p \in P \tag{4.23}$$

Scenario 2 constraints are defined from equation 4.24 to 4.33.

The conservation of flow constraints (4.24) ensure that the quantity of products entering a DC must be equal to the sum of the quantity sent to customers and the stock remaining in the distribution centre itself.

$$\sum_{i \in W} x_{ijp} = \sum_{k \in C} u_{jkp} + I_{jp}, \quad \forall j \in DC, \, \forall p \in P \tag{4.24}$$

Constraints 4.25 ensure that each customer's demand for each product is satisfied by the quantity dispatched from the DC.

$$\sum_{j \in DC} u_{jkp} \geq dem_{kp}, \quad \forall k \in C, \, \forall p \in P \tag{4.25}$$

Constraint 4.26 ensures that at least one DC is open.

$$\sum_{j \in DC} z_j \geq 1 \tag{4.26}$$

Constraints 4.27 and 4.28 ensure that DCs can only be used to ship products if they are open. This is controlled by the binary variable z_j.

$$x_{ijp} \leq bigM \times z_j, \quad \forall i \in W, \, \forall j \in DC, \, \forall p \in P \tag{4.27}$$

$$u_{jkp} \leq bigM \times z_j, \quad \forall j \in DC, \, \forall k \in C, \, \forall p \in P \tag{4.28}$$

Constraints 4.29 ensure that the respective DC can only serve a customer if it is in operation.

$$w_{jkp} \leq z_j \qquad \forall j \in DC, \;\; \forall k \in C, \;\; \forall p \in P \tag{4.29}$$

Constraints 4.30 ensures that each customer is allocated to only one DC, avoiding multiple allocations.

$$\sum_{j \in DC} w_{jkp} = 1 \qquad \forall k \in C, \ \ \forall p \in P \tag{4.30}$$

Constraints 4.31 ensure that the flow of products from the DC *j* to Customer *k* only occurs if the customer is allocated to the DC.

$$u_{jkp} \leq bigM \times w_{jkp}, \quad \forall j \in DC, \, \forall k \in C, \, \forall p \in P \tag{4.31}$$

The delivery time constraints (4.32) guarantee that the time taken to transport the products from the DCs to the customers does not exceed the limited time window, tw, ensuring that the products are delivered on time.

$$\frac{adjd_{jk}}{vel} \times w_{jkp} \leq tw, \quad \forall j \in DC, \, \forall k \in C, \, \forall p \in P \tag{4.32}$$

The service level agreement constraint (4.33) ensures that customer demand is met at a specified minimum level.

$$dem_{kp} \times sl \leq \sum_{i \in W} \sum_{j \in DC} x_{ijp}, \quad \forall k \in C, \, \forall p \in P \tag{4.33}$$

Finally, the last two constraints, 4.34 and 4.35 are variable domain constraints.

$$w_{jkp}, \, z_j \ \ \in \{0, 1\} \ \ \forall j \in DC, \, \forall k \in C, \, \forall p \in P \tag{4.34}$$

$$a_{imp}, \, I_{jp}, \, x_{ijp}, \, u_{jkp} \ \geq 0 \tag{4.35}$$

In this study, Python was used, alongside the Gurobi solver, to solve the optimization problems. Python served as the programming environment to model, while Gurobi was used to find the best possible solutions efficiently.

5

Case Study

Contents

This chapter presents the case study used to validate and test the developed model. Starting in the Subchapter 5.1, describes Worten's profile and trajectory, which led to the current national context and the scenario of its internationalisation process in Spain. Considering Amazon as the most attractive marketplace and the definitive choice for Worten's entry, the Supchapter 5.2 deals with the history of Amazon, from its beginnings to its current position as the largest online retailer. In this segment, the various options available to sellers interested in joining Amazon are detailed. After the services offered by Amazon have been explained, the scenarios that this thesis will explore are described in Subchapter 5.3, also covering the assumptions involved in creating and modelling the data.

5.1 Worten

This Master's Dissertation was developed through a partnership with Worten and Instituto Superior Técnico, and the topic was developed and worked on with Worten's International Distribution and Transport Department.

Worten is a Portuguese company specialised in electronics retail, selling all kinds of electronic products, having recently expanded into the beauty, health & baby sector. Worten belongs to one of Portugal's largest groups, Sonae, a multinational that manages a diversified portfolio of businesses in the areas of retail, financial services, technology, real estate and telecommunications, operating in more than 62 countries.

Headquartered in Carnaxide, Portugal, Worten opened its first shop in Chaves on 12 March 1996, and today has more than 240 shops throughout the Iberian Peninsula. The national market leader in the areas of household appliances, consumer electronics and entertainment, Worten began its internationalisation in 2009, with the acquisition of the Boulanger chain of shops in Spain.

In 2018, Worten started investing in e-business, launching its marketplace, which includes an online shop, where any customer can access information on an entire range of products, and make a purchase, offering more than 6 million items. With the development of the digital market, it can offer customers a new shopping experience, by making it easier to search for, evaluate and buy products. Customers using the online platform can choose to have their orders delivered to their home, or collected from any Worten shop, free of charge, using the Click and Collect service.

For 20 years, Worten has continually distinguished itself, both in terms of operational efficiency and in terms of creating value for its customers and partners, winning various awards, from Consumer Choice to Product of the Year and Trusted Brand [69].

Over the last years, Worten has invested heavily in developing its own brand products (Becken, Kubo, Kunft, Goodis, among others). The sale of these products is more profitable for Worten, as it is a direct sale, with no loss of margin, where Worten has total control over prices, as well as the flexibility to expand and adapt to market trends. In addition, Worten has also invested heavily in its marketplace, and in the possibility of offering customers ”tudo e mais não sei o quê” (translated to english ”everything and more”), which is its ultimate goal, and for which it has been putting a lot of effort.

Worten, in electronics retail, strengthened its market leadership position, continuing to expand the value proposition of its digital marketplace and growing in the area of the adjacent services it offers. Worten’s total turnover reached 1.3 billion euros in 2023, an increase of 4.9% over last year, and an increase in Like for Like of 4.3%. The marketplace continued to be an important positive contributor, with sales increasing by 6% year-on-year and representing 16% of Worten’s total sales in 2023. In terms of investment, Worten allocated €59M essentially to advance its digital transformation programme and open 18 new own shops, including 14 iServices shops [70].

As already mentioned, Worten began its internationalisation process in 2009, and operates currently in Spain with First-Party Sellers (1P) and Third-Party Sellers (3P) operations. It interacts directly with the end consumer, in B2C operations, through its official website in the country, and through B2B sales, either through Amazon’s marketplace, petrol stations, or other retailers.

In 2019, Worten joined Amazon in Spain, using Amazon as a B2C channel, to reach the end customer, with Worten ensuring the fulfillment of the products. Due to the lead time expected by Amazon, which Worten was unable to satisfy in a direct flow from Portugal, Worten ended up changing its fulfillment strategy, taking leverage of Amazon’s Fulfillment Services. In this programme, Worten manages the stock, delivering the units to Amazon’s logistics warehouses, and Amazon is in charge of the entire fulfillment process up to delivery to the end customer (including returns), with the sale being operated on a B2B basis.

Given the investment in its own-brand products, and the profitability associated with them as they are not subject to the double marginalisation effect, Worten’s internationalisation strategy is focused on introducing these products to European markets. The globalisation of markets and the limited possibilities for growth in national markets, have led more and more retailers to internationalise their operations [71]. As such, with the aim of achieving rapid growth over the next few years, Worten’s strategy is driven by the internationalisation of its own brand, expanding its presence throughout Europe, beyond Portugal and Spain, as a way to capture more value for the company. In this sense, joining Amazon is a strategic priority, given the opportunity it offers to reach a wider and more diversified audience. The scale of Amazon’s reach, combined with its leading position as a global marketplace, makes its presence on this platform a priority, compared to other smaller marketplaces.

In order to achieve its goal of rapid sales growth over the next few years, Worten’s choice to expand and internationalise its private labels is through Amazon, as it is based on the need to achieve greater operational scale. Amazon, due to its size, allows Worten to maximise operating costs, reducing the cost per item shipped and increasing the profit margin, while at the same time achieving scalability in terms of sales.

Thus, as it expands its horizons and enters other marketplaces, Worten faces a new decision: how to supply customers, whether to use the e-fulfillers offered by Amazon, or to maintain total control over the process. As the new markets are even further away from the point of origin, a comparative analysis will be necessary, using sensitivity scenarios, depending on the type of sales expression, based on the costs Worten will incur, the lead time it can offer customers, and Amazon's requirements.

In this light, the developed methodology in this thesis will help Worten decide on how to internationalise its private labels, through Amazon in Germany and France, by analysing different strategies and approaches, as a means of achieving this goal. By entering the European market through Amazon, Worten has the opportunity to expand its global presence, reinforcing its commitment to achieving its ambitious growth targets. By establishing its presence on the market's leading platform, Worten is consolidating its position in Europe as well. In this way, the study focuses on finding the break-even point at which it is feasible for Worten to handle the entire process without having to outsource any part of it, minimising logistics costs.

5.2 Amazon

The strategy of many companies, in order to remain competitive and achieve their growth objectives, is to join marketplaces, such as Amazon, which is already well developed and internationally recognised for the number of services it offers, as well as its well-defined structure, reliability and convenience.

Amazon is the world's largest online retailer and web service provider. Its goal is to revolutionise traditional shopping by becoming an all-in-one store that offers an infinite variety of products, becoming a place where customers can find and discover everything they wish to buy online.

Founded in 1994 by Jeff Bezos as an online bookselling company, with the aim of revolutionising the purchase of books over the internet. Amazon's initial strategy relied on minimal stock and partnerships with wholesalers to fulfil customer orders. As the company grew, it expanded its selection of products and services, evolving into an Internet-based company that focuses on providing e-commerce services, cloud computing, digital streaming and artificial intelligence (AI) [72].Headquartered in Seattle, Amazon has established distribution centres and built infrastructure to support growing demand and ensure faster order fulfilment.

Amazon revolutionised logistics to suit the needs of e-commerce, redesigned warehouses and designed cutting-edge software to manage inventory and better serve its customers, both in terms of speed and reliability. Amazon's ability to efficiently meet customer demands allowed it to expand into new product categories and introduce the Prime programme in 2005, offering fast shipping at no extra cost [5].

As Amazon continued to grow, it opened up to third-party sellers, which, as of 2022, accounted for almost 60% of the sales. As such, Amazon houses now, both its own retailers, 1P, which are items purchased directly from suppliers and sold by Amazon, as well as offerings from 3P, who use Amazon's marketplace services. Amazon therefore offers a wide range of products, often from several sellers, as it acts in a dual role: as a retailer and logistics service provider, fulfilling rapidly in more than 100 countries [72] [73].

The attractive way in which Amazon allows consumers to shop, offering more than 350 million products, allowed a significant shift away from traditional offline shopping experiences. In 2023, Amazon accounted for a 37.6% share of e-commerce spending in the US, a value that is expected to increase by 11.7% in 2024 [74]. Amazon's sales speed is impressive, with transactions totalling 4722 dollars per second, which translates into an hourly average of over 17 million dollars. Amazon's sales in Europe represent around 24% of Amazon's global sales. In 2021 there was a 16% increase in Amazon's European revenue, driven by the presence of more than 1.4 million European Amazon sellers, who contributed to this high sales volume [74].

As can be seen from the data presented, Amazon has become an unarguable leader in online commerce around the world, offering a wide variety of products. As such, it is continually reaffirming its status as a global retail powerhouse, dominating the market, offering very lucrative opportunities to sellers and revolutionising the way people shop around the world. A good indicator of this achievement on Amazon's part is reflected in the customers' search behaviour, which in 2018, in the US, the shift towards online marketplaces was so evident that more than 40% of searches were starting on Amazon, instead of search engines like Google [75]. Thus, the desire for brands' internationalisation strategy to go through Amazon is justified, as it can increase a brand's visibility and exposure to a vast customer base, as it allows sellers to reach an audience they would not be able to reach through standalone websites. As Amazon operates in several countries, it allows sellers to expand their reach beyond their own country and access international customers, which translates into more opportunities for growth and increased sales potential. Brands can then take advantage of the association with Amazon, which is known for its recognition as reliable, inspiring confidence in customers [76] [77].

In the following Subchapter, there are some descriptions of the types of scenarios that companies can adopt when entering Amazon, since they will be key to influencing the decision.

5.2.1 Amazon Business Platforms

When joining Amazon, companies can choose how they want to join, whether as a seller or a vendor. For different types of products, depending on how they are supplied, it may be more worthwhile for a digital platform to act as a seller, or as a marketplace. For some types of products, it may be more efficient for the platform to supply them, as for other products, for third-party sellers, while still being able to offer all of them in the same place, offering one-stop shopping benefits for consumers.

The main difference between an Amazon Seller and an Amazon Vendor lies in the relationship they have with Amazon: while a Seller functions as an individual business that sells products directly to Amazon customers via the marketplace platform, a Vendor is a manufacturer that sells its products to Amazon at a wholesale price. When a brand becomes an Amazon merchant, they are given two platforms. Depending on the scope and objectives of the business, the company can choose the one that best suits their business [78].

Amazon Seller Central (ASC) is a primary hub for sellers that allows companies to sell their products through Amazon. As such, it is a centralised dashboard that allows any seller to start and expand their business on Amazon, by helping them monitor incoming orders, streamline inventory management and execute shipments promptly. As for other logistical aspects, such as shipping, customer service, and returns, the company can either assume them or delegate them to Amazon. The figure 5.1 below represents this business model.

Figure 5.1: Amazon Seller Central

On the other hand, there is Amazon Vendor Central (AVC). AVC is a web-based platform that allows manufacturers and distributors to sell their products to Amazon: Amazon's purchasing team buys the products and resells them to customers on the platform. It is a platform designed for large companies with an extensive catalog of products. These companies are called 1P sellers or Amazon vendors. With this modality, the company becomes Amazon's supplier and sells its products to Amazon, with Amazon selling, promoting and managing the logistics of delivery to the end consumer. With this option, the products appear labelled on the website as "Sold by Amazon", which is usually a guarantee of trust for many consumers. AVC is an invite-only portal where participating businesses can monitor their product inventory, add new products, receive and acknowledge purchase orders, and gain a general overview of their Amazon account health. Following the placement of a purchase order with the vendor or distributor, the goods must make their way to an Amazon fulfillment centre. Whether Amazon picks up the parcel or the supplier dispatches it, is defined during the initial contract negotiations. The figure 5.2 below represents this business model.

Figure 5.2: Amazon Vendor Central

Using AVC essentially means that Amazon is the retailer that is buying products in large quantities to list on its marketplace. In this case, the seller is not transacting directly with the consumer or dealing with customer service, and it's a slightly more hands-off process [79]. Whereas, through the ASC platform, the Seller has total control over the prices of its products, since it sells them directly to customers, with Amazon acting only as a storefront; through the AVC platform, once the products have been sold to Amazon, it controls the prices. By controlling prices, sellers have increased margins compared to Vendors.

While Sellers have a lot of control over the products and all the operations that concern them, they also have a lot of logistical responsibilities, which include inventory management, pricing, and customer service. Vendors, on the other hand, can concentrate purely on completing orders, with Amazon taking care of all aspects of the sales process, from pricing and listing to shipping and customer support. For Sellers, having to deal with customer service can be quite challenging, especially when dealing with large volumes of orders.

In short, there can be concluded that these two platforms are quite different, offering different programs and tools. It is therefore up to the companies to decide, taking into account their long-term objectives, strategy and business model, which platform is the best fit [78] [80] [79].

Once chosen the Business Model and Platform, it is up to the merchants, to decide which fulfillment methods to choose for their business.

5.2.2 Amazon Fulfillment Methods

When choosing the AVC program, Amazon needs to have a specific logistics infrastructure to fulfill its orders, which means that Vendors have to adopt the Fulfillment By Amazon (FBA) logistics supply plan. In this option, the seller sells, and the product is collected, packaged, and shipped by Amazon. Customer service and possible returns are also managed by Amazon.

Companies subscribing to the Amazon Seller plan, on the other hand, can decide which logistics option interests them more, Fulfillment By Merchant (FBM) or FBA. In the FBM option, sellers list, price, commercialise, prepare, and ship their products themselves, directly to the customer.

Individual products are identified either as ‘sold and shipped by Amazon’ (FBA), or ‘sold and fulfilled by the “merchant”’ (FBM).

There is an important difference between the FBA and FBM programs and, depending on what is wanted and what logistical, transport or production capacities a company has, it may be better to manage this through the FBM programme or delegate it entirely to Amazon.

5.2.2.A Fulfillment By Amazon

Amazon, being one of the largest retail platforms, selling hundreds of millions of products, require an efficient logistics system that saves costs, adds value to transactions and increases consumers’ willingness to buy online. Amazon has invested heavily in its logistics system, offering fast and reliable delivery services, such as same-day, one-hour and Sunday delivery services. Reverse logistics is also crucial for online retailers, which can provide free return labels and immediate refunds for purchases.

Fulfillment by Amazon FBA: A fulfillment method on Amazon, in which the products are shipped straight to Amazon fulfillment centres by a seller or the vendor’s supplier. Following that, Amazon maintains the inventory and takes care of all order picking, packing, and shipping; for orders fulfilled through FBA, customer service is also managed by Amazon [81].

Furthermore, if something goes wrong with an order or a delivery, Amazon provides 24/7 customer service. Thus, by utilising Amazon’s distribution network, FBA’s client companies can focus on activities other than those related to logistics and the distribution of products to their customers, which is an advantage if these activities are not core competencies for these companies.

Another important factor when choosing a fulfilment method, is the Buy Box concept. The Buy Box is the recommendation made by Amazon, which presents the customer the most convenient offer among all the offers available for that product, from sellers. These recommendations capture a large proportion of sales for each product search on Amazon. According to the Reprice Express article, because FBA increases the likelihood of winning the Buy Box, thus speeding up the sales process, around 86% of sellers end up opting for this method [82].

Amazon’s distribution service, FBA, allows companies to improve their competitiveness and increase sales, facilitating sellers, by taking care of all fulfillment steps, since the items arrive at their fulfillment centres. It’s important to note that the quantities of product to be sent to Amazon’s FCs, as well as the distribution of the products to the different FCs, according to the countries chosen by the company, is selected by Amazon’s algorithm.

5.2.2.B Fulfillment By Merchant

Fulfillment by Merchant FBM: A fulfillment method on Amazon in which a seller lists their products on the platform, but handles all aspects of storage, shipping, and customer support themselves (or through a third-party fulfillment centre) [83].

The FBM fulfillment option also offers a variation, which allows sellers to participate in Prime shipping, Seller Fulfilled Prime (SFP), increasing potential sales. Thus, if the seller commits to fulfilling orders within 2 days, at no extra cost to Prime subscribers, their products will display the Prime badge. This variation also allows the seller to be eligible competitors to participate in the Buy Box, as it gathers more of the fetures the Buy Box algorithm takes into account to decide the better offer.

5.2.2.C FBA vs. FBM

As already mentioned, FBA sellers, by transferring fulfillment operations to Amazon, are entrusting and handing over the entire order process to an infrastructure that is already established, enabling them to focus on manufacturing and developing products, advertising and sales. Although they lose control of inventory and the fulfillment process, they have far fewer responsibilities. For some sellers, being able to control the entire customer experience is very important. The fact that FBM sellers self-fulfill their merchandise, allows them to continue to control inventory levels, giving them more flexibility throughout the order fulfillment process. Unless they join the SFP plan, FBM sellers are not eligible for Prime Shipping. Products from FBA sellers, on the other hand, have the Prime badge, and can be read ”Fulfilled by Amazon”, which increases consumer confidence, as well as sales potential. The possibility of receiving the product in 1-2 days, at no additional cost, is very attractive to Prime Subscribers.

The Buy Box is a feature that can be seen on most Amazon product listing pages and allows customers to quickly buy what they are looking for. Of all the sellers eligible to win the Buy Box, only one wins. The faster, the cheaper, the more convenient and reliable the shipping and delivery to the consumer, the more chances of winning the prise, with FBA sellers having all these aspects in their favor. This award is more relevant for products belonging to more competitive categories. Through the SFP program, FBM sellers increase their chances of entering the competition for this award.

Search engine optimisation (SEO) is the process of maximizing the number of visitors to Amazon's marketplace by ensuring that the products advertised are at the top of the list of results displayed on the search page. This search algorithm favors FBA vendors, since it is in Amazon's interest to ship the inventory it has in its fulfillment Centres.

With FBM, the merchant handles customer service and the returns process, unlike FBA sellers, who have Amazon handle these operations. On the other hand, FBM sellers get a better understanding of customers' needs and preferences as they directly interact with them, whereas FBA vendors have no contact with customers.

Amazon has strict requirements on the packaging and labeling of goods before accepting them into its warehouses. Therefore, FBA sellers have to properly prepare their inventory, to ensure that everything is in accordance with Amazon's requirements, so as not to have their products rejected.

According to the study carried out on both business models, there are seven factors to take into account when choosing an execution method, which determine which method offers the most advantages to the merchant [84]. Among the various reasons for adopting another fulfilment service, the following stand out as the main ones, both characteristics related to the product itself and characteristics related to the service: the weight and size of the product, since storage fees are calculated based on these factors; the turnover rate of the products, in other words, the speed with which they are sold, since Amazon charges a fee for products that have been stored in its fulfilment centres for more than a year (Long Term Storage Fee (LTSF) [85]); the option to offer a 1-2 day delivery service to Prime subscribers, using the FBA programme, a very attractive service for the buyer, which an FBM seller can only offer if they use the SFP option; all the logistics involved in the supply process to the end customer, where the FBA programme facilitates vendors who don't have a logistics supply network set up, ensuring all operations; control over customer experience, as FBM sellers, by handling the entire process, including customer service, can control the consumer experience, unlike FBA vendors, who have no contact with the end consumer [84].

Amazon encourages sellers to adopt FBA, promising to help them expand their business and reach more customers by providing a variety of services, from faster shipping options to reliable return services. In return, sellers incur additional service fees if they adopt this fulfilment option [72].

5.3 Scenarios

The scenarios for Worten's international expansion will be described in this subchapter. Studying these options will allow to determine the scenario that best fits Worten to expand its physical distribution network at international level, enabling it to offer the customer a good, fast and efficient experience.

5.3.1 FBA

In this scenario, as described above, the items will be sent directly from Worten's Warehouse to Amazon's FCs in Europe, and will be then distributed among them, according to Amazon's algorithm, which then decides where to allocate the products. In this case, the decisions involve determining the quantity of products to be sent from the main warehouse to each marketplace's FC. The costs associated with this scenario cover transport costs from Worten's warehouse to Amazon's FCs, according to the distribution decided by Amazon's algorithm, and the cost of FBA service fees, which include storage, picking, packing and fulfilment costs.

This algorithm allocates orders to their FCs in order to optimise the distribution of products and ensure that they are positioned as close as possible to the places of greatest demand. However, it is not possible to access detailed information on how demand is allocated between the different FCs, which is a limitation for logistics planning and demand estimation, in scenarios involving the delivery of products to Amazon's FCs. In order to overcome this limitation, an attempt was made to manually allocate Amazon's FCs to the zip codes, by combining the geographical dispersion and economic representativeness of the respective zip codes, based on regional GDP. However, since the locations of the FCs are not very widely distributed, as can be seen in Figure A.1 in Appendix A, it was not feasible to allocate them in a way that took into account the wealth distributed among the regions, and the area of demand to cover. As a result, an equal distribution was assumed for all the FCs. In this way, the demand allocated to each FC, cannot be considered to reflect the actual demand distribution behaviour given by Amazon's algorithm.

5.3.2 FBM

In the physical distribution process for omni-channel retailers, intermediary stations play a significant role in fulfilling online orders and enhancing the overall customer experience. These intermediate stations are used as forward fulfilment centres, which act as facilitators for last mile delivery services, also helping with the exchange and returns process. Thus, integrating these intermediate points into the physical distribution network, allows brands to manage more quickly supplies, which will go directly to the end consumer (FBM), meeting their lead time objectives. These DCs will act as intermediary hubs between Worten's warehouse and demand nodes, facilitating efficient order processing, consolidation and distribution, optimising inventory management, reducing transport costs and enabling faster delivery.

The goal of having these intermediary stations is to optimise route planning and utilise spare capacity in the vehicles. This way, by positioning the DCs closer to the end customers, it is possible to provide a more efficient and distributed network, where the DCs act as strategic points. This integration helps minimise fulfillment costs, reducing delivery times, and improving the overall efficiency of the omni-channel fulfillment process.

In this scenario, decisions include how many DCs to open, where to locate these DCs, the quantity of products to be sent from the main warehouse to each DC, and the distribution of products from each DC, to the end customers. The costs associated with this scenario include the transport costs from Worten's warehouse, to the DCs chosen by the model to be open, the costs associated with the operations that take place in the DCs, from storage, to receiving and shipping costs, as well as the transport costs from the DCs to the assigned demand nodes, and finally, the fee associated with the marketplace being used as an intermediary in the sale of products.

Figure 5.3 is a schematic of the scenarios to be studied.

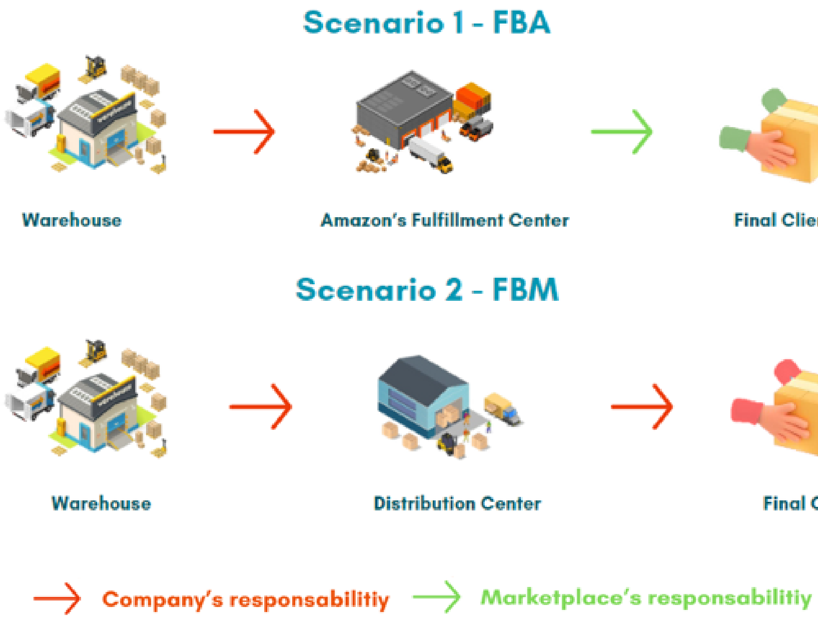

Figure 5.3: Scenarios

5.3.3 Data Collection and Assumptions

For this study, due to the fact that various specific data were not available, several assumptions were made, in order to justify the generation of various data.

Firstly, the products were grouped into 11 families based on their similarities in product type, average volume and weight. For example, several models of the same product, despite being from different brands, were grouped into a single product family. These groupings facilitate logistical and financial analysis. The selection of 11 product families includes blenders, mini blenders, hand blenders, toasters, fryers, coffee machines, gaming chairs, dehumidifiers, scales, microwaves and mini ovens. For these products, Worten provided their volumes, their prices, and the fees charged by Amazon for the FBA service in both countries, as well as the commission for using Amazon's marketplace. Since the products are grouped by families, the average volume, price, FBA fee, and FBM commission, for each of the 11 product families was estimated. Tables A.2 and A.1 show the average price and weight for these family products. Tables A.4 and A.5 represent the costs associated with the Amazon's services (FBM and FBA, respecively) for Germany, while tables A.7 and A.8 represent these same fees, for France.

The analysis considered one year of operations, since the data was derived from Worten's 2023 sales data on Amazon Spain, taking into account the similarity of the market and consumer behaviour. This adaptation makes it possible to distribute demand more realistically in the target markets, based on a proven sales history. Total annual demand for each country accounts for aproximately 25.200 units, of all 11 products.

The locations of the Amazon FCs are also among the data provided by Worten, and their locations (in zip codes) can be seen in figures A.1 a) and b) for Germany and France, respectively.

The costs provided by Worten for the transport of products leaving the Warehouse are per pallet, for the 95 zip codes, for both and each Germany and France. These are the prices charged by the *Schenker* carrier, depending on the number of pallets to be transported, from range 1 to 33, corresponding to a FTL, and the destination zip code [68].

In this way, all the data was modelled so that all customer locations, DCs, FCs, and warehouses were represented by the zip codes of the cities in which they are located. Germany's and France's zip codes can be seen in Figures A.2 a) and b), respectively. The geographical coordinates (latitudes and longitudes) of the zip codes were calculated based on the centre of gravity of each zip code, allowing the exact distances between zip codes to be determined.

In the specific case of customers, 95 customers were considered for both France and Germany, where each of these customers was represented by the zip code corresponding to their location. In other words, each zip code used in the model represents an unique customer, reflecting the geographical distribution of customers for each country.

As such, for the transport costs, data corresponding to the costs from the origin of the warehouse in Portugal to, as already mentioned, the respective zip codes in Germany and France, was used, depending on the number of pallets. These costs vary for the destination (zip code), based on the number of pallets to be sent, so the number of pallets is calculated based on the total volume of products to be transported, and the total volume of a pallet. The pallets will be multi-product, to ensure efficiency and maximise the use of space. Although the usual height of a euro pallet is 1.80 metres, the height of the pallets has been set at 1.70 metres, to ensure safe transport [86].

The distribution of demand was estimated in proportion to the wealth of each region, represented by the Gross Domestic Product (GDP) per district, by calculating the GDP of each zip code, based on the districts that make up that zip code. Using GDP as a basis for making assumptions about the demand for a product in a country, is an approach based on various economic and social aspects. Firstly, GDP is one of the main indicators of a region's economic capacity, as it provides a detailed view of the distribution of wealth within a country, making it possible to identify where wealth is concentrated. As Cadil highlighted, regions with higher GDP tend to have greater purchasing power, which is reflected in a greater capacity and willingness to consume goods and services [87]. Thus, when analysing regional GDP, it can be inferred that areas with more robust economies have a higher potential demand for various products.

As such, to estimate the demand for each zip code, the regional GDP of all the districts contained in that zip code, were added together. This aggregated GDP value was then used to proportionally distribute the total annual demand, which was derived from Worten's 2023 sales data on Amazon Spain, across the different zip codes. By doing so, the demand for each product family, in each zip code, was estimated based on the relative economic activity and purchasing power of the regions, ensuring a realistic and data-driven allocation of demand. As regional differences are significant in terms of purchasing power, an estimate was made, according to the proportionality of the GDP of the respective zip codes [88].

Scenario 2, involves an intermediate storage centre and, as no locations were obtained for possible DCs locations, the model will decide which DCs to open, from the set of zip codes of each country. In this way, each country has 95 possible locations for the model to chose from. As there was no public information available for costs associated with operating DCs in these countries, these costs were estimated based on the costs of storage, reception and expedition for Portugal in 2024, and extrapolated to the French and German markets, using a conversion factor that takes into account the cost of living in these countries, compared to Portugal. For Germany, a rate of 41% was applied, while for France, the rate used was 35% [89] [90]. The exploitation made can be seen in Table A.9, and the operating costs (storage, expedition and reception costs) can be seen in Tables A.10 and A.11 for Germany, and in Tables A.12 and A.11, for France.

DC operating costs are calculated per pallet. To do this, it was determined how many products from the same family fit on a pallet, and then the cost per "product" was obtained. The cost of storage is also per pallet, but also, per day. As such, in order to simplify the calculations, it was assumed that the products remain in the DC for 30 days. No fixed costs were taken into account, since the DCs are subcontracted, and these costs are diluted in the operating costs.

Although the capacity of the DCs was originally a parameter to be considered, such that it could influence the final result, as no data was obtained for them, it was dismissed.

As it was also not possible to find the actual prices charged by carriers in France and Germany for the final delivery between the DC and the end customer, the value per kilometre taxed in Portugal was used as the basis for the calculation. In order to adjust these values to the cost of living for Germany and France, the same rates of increase mentioned above, were applied: 41% for Germany and 35% for France. These rates made it possible to adjust the cost of transport, in proportion to the differences in living and operating costs between the countries, considering a cost of 1€ for Germany, and 0.96€ for France. All parameters assumed can be found in Table A.14.

The main assumptions are summarised as follows:

- **Product Families:** Products were grouped into 11 families based on similarities in type, volume, and weight to simplify logistical analysis.
- **Time Frame:** One year of operations was considered, using Worten's 2023 sales data of these products, from Amazon Spain as a reference.
- **Customer Representation:** All customer locations, DCs, FCs, and warehouses were represented

by the zip codes of their cities. A total of 95 customer locations were considered for both and each France and Germany. In this way, each client is represneted by a unique zip code.

- **Transport Costs:** Transport Costs from the Warehouse to the DCs were based on data from Worten's Warehouse to the 95 zip codes of each Germany and France. Transport Costs from the DC to the End Client were calculated based on the taxed cost per kilometer used in Portugal, adjusted to the cost of living of these countries.
- **Demand Distribution:** Demand was estimated using regional GDP per zip code, with GDP serving as a proxy for economic activity and purchasing power in each region.
- **DCs' Costs:** DCs' Operating costs were estimated based on Portuguese data, adjusted to the Countries in question.
- **Pallet Transport:** Pallets were used as the unit for transport between the Warehouse and the DC or the FC.
- **Storage:** Storage calculations, assumed products stay in the DC for 30 days.
- **DC Capacity:** DC capacity was not considered.

These assumptions ensure that all data and parameters are clearly defined and used consistently in the model, providing a robust basis for analysing and comparing the internationalisation scenarios.

6

Results and Discussion

Contents

This Chapter will present the results obtained from the application of the developed methodology to the two countries under study, Germany and France, in the context of Worten's logistics expansion. Section 6.1, discusses the key simplifications made in the modeling process. Section 6.2 delves into the tests' results, starting with an analysis of global patterns observed across both markets, followed by specific findings for Germany and France, ending with the comparison of the results obtained in both countries, highlighting the differences in costs and operational strategies between them.

6.1 Model Simplifications

During the development and implementation of the model, various limitations were encountered, which required several adaptations, both in the treatment of the data, and in the way the problem was approached.

The initial aim was to incorporate all the scenarios into a single model which, by considering all the costs and constraints, would be able to determine the scenario that minimised total costs. However, it was realised that this approach was not feasible for the context of this thesis as, after 24 hours of processing, the gap had only advanced by 12%, being stopped at 52%. As this progress was not linear, it was decided to split the model into two different scenarios to manage the complexity and computational load.

Another intended objective was for the model to integrate time with the 12 months of the year, with the demand parameter being the demand for each product, for each zip code, for each month. However, during the development of the model, it was identified that the time needed to process the calculations for a 12-month period was excessively long, which made it impossible to carry out the full run within a reasonable timeframe. To overcome this computational limitation, it was decided to adopt a micro-tests approach, dividing the analysis period into quarters. This decision is based on the observation that product demand generally shows a similar behaviour throughout each quarter, which allows the quarterly planning scenarios to offer a representative view of annual behaviour. In this way, the demand became, for each quarterly micro-tests, the demand for each product, for each zip code, for a three-month period.

By carrying out these micro-tests per quarter, the model was able to process the information more efficiently, significantly reducing execution time. However, it is important to recognise that this approach has its limitations, namely that there is no single optimal solution for the location of the DCs to open for the year, as each quarter has an optimum solution to that specific demand. Micro-tests provide results that, although insightful, are partial. As such, interpreting the results requires a qualitative and subjective analysis, where strategic decisions are made, based on the behaviour observed in the different quarters, rather than a comprehensive analysis of the entire annual period.

Another important simplification is that, regardless of the variation in the SLA, the model always covers 100% of demand. This means that, for the model, the entire volume of products entering the system is ”immediately” fulfilled, since there is no time component, without any inventory accumulation, totally unrealistic, especially when analysing a three month period. For this reason, the storage cost had to be adjusted, in order to reflect the continuous flow of products, as otherwise the storage cost value would be 0, since no inventory was being accumulated. Therefore, the inventory variable, I_{jp}, had to be removed from the storage cost equation (Equation 4.7), and replaced by the variable x_{ijp}, to become equation 6.1.

$$stc = \sum_{j \in DC} \sum_{p \in P} (stor_{jp} \times (\sum_{i \in W} x_{ijp})) \tag{6.1}$$

However, as the analysis is being done by quarter, the storage cost had to be calculated for a period of three months, assuming that all the volume arriving at the DCs remains in storage for that entire time, which does not reflect reality. In this way, storage costs end up being inflated, since the model assumes that all products remain in storage for three months, contributing to an increase in storage costs.

Although the tests for the FBM scenarios were carried out on a quarterly basis, which required the analysis of data on a quarterly scale, for the FBA scenario, the tests were also conducted quarterly but using the FBA monthly fee. In this way, the main difference lies in the fact that the products are taxed on the basis of the monthly demand for each quarter, rather than on a quarterly basis, as is the case with the FBM analysis. This approach was necessary due to the structure of Amazon’s fulfillment service fees, which are charged monthly. Since these fees represent around 90% of the total cost in the FBA scenario, using a quarterly analysis would have led to unrealistically and excessively high cost estimates. By analysing the FBA scenario on a monthly basis, the results reflect more accurate and realistic costs, as they align with the actual monthly billing cycles of Amazon’s fulfillment services, preventing inflated results that could distort the analysis.

The capacity of the DCs was initially considered as a factor that could influence the results of the model. However, due to the lack of available data on the exact capacities of DCs, it was not possible to test and include this variable in the analysis. As a result, it was not possible to accurately determine the impact that the capacity of DCs could have on the final results. Despite this, other factors, such as transport costs and fulfilment commissions, were considered more relevant when analysing total costs.

It should be remembered that, as already mentioned in Subchapter 5.3.3, the absence of the algorithm that Amazon uses to distribute the products to its FCs, prevented the application of a more refined distribution strategy. Amazon employs an algorithm that analyses various factors, such as customer location, FC storage capacity and demand forecasts, to decide how to optimally distribute products to its FCs. However, without access to this algorithm, the approach adopted in the model implied the uniform allocation of demand, sending the same quantity of each product, to each FC. This simplification can lead to sub-optimal use of truck and FC capacity, as it does not take into account the particularities of demand in different regions, or the specific logistical capacities of each centre. This limitation can result in inefficiencies, as truck capacity may not be fully exploited, and the quantities dispatched may not reflect the real needs of each FC.

Before starting to analyse the results, it is important to note that in general, demand throughout the year, varies between the different quarters and is influenced by seasonal factors. While the first and fourth quarters typically see high demand, driven by events such as ”back to school”, Christmas, post-Christmas sales, and ”Black Friday”, which encourage consumers to buy at these specific times; the third quarter tends to see lower demand, essentially due to the summer holidays. The second quarter continues to see moderate demand, sustained by public holidays such as Easter. In this way, seasonality can be identified in consumption patterns, both at the level of the products in question, and at the level of the quarters studied.

6.2 Presentation and Discussion of Results

To evaluate the logistical feasibility of the FBA and FBM scenarios, different tests were carried out covering both countries, France and Germany, for all four quarters of the year. In the FBA scenario, costs were estimated for both countries for each quarter, in order to capture seasonal fluctuations and analyse the impact of variations in demand throughout the year.

In the FBM scenario, the model must decide which geographical locations, identified by zip codes, to open DCs in, so that the products can be transported from the warehouse to these DCs, and from there to the customers, in order to minimise total costs. To do this, the model takes into account the transport costs from the warehouse to the DCs chosen by the model to be opened, the respective operating and storage costs of each DC, the commission costs charged for each product, and the transport costs between the customer and the DC, dependent on the proximity between these two points.

In this way, different analyses were carried out, in order to understand the factors that the model considers important, in order to obtain the locations of the DCs that minimise all these operations.

In addition to these main tests, sensitivity analyses were carried out, to assess the impact of possible variations in FBM costs, as well as in FBA rates, combining with different scenarios tested. These analyses made it possible to understand how changes in these variables could affect the results of the two strategies, providing a more robust view of the viability of the different logistics models in different economic contexts.

6.2.1 Scenarios

In this analysis, the logistics distribution costs for both Germany and France were evaluated, under two distinct fulfillment models: FBA and FBM.

For the scenario in which the strategy to be adopted is FBA, there is little flexibility for the analysis, since it ends up being the sum of the shipping costs to Amazon's FCs, and the costs charged by the FBA service. In this case, the model only has freedom to optimise the shipment of products (monthly) to the different locations of the FCs, and the only possible variation for this strategy, would be to change the distribution of demand among the FCs (which in reality is given by Amazon's algorithm). In this way, the FBM model is the protagonist of the analyses, as it allows for greater variation in costs.

For the FBM base scenario, the model decides the number of DCs to open, with the cost of transport between the DC and the customer being 1€$/km$ for Germany, and 0.96€$/km$ for France. For the transport between the DC and the customer, the number of units allowed in this shipment is limited to 15.

To study how variations in factors such as the cost per kilometer (for the transport between the DC and the customer), the number of units allowed per shipment (in the journey between the DC and the customer), and the number of DCs to open, impact total costs, sensitivity analysis tests were conducted across these scenarios.

Figure 6.1 illustrates the scenarios to be studied.

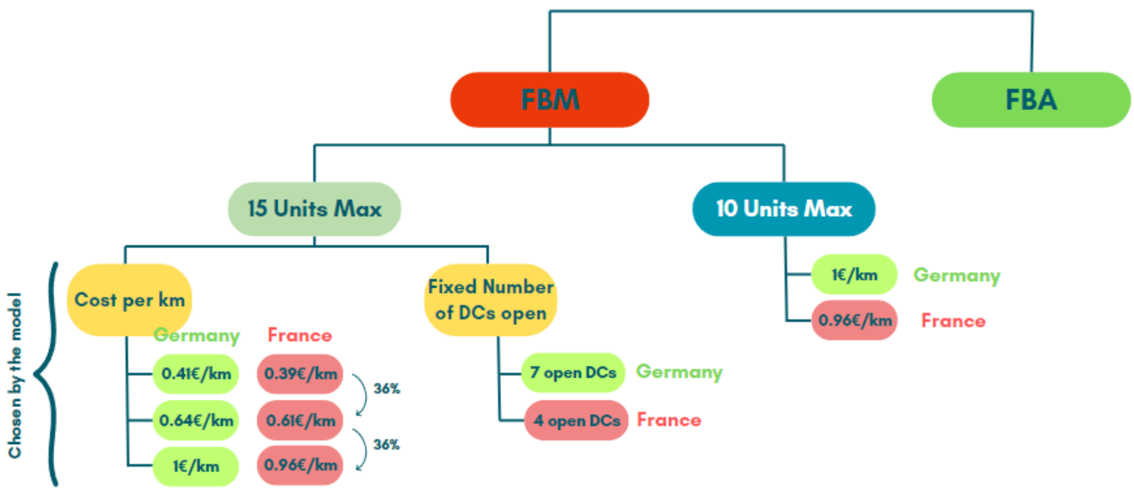

Figure 6.1: Problem Representation

6.2.1.A Observed Global Patterns: Germany and France

In the FBM scenario, similar patterns can be identified in the analysis for Germany and France. In this way, it is intended to understand the adjustments that the model makes throughout the year, in response to the variation in demand, for the different quarters, in both countries.

To deepen the analysis, the model "as is" was tested, considering: one scenario opening only one DC, another with two DCs open, and finally, the scenario where the model determines the number and location of DCs, which results in the optimised solution. This approach makes it possible to compare the impact of a centralised versus distributed structure, on transport and operating costs.

Figures 6.2 and 6.3 illustrate the tests ran for Germany, showing the variation obtained in transport costs and total costs, as a function of the number of open DCs.

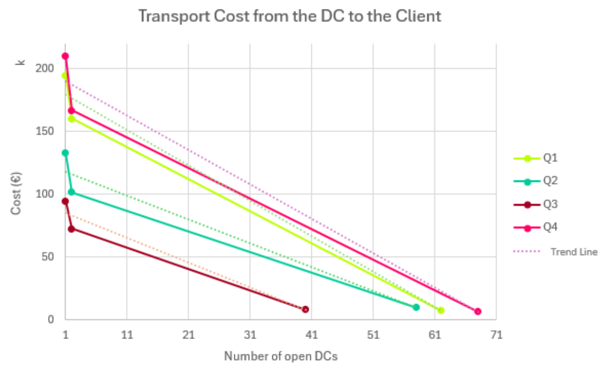

Figure 6.2: Transport Costs from the DC to the end Client - for Germany (€)

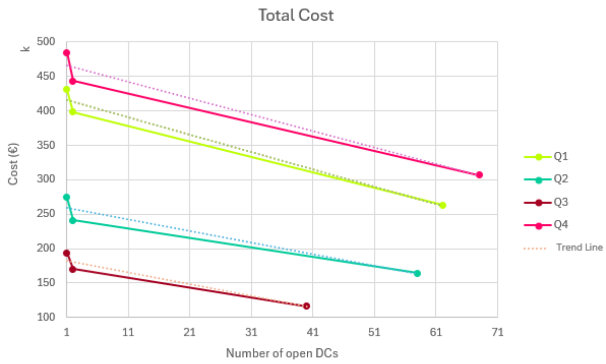

Figure 6.3: Total Costs for Germany (€)

Looking at the graph in Figure 6.2, the first thing that stands out is the clear downward trend in transport costs between the DC and the customer, as the number of DCs increases. Since the cost of transport between the DC and the end customer is given by the distance between these two points, by increasing the number of DCs to be opened, it is possible to significantly reduce the average distances between DCs and customers, thus reducing transport costs. This increase in the number of DCs allows for greater proximity to demand and, consequently, more efficient distribution, which helps to offset the high transport costs per kilometre, and keep total costs more under control.

For the opening of one or two DCs, this cost is noticeably high, especially for the quarters with the highest demand. However, for the number of DCs open for the optimal solution, regardless of the quarters, this cost tends to a very low and similar value. This is a reflection of the model's ability to adjust the number of open DCs, to respond to seasonal variations in demand, in order to reduce total costs to the greatest. Thus, for the high-demand quarters, Q1 and Q4, the model opens more DCs, in order to optimise geographical coverage, and reduce these distances as much as possible.

The reduction in transport costs is most noticeable in the transitions between the scenarios with one and two open DCs, where there is an extremely steep, almost vertical slope. This almost vertical slope indicates the significant impact that geographical distribution has on logistics costs, showing that the first expansion from a single DC to two, makes it possible to substantially reduce the distance between the DC and the customer, offering the greatest benefit in terms of transport costs. This reduction is also more pronounced for the quarters with the highest demand, which suggests the need for a dispersed distribution network, for operations with large sales volumes.

In the transition from two DCs to the optimised scenario (where the number of DCs is determined by the model), the slope remains steep, but less so than in the previous transition. This suggests that, although the cost of transport still benefits from opening more DCs, the marginal impact is less with each new unit opened.

Furthermore, in the graph of Figure 6.2, it can be seen that the slope of the cost reduction is steeper for the quarters with the highest demand. This is because when demand is high, transport volumes are higher, making the proximity of the DCs to the customers even more important to reduce transport costs. Thus, by opening more DCs for quarters with higher demand, the model manages to reduce the unit cost of transport more significantly.

On the other hand, the solution that minimises transport costs, tends to have a less pronounced slope, for quarters with lower demand. This is due to the fact that, with lower demand, the additional cost of opening and operating more DCs, begins to outweigh the advantage of reducing transport costs, since for lower volumes of orders, the model is able to efficiently serve customers, without the need for a very dispersed network, centralising operations more in a smaller number of DCs, and avoiding unnecessary operational and storage costs.

In the graph of Figure 6.3, showing the total cost in relation to the number of DCs opened, there is a similar trend to the transport cost graph where, as more DCs are opened, the total cost shows a marked reduction, especially in the transition from one to two DCs. However, the slope for this cost is less pronounced as the one observed for the transport cost, indicating that, although opening more DCs continues to reduce total costs, the weight of this reduction decreases. This difference in the slope suggests that, while increasing the number of DCs is an effective strategy for reducing the cost of transport between the DC and the end customer, other costs also play an important role in the total cost. This can be corroborated as, contrary to what was observed for transport costs, the quarters with the highest demand, have higher total costs, since this cost is the sum of several costs, which depend on the volume of demand. In this way, although opening more DCs, makes it possible to reduce the average distance travelled to the customer and, consequently, the cost of transport, it also entails additional costs, such as the storage and operational costs, associated with each DC, as well as the transport costs of leaving the warehouse to more DCs. These costs increase with the number of DCs operating, which creates a trade-off effect, that the model takes into account, when looking for the most economical configuration.

It can therefore be concluded that the reduction of transport costs between the DC and the customer, achieved by opening more DCs, is driven by the input data, which leads the model's objetcive: to minimise the total cost. As such, the model takes some freedom away from other costs through a trade-off, not allowing the reduction in total cost to be as pronounced as for transport costs between the DC and the customer.

Table 6.1 shows a comparison of the relative weights of the different types of costs, when only one DC is opened, and when the number of DCs open is determined by the model's optimal solution, for

Germany. By comparing the weights of the different costs in the scenarios of one open DC and the optimal solution, it is possible to see the trade-off between the costs, which are more evident for the transport costs between the Warehouse and the DC, and from the DC to the customer, and for the commission costs.

Table 6.1: Relative weights of the costs in the different scenarios for Germany

	Q1		Q2		Q3		Q4	
Number of DCs open	1	62	1	58	1	40	1	68
Transport Cost from the Warehouse to the DC	6.0%	16.1%	5.0%	15.3%	5.0%	15.1%	5.8%	16.2%
Transport Cost from the DC to the Client	45.2%	2.8%	48.4%	6.0%	48.9%	7.2%	43.2%	2.2%
Storage Cost	0.4%	1.5%	0.3%	1.3%	0.4%	1.2%	0.3%	1.4%
Operating Cost	0.1%	0.4%	0.1%	0.3%	0.1%	0.3%	0.1%	0.4%
Commision Cost	48.3%	79.1%	46.1%	77.0%	45.7%	76.2%	50.5%	79.8%

In this way, the model's objective of minimising the costs that vary quarterly, as the commission cost, although the most significant, remains fixed as it is solely demand-dependent. In the optimal solution, commission costs dominate, carrying substantially more weight than any other cost.

It can also be seen that, for the quarters with the highest demand, the commission cost is, in the scenario in which only one DC is opened, the cost with the greatest weight, as opposed to the quarters with the lowest demand, where the transport cost between the DC and the customer have the greatest relative weight. This can be explained by the fact that the commission cost is per product, and that for quarters Q1 and Q4, the volume of demand is greater. Furthermore, considering the aggregation of shipments between the DC and the customer, for the quarters with the highest demand, this is greater, which has a greater impact on reducing transport costs on this route, thus reducing its relative weight.

It should also be noted that the trade-off between the costs associated with opening more DCs can be observed, as the weights of transport costs from the warehouse to the DC, the operating and storage costs, increases.

Before starting to analyse the results obtained for France, it is important to point out that, during data collection, it was found that the costs associated with Amazon's fulfilment service for France are considerably higher than those applied for Germany. This increase is reflected both in the fulfilment service fee, FBA, and in the commissions charged when using only Amazon's marketplace, as in the case of FBM. An average increase of around 4% per product for the FBM commision, and an average increase of 14% for the FBA fee, stood out in costs for the French market, compared to the German market.

This increase applies to each product, which, when multiplied by quarterly demand, translates into significantly higher total costs for France. It is worth recalling that the service fee is calculated per product, and its value depends on the price listed on the Amazon page for the respective country. Therefore, the impact of this increase directly affects the total cost of operation in both the FBA and FBM models, making operation in France more expensive than in Germany.

Looking at the graphs for France, Figures 6.4 and 6.5, a very similar behaviour to the one described for Germany can be seen, where for quarters with lower demand, opening a smaller number of DCs, allows for a more economical solution, where the fixed and variable cost of each DC, is offset by the lower need to move products; while for quarters with higher demand, the strategy of opening more DCs, brings a significant logistical advantage. In this way, it can be seen that the cost of transport is directly affected by the proximity of the DCs to the customers, reflecting the impact of opening more DCs on the total cost.

The model's efficiency in minimising transport costs between the DC and the customer is also visible, in Figure 6.4 as, for the different quarters, the value of this cost tends towards the same value. It is possible to obtain very similar transport costs for this route, for the different demands, by adjusting the number of DCs.

Again, the total cost, given by Figure 6.5, reflects a balance between transport savings, and the additional costs associated with running more DCs.

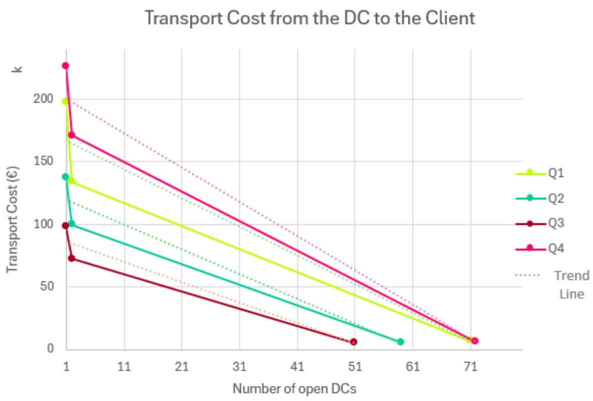

Figure 6.4: Transport Costs from the DC to the end Client for France (€)

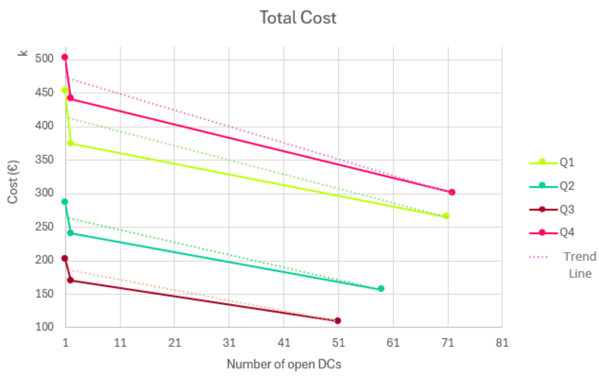

Figure 6.5: Total Costs for France (€)

The slopes observed indicate the importance of the geographical distribution of DCs at a strategic level, where an efficient distribution allows the model to minimise the distances between the service points and the end customers, significantly reducing transport costs, which is the variable cost with the greatest weight (as the commission cost, which effectively has the greatest weight, cannot be varied by quarter). In this way, a more dispersed network of DCs, makes it possible to serve more regions at a lower unit transport cost, especially in markets with high volumes and dispersed demand like these.

Since the data for transport costs, as well as operating and storage costs, are lower for France than for Germany, according to the cost of living used, it would be expected that fewer DCs would be opened for this country, as there is no such need to lower the transport cost between the DC and the client, as there is in Germany. However, despite the same trend observed for Germany, where the number of DCs to be opened increases with the demand for the respective quarter, for France, the option that minimises the total costs, involves opening even more DCs.

By looking at the total costs obtained for opening just one DC, it can be seen that this cost is higher for France, than opening one DC in Germany. After examining the transport costs between the DC and the customer in France, Figure 6.4, it can again be seen that this cost is also higher, than in Germany, suggesting that the average distances to serve customers in France, require longer journeys.

In the light of these observations, it is possible to conclude that, both the increase in the number of DCs to be opened, and the higher cost of transport between the DC and the customer, may reflect a very geographically dispersed demand, forcing higher transport costs to be incurred on this journey.

Therefore, the increase in the number of DCs in France, is a response by the model to mitigate these high transport costs, that result from the wide geographical distribution of demand. By opening more DCs, the model is able to reduce average delivery distances, by strategically distributing the distribution points, allowing for the total costs obtained for the different quarters, to be very similar to the ones obtained for Germany.

Table 6.2 compares the relative weights of the different types of costs, when only one DC is opened, versus the number of DCs opend is determined by the model's optimal solution, for France. The conclusions that can be drawn are very similar.

Table 6.2: Relative weights of the costs in the different scenarios for France

	Q1		Q2		Q3		Q4	
Number of open DCs	1	71	1	59	1	51	1	72
Transport Cost from the Warehouse to the DC	4.5%	14.2%	3.7%	14.4%	3.7%	14.4%	3.5%	14.0%
Transport Cost from the DC to the Client	46.8%	2.6%	51.6%	3.6%	52.6%	3.6%	45.8%	2.0%
Storage Cost	0.6%	1.1%	0.5%	0.9%	0.5%	0.9%	1.0%	0.9%
Operating Cost	0.1%	0.2%	0.1%	0.2%	0.1%	0.2%	0.1%	0.2%
Commision Cost	48.0%	81.8%	44.1%	80.9%	44.1%	80.9%	50.2%	83.0%

In the quarters with the highest demand, as there are more volume of orders, the cost of the commission is higher for both scenarios. The dispersed distribution of demand in France can be corroborated by looking at the table 6.2 since, even with high commission rates, the cost of transport between the DC and the client is, in the scenario where only one DC is open, similar to the weight of the commission cost, for Q1 and Q4. For Q2 and Q3, the cost of transport between the DC and the customer is higher than the commission cost because, for low volumes of orders, for dispersed demand, the cost of delivery outweighs the commission cost (which, although high, is lower for lower demand).

Once again, the impact of opening more DCs can be seen in the increase in the weight of logistics costs, which are even higher than in Germany, an increase justified by the geographically dispersed demand, which forces the opening of a greater number of DCs.

In the scenario in which only one DC is forced to open, the model chooses, for Germany, the DC located in zip code 99, with a central location in the country, making it possible to significantly reduce transport costs between it, and the demand node. For France, the model chooses to open zip code 95, which is located in the neighbourhood of Paris, where there is a great concentration of demand (given the region's GDP), positioning the DC strategically, closer to the demand. The geographic location of these DCs can be seen in Figure A.1 a) and b), for Germany and France, respectively. It should be noted that the DCs chosen by the model to open, in order to obtain the optimal solution, were not the same for the different quarters, nor was the number of DCs to open, unlike when only one or two DCs are opened.

6.2.1.B Sensitivity Analysis on Transport Costs between the DC and the Client

As identified in Tables 6.1 and 6.2, when the model is not looking for the optimum solution and forces the opening of a DC, the variable cost with the greatest weight, is the cost of transport between the DC and the customer. This is therefore the main variable to be studied in order to draw conclusions about its importance in total costs, and in the efficiency of a distribution network.

Number of units allowed per shipment

Given that demand is being analysed on a quarterly basis, it was necessary to set a limit on the number of units per shipment, considering that the total demand of a client, for a quarter, will not be delivered in one single trip, nor in an excessive number of individual journeys. To this end, a maximum limit was set on the number of units that could be transported in each journey, during the quarter. Initially, a limit of 15 units per shipment from the DC to the end customer was set.

For a more accurate comparison, the impact of this limitation on the cost of transport from the DC to the customer, and on the total cost, was analysed, considering a reduction in the limit of units per journey, from 15 to 10 units. The aim was to understand how the variation in the limit of units per journey would influence the logistics costs involved.

The graphs presented in Figures 6.6 and 6.7 represent the quarterly impact of allowing, for Germany, 10 and 15 units per shipment, on the journey between the DC and the customer, in the total costs, and in the transport costs between the DC and the customer, respectively. The variation in the number of DCs decided by the model to open is captured by the size of the bubbles.

By reducing the number of units per shipment from 15 to 10 (50%), reading the graph from right to left, as the aggregation of the number of orders to be sent is reduced, the number of journeys needed to meet the quarterly demand increases, which directly influences the cost of transport between the DC and the end customer.

By making this change, it would be expected that the cost of transport between the DC and the demand node would increase, since with 15 units allowed, the capacity for each shipment was greater, requiring fewer shipments for the same demand. However, as can be seen in Figure 6.6, this impact did not occur on transport costs, which remained practically stable, with a very slight increase.

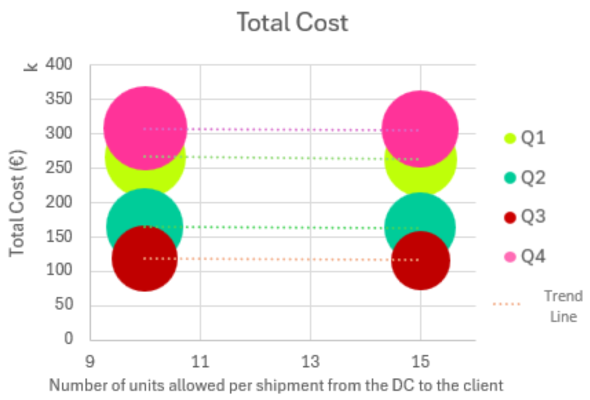

Figure 6.6: Total Cost for 10 vs. 15 units per shipment (€) - Germany

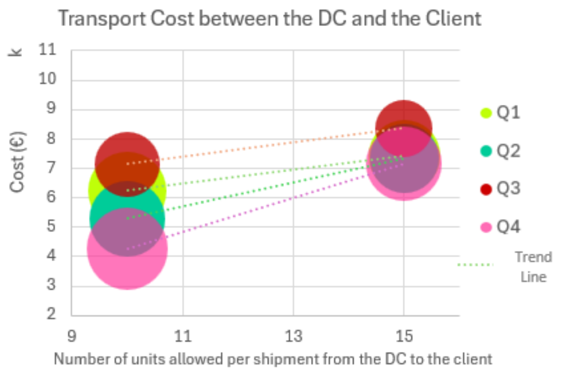

Figure 6.7: Transport cost from DC to customer for 10 vs. 15 units per shipment (€) - Germany

Thus, although costs have not increased with the reduction in the number of units allowed per shipment, there is an increase in the diameter of the bubbles, which indicates an increase in the number of DCs to open. This is due to the fact that, with the limitation of sending fewer units per journey, the model needs to operate with more DCs, so as not to incur high transport costs per unit, which comes from the increase in journeys needed to meet demand, as the consolidation of shipments does not allow large areas to be covered. By opening more DCs, it is possible to reduce the distances between them and the demand points, compensating for the increase in the number of shipments needed, by reducing the average distance of each delivery.

The stabilisation seen in total costs can be justified in the light of the fact that the total cost is made up not only of the cost of transport between DC and customer. In this way, other costs associated with the number of open DCs, such as shipping costs from the warehouse, storage and operating costs, vary with each other, so as to achieve a balance, resulting in the optimisation of the network, in order to keep the total cost as little as possible.

When focusing on transport costs between the DC and the customer, given by the graph in Figure 6.7, there is, with the increase in the number of units allowed, an increase in costs, for all quarters. This increase in transport costs is accompanied by a reduction in the number of operational DCs. This happens because, by allowing greater aggregation of orders, there is no justification for opening such a large number of DCs, in order cover the demand efficiently.

It can also be seen that, for the quarters with the highest demand, Q1 and Q4, transport costs between the DC and the customer are consistently lower, regardless of whether there are 10 or 15 units allowed per shipment. This can be justified by the greater efficiency in consolidating deliveries that comes from the high demand, but also by the number of DCs that the model chooses to open, which is much higher for these quarters, allowing to reduce the number of shipments needed to satisfy the demand.

The impact on costs was also tested by further reducing the number of units allowed per shipment between the DC and the client to 5, and the result was the same: very slight variations in total costs, and the opening of around 98% of DCs.

The analysis for the two countries are similar, differing mainly in the value of the transport cost between the DC and the client, and the number of DCs to open, which are higher, as the demand is more disperse across France, and in the number of DCs proposed by the model to open.

Cost per Kilometre

In order to study the impact of varying the transport cost per kilometre between the DC and the end customer, various sensitivity analyses to this value, were carried out. To do this, an initial cost of 1€$/km$ (obtained from the value practised in Portugal, and extrapolated to Germany, based on the assumed cost of living) was gradually reduced by 36%. The aim is to understand how a reduction in the cost per kilometre influences the model's strategy for opening DCs, as well as in the balance between the different types of cost.

As already noted, for any variations in this transport cost, the model prioritises the optimal solution as a configuration that keeps the total cost stable, by changing the number of DCs to open, since this directly influences transport costs from the warehouse, operating and storage costs.

Figures 6.8 and 6.9 represent the variations in the cost per kilometre in the total cost and in the transport cost between the DC and the customer, for Germany, respectively.

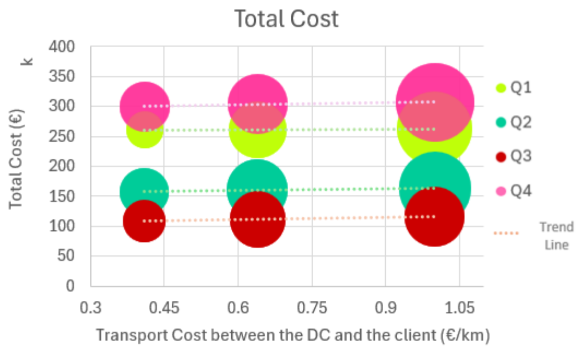

Figure 6.8: The impact of variations of Cost per km on the Total Costs (€) - Germany

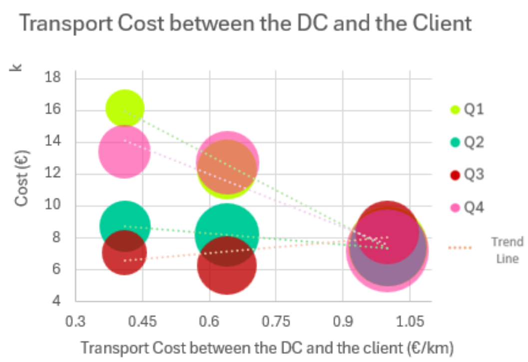

Figure 6.9: The impact of variations of Cost per km on the Transport Costs between the DC and the Client (€) - Germany

The graph in Figure 6.8 shows the impact of variations in transport costs between the DC and the customer, on the total costs for each quarter. The analysis shows, as might be expected, that despite the reductions in the transport cost per kilometre, the total costs remain practically unchanged, with only slight decreases. This stability in total costs, verified in the graph, is justified on the basis that, as the cost per kilometre increases, the model chooses to open more DCs, with the aim of minimising transport costs, by distributing them closer to customers, resulting in a trade-off between all other costs. This suggests that, although the cost of transport between the DC and the customer decreases, there is an increase in the costs of storage, operation and transport from the warehouse to the DC, which comes from increasing the number of DCs to open.

The graph in Figure 6.9 show, for each quarter, the impact of variations in the cost per kilometre between the DC and the customer, specifically on the DC-customer transport cost. As the cost per kilometre increases, the model tends to decrease the cost of transport between the DC and the customer, and increase the number of DCs needed to open. As can be seen from the trend lines for each quarter, this variation in cost is more marked for the quarters with the highest demand, while for Q2 it is only slight. In Q3, there is a positive trend line, with an increase in transport costs, as more DCs are opened.

As would be expected, as transport costs rise, the model needs to open more DCs, distributing them closer to demand, with the aim of reducing the distance between the DC and the customer. Having the DCs distributed across strategic locations, the model then manages to reduce the costs associated with shipping products from the DC, justifying the negative slope. However, for Q3, as the cost per kilometre increases, so does the cost of transport. This suggests that, for the highest transport cost per kilometre in Q3, the trade off in the transport cost between the DC and the customer, and the increase in the number of operational DCs is less meaningful, than the trade off registered for a lower cost per kilometre.

On the other hand, in quarters with higher demand, opening more DCs allows the high volume of transport to be distributed efficiently, making the most of the reduction in distances.

In addition, for the quarters with the highest demand, as the cost of transport rises, the number of DCs operating is more evident, which is justified by the strategy of meeting the high demand efficiently, which involves this number to rise. As for the quarters with the lowest demand, the increase in the number of DCs, with the increase in the cost per kilometre, is less intense.

It should also be noted that, contrary to what might be expected, when the cost per kilometre is the lowest, the value of the transport cost for Q1 exceeds the value of the transport cost for Q4, despite having less demand. However, this high value can be justified in the light of the size of the bubble, which represents the number of DCs opened: by opening fewer DCs, despite having lower demand, the dispersion of the DCs across the region is lower, requiring a greater number of journeys to satisfy demand, increasing transport costs.

In order to study the trade-offs that occur in other costs in more depth, sensitivity analyses were carried out on transport costs between the warehouse and the DC, and on operating and storage costs, which are illustrated in Figures 6.10 and 6.11, respectively.

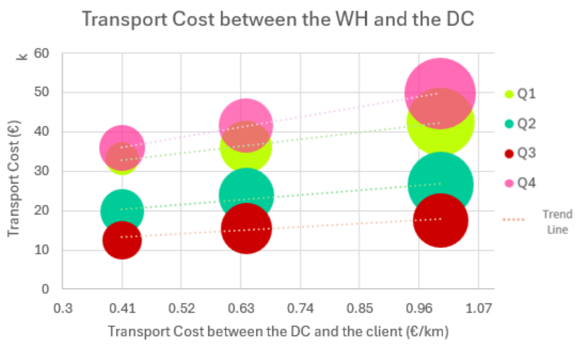

Figure 6.10: The impact of variations of Cost per km on the Transport Costs between the Warehouse and the DC (€) - Germany

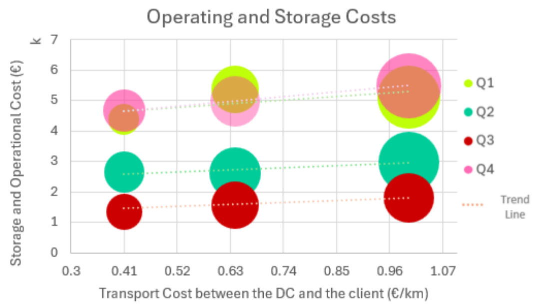

Figure 6.11: The impact of variations of Cost per km on the Operating and Storage Costs (€) - Germany

As might be expected, with the increase in the number of DCs operating, given the increase in the cost per kilometre, there is also an increase in the cost of transport, from the warehouse to the DCs, as can be seen in Figure 6.10. This increase can be justified by the increase in the number of shipments destined for more regions, that translates into a loss of logistical optimisation, as there is less utilisation of the loads. With more DCs in operation, the number of LTL shipments increases, making this cost higher per unit of cargo. It should be noted that the costs for the quarters are in line with their respective demands, being higher for quarters Q1 and Q4.

The sensitivity analysis of operating and storage costs, given by the graph in Figure 6.11, shows, albeit less markedly than that recorded for transport costs between the warehouse and the DC, an increase in these costs, followed by an increase in the number of open DCs. This variation is most noticeable in the quarters with the highest demand. This increase occurs because, if only a few DCs are opened, the model has the liberty to select the DCs with the lowest costs. However, as the number of DCs increases, the model loses flexibility in its choice, since there is a need to meet demand in more locations. Thus, by opening more DCs, the model is forced to include higher-cost units, which generates an increase in storage and operating costs proportional to the number of DCs in operation. It is possible to identify an outlier for the cost of 0.64$€/km$, for Q1, where this value would be expected to be lower. This high value, which exceeds the value obtained for Q4, may be due to the number of DCs open, and the distribution of products across them.

In this way, it can be seen that, although the increase in cost per kilometre generally reduces the cost of transport between the DC and the customer, this cost is offset by an increase in transport costs from the warehouse, and in storage and operating costs, resulting in the stabilisation observed in the total cost.

With the increase in the cost per kilometre, and the trade off that occurs in the variable costs, the relative weight of the commission cost per product, which is fixed for each quarter, decreases, by around 4% for the quarters with the lowest demand, and around 2% for those with the highest demand. This happens because, with the increase in the cost per kilometre, and the corresponding increase in the number of DCs operating, the costs are readjusted in such a way that the weight of the commission cost becomes more diluted. This suggests that the costs incurred to open more DCs (given by the increase in transport costs from the warehouse to the DC, and in operating and storage costs), especially in the lower demand quarters, absorb a greater part of the total costs, proportionally reducing the representativeness of the commission cost.

The same sensitivity analysis was carried out for France, representing the graphs in Figures 6.12 and 6.13, the variations in the cost per kilometre in the total cost, and in the transport cost between the DC and the customer, respectively. For this analysis, the same percentage of cost reduction was used (36%), starting at 0.96€. Transport cost per kilometre is, for this country, cheaper, due to the percentage assumed for the cost of living,

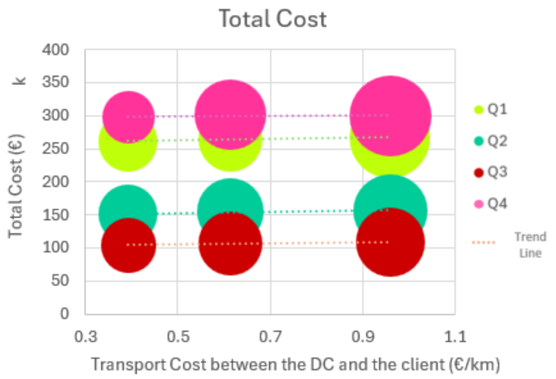

Figure 6.12: The impact of variations of Cost per km on the Total Costs (€) - France

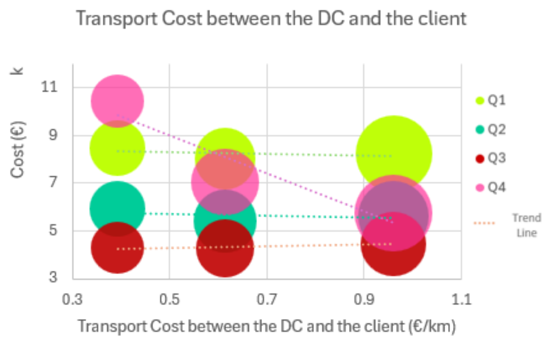

Figure 6.13: The impact of variations of Cost per km on the Transport Costs between the DC and the Client (€) - France

As was the case for Germany, an increase in the cost per kilometre of transport between the DC and the customer has practically no impact on the total cost, Figure 6.12. However, the increase in the number of DCs to be opened, resulting from the increase in the cost per kilometre, is due to the model's need to reduce the cost of transport between the DC and the customer, by positioning the DCs closer to the demand nodes.

As for the transport costs between the DC and the customer, given by Figure 6.13, the increase in the cost per kilometre shows that the model adapts differently to each quarter, reacting according to the specific demand of each one.

For quarters 1 and 2, with an increase in the cost per kilometre, there is a slight reduction in transport costs, while there is an increase in the number of open DCs (more noticeable for Q2). This suggests that, for the case of France, the model does not have much flexibility to reduce costs, which can be justified by the fact that transport costs are already quite low, for the ratio between the number of DCs to be opened. Thus, an increase in costs per kilometre can only be offset by opening more DCs, without a major reduction in cost.

In the case of Q3, the cost of transport increases slightly, as the cost per kilometre rises. This may happen since, for low demand, the extra operating costs that would come with opening new DCs is greater, when compared to the reduction obtained for the previous cost per kilometer.

For Q4, the behaviour is the opposite of the other quarters, with the cost of transport reducing, as the cost per kilometre increases. This is explained by the fact that Q4, having the highest demand, encourages the model to open more DCs, in order to reach more cost-effectively the disperse demand observed, diluting the transport costs. This increase in the number of DCs opened, allows the average delivery distances to the customer to be reduced, compensating for the higher cost per kilometre, and leading to a reduction in the total cost of transport.

A further analysis was made of the impact that the increase in cost per kilometer has on the other costs that contribute to the total cost. Figures 6.14 and 6.15 represent the graphs of these analyses for the transportation costs between the warehouse and the DC, and for the cost of operation and storage, respectively.

Since the variation in transport costs between the DC and the customer, with the increase in the cost per kilometre, Figure 6.13, is only significant for Q4, it could not be expected that storage, operating and transport costs between the warehouse and the DC, would show significant variations either.

With an increase in the cost per kilometer, the graph in Figure 6.14 also shows an increase in the cost of transportation between the warehouse and the DC, as there is an increase in the number of DCs operating. This increase is less pronounced for France than for Germany, which can be explained by the fact that France is closer to Portugal, reducing overall transport costs between the warehouse and the DC, as well as reducing the variance between transport costs for different DCs. In this way, this parameter removes flexibility from the model, for possible combinations of DCs that minimise significantly these costs.

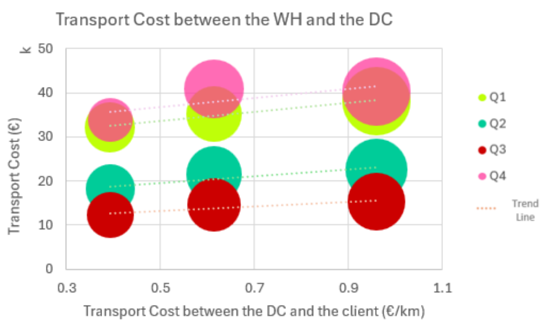

Figure 6.14: The impact of variations of Cost per km on the Transport Costs between the Warehouse and the DC (€) - France

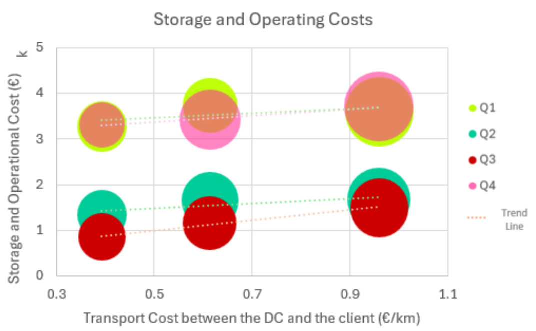

Figure 6.15: The impact of variations of Cost per km on the Operating and Storage Costs (€) - France

For operational and storage costs, with an increase in the cost per kilometer, an increase in these costs can also be seen, Figure 6.15. The overlapping of costs for quarters 1 and 4 stands out. The fact that both quarters have a high demand, explains the similar number of open DCs to minimise transport costs. Even so, it would be expected that the costs for Q1 would be lower. However, these high values can be justified by the fact that the set of DCs chosen by the model to open, may be more expensive for Q1.

An interesting conclusion would be that, although transport, storage and operating costs are higher for Germany, than for France, the number of DCs that minimises total costs is, for all quarters, and for all costs per kilometer, higher in France. Considering, from the previous analysis that the distribution of demand in France is more dispersed, the model's decision to open more DCs can be corroborated, as increasing this number, allows for a more significant reduction in the distances between the DC and the customer, which translates into a reduction in transport costs, overcoming the dispersion observed.

As expected, since commission costs are much higher for France than for Germany, their relative weight is around 4% higher for all quarters in France, than in Germany. As observed for Germany, this weight also decreases as the cost per kilometre increases.

After this analysis, it can be concluded that the stabilisation of the total costs, within each quarter, obtained for different variations in transport costs between the DC and the customer indicates that, for the parameters used, there is a limit to the cost savings, that can only be achieved by varying the number of DCs.

Having clarified this, the scenarios and the results obtained for the different countries can be analysed, assuming that the limit of units transported from the DC to the customer is set at 15 units, using for the transport cost between the DC and the client, the highest cost per kilometre for each country. This adjustment is based on the fact that 15 units per shipment result in a more balanced number of open DCs.

6.2.1.C Germany

For the German analysis, several tests were carried out for each quarter, with the aim of assessing how different logistics scenarios affect total costs. As noted in the previous analyses, variations in the cost of transport between the DC and the customer, only influence the number of DCs to open. Therefore, in order to simulate different market conditions, several scenarios were tested, to compare costs between the different fulfilment strategies. The graphs can be found in Figures 6.17, 6.18, 6.19 and 6.20, as well as their color caption, on Figure 6.16.

For FBA, scenarios were analysed with the fulfilment service rate increased by 5% and 10%.

For the FBM model, since opening more or fewer DCs has little influence on total costs, in order to compare different costs for this model, a further scenario was tested. In this scenario, DCs were opened in the seven zip codes with the highest demand, meaning that seven DCs were opened in the zip codes with the highest GDP (since, as assumed, GDP was the indicator used to distribute demand). Having a fixed number of DCs, it was then possible to assess the impact that sending 10 or 15 units (in shipments between the DC and the customer) has on total costs. Thus, the analysis is based on three scenarios: opening the number of DCs given by the optimal solution; opening 7 DCs in the zip codes with the highest demand, varying the number of units allowed to be sent from the DC to the customer, between 10 and 15. The location of the 7 DCs proposed to be opened, can be found in Figure A.2 a).

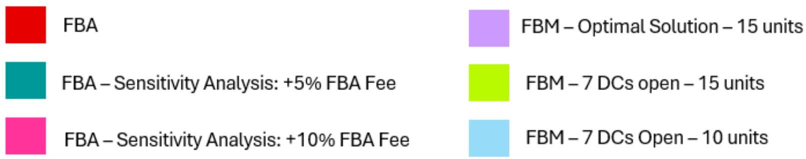

Figure 6.16: Sensitivity Analysis Colour Caption for Germany

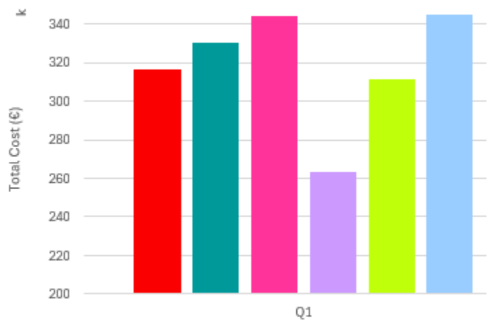

Figure 6.17: Sensitivity Analysis for Germany in Quarter Q1

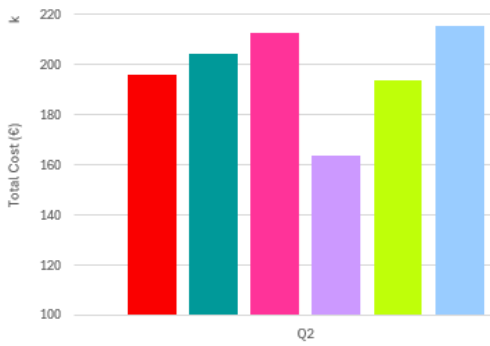

Figure 6.18: Sensitivity Analysis for Germany in Quarter Q2

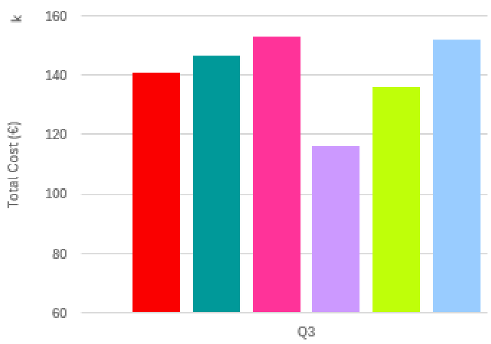

Figure 6.19: Sensitivity Analysis for Germany in Quarter Q3

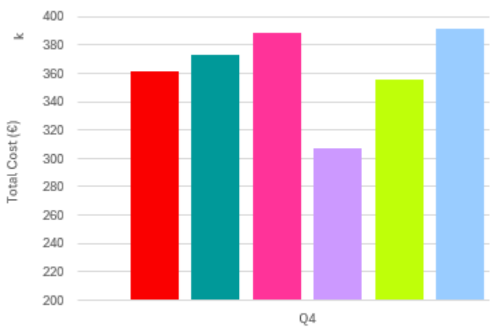

Figure 6.20: Sensitivity Analysis for Germany in Quarter Q4

When analysing the data obtained for the different scenarios, a first conclusion stands out without the need for a very detailed analysis: the cost associated with Amazon's fulfilment service is, transversally for all quarters, higher than the cost of FBM, opening the number of DCs given by the optimal solution, or opening the seven DCs, and transporting 15 units per shipment. This suggests that the FBM model is generally cost-effective.

A more detailed analysis shows that the difference between FBM and FBA costs is more pronounced for the quarters with the highest demand (Q1 and Q4). This can be justified by the fulfilment fees charged by Amazon which, for a higher volume of sales, have a greater influence on the total cost, thus discouraging the hypothesis of using Amazon's services as an attractive option.

Also in the quarters with the highest demand, the FBM scenarios, with the number of open DCs given by the optimal solution and seven open DCs, are further apart. The fact that this difference in costs is more marked for the quarters with the highest demand highlights the impact that opening more DCs has on total costs, allowing them to be reduced significantly, with higher volumes of sales.

Contrary to what was observed for the optimal solution given by the model, by opening a fixed number of DCs, it is possible to see the effect that sending 10 or 15 units (in the shipment between the DC and the customer) has. Thus, by going from 15 units allowed (green bar), to 10 (blue bar), an increase in total costs is observed, revealing the importance that the aggregation of orders has on total costs. With 10 units allowed, the number of journeys needed to satisfy the quarter's demand increases, directly impacting the transport cost between the DC and the final client. This difference is also more noticeable for the quarters with the highest demand, where the number of journeys needed to satisfy the demand, has a more significant impact on transport costs. The increase verified in total costs with the reduction of the aggregation was, for Q2 and Q3, 10%, and for Q1 and Q4, 12%.

It is worth noting that the only value that competes with the scenario where there is an increase in the service fee provided by Amazon, by 10%, is the FBM scenario, opening seven DCs, and limiting the units per shipment between the DC and the customer, to 10.

6.2.1.D France

For France, the same base scenarios used to study costs in Germany were used. However, instead of offering the model the seven DCs located in the zip codes with the highest demand (zip codes with the highest GDP), only four were given as an option. This can be justified because, for France, the fifth and sixth zip codes with the highest GDP are neighbouring zip codes to one of the four zip codes with the highest GDP. Therefore, since opening DCs in neighbouring locations would not add major improvements to the distribution network, it would even become more inefficient, since there would be less utilisation of shipments from the warehouse to neighbouring zip codes, resulting in an increase of unnecessary journeys, it was decided to opt for four, rather than seven locations, for possible DCs. The distribution proposed by the model for the allocation of customers, when opening the four DCs with the highest demand, can be seen in Figure A.2 b).

Figures 6.22, 6.23, 6.24 and 6.25 illustrate the sensitivity analysis made for France, adopting the same scenarios as the ones discussed for Germany. Figure 6.21 represents the colour caption used for these scenarios.

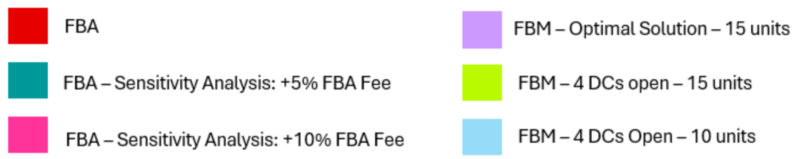

Figure 6.21: Sensitivity Analysis for France Colour Caption

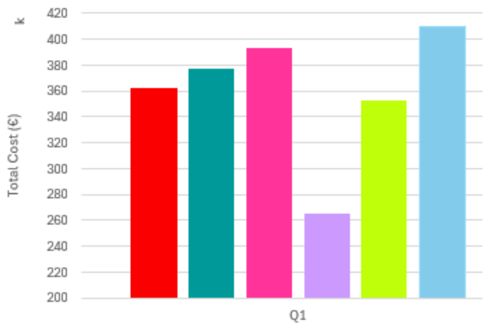

Figure 6.22: Sensitivity Analysis for France in Quarter Q1

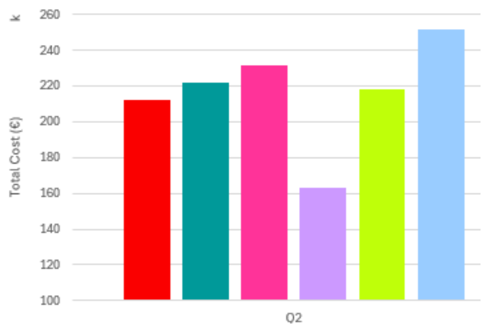

Figure 6.23: Sensitivity Analysis for France in Quarter Q2

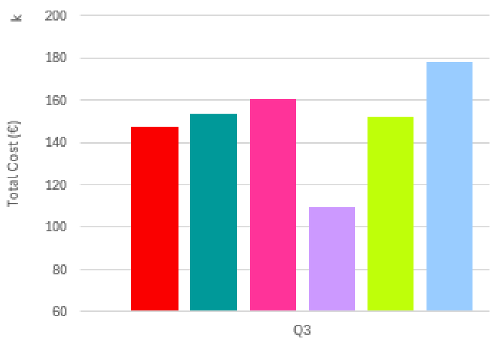

Figure 6.24: Sensitivity Analysis for France in Quarter Q3

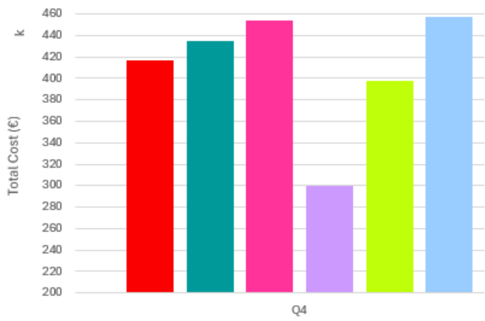

Figure 6.25: Sensitivity Analysis for France in Quarter Q4

As was observed for Germany, the cost for the FBM scenarios of opening the number of DCs given by the optimal solution is, for all quarters, lower than the FBA cost, making the FBM fulfilment strategy the most attractive.

For France, the cost of the scenario where the the number of DCs to open is given by the model, is much further away from the cost of opening a fixed number of DCs, than it was observed for Germany. This can be justified because, as already mentioned, for France, the model opens consistently a larger number of DCs. Thus, when analysing costs for scenarios where there is a discrepancy between the number of DCs to open, the difference in costs becomes more evident.

As already mentioned, the costs charged for using Amazon's fulfilment services are much higher for France than for Germany. This difference translates into an increase, not only in the cost of the FBA scenario, but also in the cost of the FBM scenario, where the commission cost per product, is also higher. Even so, it is in the FBA scenario that this cost has the greatest weight, representing around 92% of the total cost. The weight of the FBM commission costs charged to France can be seen by analysing the graphs as, for the quarters with the lowest demand, the FBM option of opening four DCs, outweighs the FBA scenario. This shows that, for lower demand, the costs associated with opening fewer DCs, handling the fulfilment process and paying FBM commissions, may not be worth it. On the other hand, for the quarters with the highest demand, the service fee is so high, that even opening a few DCs compensates for the total costs.

By comparing the scenarios in which a fixed number of DCs are opened, while varying the number of units allowed per shipment, it is possible to see the impact that aggregation has on transport costs, reflected in total costs. This variation is more marked for France than for Germany, as the number of DCs to be opened in France is lower. It is therefore possible to see the impact that opening three more DCs has on total costs. For France, there was an increase seen in costs for the variation in the number of units allowed per shipment, of 15% for the quarters with the lowest demand, and an increase of 17% for the quarters with the highest demand.

It is also possible to see, by analysing the graphs, that the weight of the FBA service charge in this model is quite high, by looking at the bars representing the scenarios in which this cost increases by 5% and 10% (shown by the oil blue and pink bars), with this increase being more noticeable for the quarters with higher demand.

6.2.1.E Cost Comparison

Although the cost of living is higher for Germany, which leads to higher operating and transport costs, according to the assumptions made, it would make more sense for France to have the lowest costs. However, this is not the case, which can be justified by the higher fees charged for both FBA and FBM scenarios in France, as this is the cost with the greatest weight. Since this fees (FBM) are about 4% higher per product for France, compared to Germany, this significantly raises the overall costs, regardless of the scenario studied. This factor adds a substantial burden to the total operational expenses, making France a more costly market to operate in, despite the relatively lower living and transportation costs. The fact that demand is more widely distributed in France may also contribute to the increase in costs registered, although this factor is offset by the opening of more DCs in this country. As a result, in order for the FBM model in France to reduce total costs, bringing them closer to those in Germany, the model decides to operationalise more DCs.

The difference between the weight of FBA costs strategy for the different countries is interesting. This difference suggests that the FBA model is more cost-efficient in Germany than in France, which may indicate that Amazon's Network is better established in the German market, allowing for lower fee costs. One reason for this efficiency could be the fact that Amazon's logistics infrastructure in Germany is more robust, with a better integrated network of FCs strategically located, which can be corroborated by the data, where Germany has 15 Amazon FCs available, whereas France only has 9, as can be seen in Figure A.1.

Moreover, this difference may also reflect Amazon's level of penetration and recognition in the French market. The higher prices of FBA in France may be an indication that Amazon is still in the process of expansion or consolidation in this market. This may be related to French consumers' preference for local or alternative shopping channels, demonstrating less initiative to buy through Amazon, which leads to lower economies of scale, and higher fees.

However, there is a proximity between both costs that suggest that the cost structures and variables involved in the logistics operation are similar in the two markets, which may be a reflection of the fact that operating costs are aligned.

6.3 Managerial Insights

Given the simplifications and assumptions within the model, the findings were analysed from a strategic perspective, rather than aiming for precise, real-world conclusions. The model offers a framework for comparing various scenarios, but its limitations mean that results should be interpreted qualitatively rather than quantitatively. This qualitative approach allows for a broader vision on how varying key variables might impact decision-making. While exact figures cannot be relied upon, due to the model's inherent assumptions, the patterns identified provide strategic direction, highlighting how adjustments in key cost factors, such as demand fluctuations, transportation and operating costs, might influence distribution network decisions. This approach allows us to assess broad outcomes and potential strategies that could be applied or further tested in real-world contexts, making the findings a foundation for informed, high-level decision-making rather than detailed operational planning.

The analyses carried out for Germany and France reveal some important strategic insights that can help in decision-making about the best logistics approaches for Worten's expansion in these markets.

- Weight of the transport cost between the DC and the customer: this cost is directly proportional to the distances between DCs and customers, which means that it has a greater weight in scenarios where the DC network is more concentrated, requiring deliveries over longer distances. Opening more DCs is a strategy to reduce these distances and thus, the weight on the total cost. However, opening a greater number of DCs generates costs with operating, storage costs, and with the cost of shipping from the warehouse. It is therefore necessary to take their weight in total costs into account, when strategically planning the distribution network.

- Operational efficiency for high demand: even in cases where the number of DCs to open is fixed, the difference between the FBA and FBM models becomes more pronounced in the quarters with the highest demand. This conclusion suggests that, for higher sales volumes, the FBM strategy will be more cost-effective. This can be justified in light of the high FBA rates, which exceed the logistical costs of an in-house fulfilment, when considering a high demand.

- Adapting the network to the profile of the market and to the distribution of demand: In Germany, where logistics costs are higher, and the demand is more evenly distributed, the model manages to centralise operations more easily, with a more contained strategy of opening DCs, thus controlling storage and operating costs. In France, on the other hand, where logistical costs are lower, and the demand is geographically dispersed, opening more DCs is the strategy that allows total costs to be minimised. This insight suggests that each country can benefit from a personalised logistics strategy, adapting the density of the DC network to the demand and cost profile of each market.

- The importance of a well-distributed distribution network: The sensitivity analysis of the cost of transport between the DC and the customer showed that, for variations such as increases in the cost per kilometre, or a decrease in the aggregation of shipments from the DC to the customer, which for a fixed number of DCs, would result in an increase in total costs, the model chooses to open more DCs, keeping the total cost practically unchanged. In this way, it is possible to reduce the average distance of deliveries and, consequently, minimise the impact of the increase that these changes would cause in transport costs. This adjustment highlights the importance of a well-distributed network, in such a way as to mitigate high transport costs. In this way, carefully analysing the location of DCs, can represent substantial savings in the long term.

- Impact of Amazon Service Fees: Amazon service fees for fulfilment are significantly higher in France, which increases total costs for both strategies in this country, but with a higher impact in the FBA scenario. Even though the cost of living was assumed higher in Germany, the higher service fees for France make this market more expensive to operate, as Amazon is probably worse established in France than it is in Germany.

In summary, to ensure an efficient logistics operation and keep costs under control, it is essential that the choice of fulfilment strategy takes into account many factors, such as the seasonality of demand, the location of DCs, the fees charged by Amazon, and transport costs.

7

Conclusion, Limitations and Future Work

Contents

This Chapter provides a final reflection on the study, summarizing the conclusions, limitations, and future work. Section 7.1 highlights the main findings and how the study's goals were achieved, focusing on the implications for Worten's fulfillment strategies. Section 7.2 discusses the constraints faced, such as data limitations and assumptions in the model, which may have affected the results. Finally, Section 7.3 suggests areas for further research, including improving the model and exploring alternative fulfillment strategies like outsourcing. This chapter connects the study's outcomes with future opportunities for development.

7.1 Conclusion

For any retail company, business success and growth are directly linked to the efficiency of logistics operations and the ability to adapt to new market challenges, especially in e-commerce.

To compete effectively in new markets, it is essential for the company to adapt, in order to live up to customers' expectations, by being able to operate efficiently through marketplaces. Nowadays, with the speed with which everything can be accessed, customers continually expect the best experience, that offers convenience and speedy delivery, with Amazon being the main channel they turn to. Therefore, aligning Worten's logistics operations to meet these demands and make the most of these channels will be crucial to ensure competitiveness and success on the international market.

With this in mind, the aim of this dissertation was to develop a model that would help companies like Worten, in the strategic process of internationalisation through marketplaces, like Amazon.

In order to acquire theoretical knowledge about distribution problems, a research was conducted in the academic literature. This research made it possible to build a mathematical model that would take into account all the logistical operations involved in the fulfilment process.

However, the implementation of the methodology faced several significant limitations due to various simplifications. In this way, although the study did not provide very realistic results, it did fulfil its objective by offering a basis for understanding Amazon's operating logic, and identifying general insights into possible distribution strategies to adopt. This study made it possible to understand which costs have the greatest impact and how, in relation to fluctuations in demand, they influence the effectiveness of the distribution network. Thus, although the results are not quantitatively precise, limiting their practical applicability, they provide a strategic vision of the factors that need to be considered, in order to optimise the logistics operation.

By offering a model that analyses the logistics costs of different fulfilment strategies, such as FBA and FBM, this thesis aims to provide a more general overview of the factors that influence a company's logistics costs in its internationalisation process. In this way, it is intended to act as a tool to support strategic decision-making, by simulating different logistics scenarios, which will allow to identify where it is possible to reduce costs and adjust operations, in order to make them more efficient and competitive in the markets. In this way, the thesis contributes directly to better-informed decisions, helping Worten to grow in an optimised way.

7.2 Limitations

The way the model was implemented had several limitations that affected its ability to provide a fully realistic solution. One key limitation was the division of the analyses into quarterly micro-simulations. While this approach significantly reduced processing time, it compromised the ability to capture the overall logistical behaviour across the entire year, limiting the scope of the analysis to shorter periods, rather than offering a comprehensive annual perspective. The model, with the aim of optimising costs on a quarterly basis, adjusts the number of DCs to open for each quarter, in response to changes in demand and transport costs. Opening a different number of DCs each quarter and changing their locations, leads to an unrealistic decision, as it creates an inconsistent distribution network throughout the year. This lack of stability makes it challenging to establish a reliable and predictable network of DCs.

Another constraint related to the quarter analysis is the fact that the model does not accumulate inventory, satisfying demand ”immediately” over a three month period, which does not reflect operational reality. In the real world, companies often plan their logistics operations based on forecasts of future demand, taking into account future drops in demand that may be expected. The model, in its current form, does not take into account forecasts of low demand in the following quarter, since the simulations are being carried out separately, which can lead to sub-optimal decisions.

In this way, this approach fails to consider optimising the use of pallets and journeys between the warehouse and the DC, since it only has a quarterly view. In a real scenario, when predicting low demand in the following quarter, the model would have to consider whether the costs of shipping products at the present time, in addition to the costs of operation and storage, would be a more advantageous option than shipping smaller quantities in the following quarter, in order to make the most of the pallets being shipped, and thus the journeys between the Warehouse and the DC. This translates into an increase in costs when considering an annual period, as it has a limited view of the three month period.

In addition, storage costs are being accounted for over the entire three-month period. This is an important factor, as the model assumes that products are stored and dispatched throughout the quarter, without accumulation or forecasting, applying storage costs evenly, regardless of fluctuating demand throughout the quarter.

Another critique of the methodology used in this thesis is related to the use of 15 units as the maximum quantity for sending products from the DC to the customer, in the FBM scenario. Although this approximation was adopted to simplify the logistics of the model, it is essential to reflect on the extent to which it actually reflects reality.

The use of zip codes as a proxy for customers means that, by representing a zip code as a single customer, a vast geographical area is being aggregated to a single delivery point. This approach reduces a diverse region, which can include both densely populated urban areas and less densely populated rural areas, to a single destination. This aggregation of zip codes may hide the variability in demand within the same region, where the volume of products sent to a single zip code can be distributed differently, by population density. In this way, the expectation of sending 15 units at once to a given zip code, may not occur as often as expected, since in less populated areas, or areas with lower demand, it may be more common for shipments to be made in smaller volumes, and more spread out over time, which was not adequately captured in the model used. This is an extremely important factor, especially as a relatively long period of time is being considered: a quarter. By adopting a fixed target of 15 units per shipment for each zip code, for the entire quarter, an uniformity in demand that may not exist, is assumed. Daily and weekly demand varies significantly, and over three months, these fluctuations can be even more pronounced, leading to an underestimation of logistics costs.

In a real scenario, demand can vary not only between different geographical areas (zip codes), but also within the quarter, where the quantity sent to different zip codes can vary significantly from one day to the next, making it difficult to predict how many times this quantity of 15 units will actually occur. In other words, multiple deliveries to the same zip code does not mean that they will all reach the limit of 15 units per shipment, especially accounting for the delivery time window imposed by Amazon, as zip codes may require deliveries with different frequencies, nor that they will be destined for the same location.

Therefore, although using 15 units as a threshold facilitated modelling and provided a clearer view of logistics costs, this approximation does not accurately capture the variability of real demand and shipping frequency. A more detailed and realistic analysis should take into account the geographical diversity of zip codes, the variability of demand within the quarter, and the actual frequency of shipments, which could lead to a more accurate representation of operating costs.

Another important limitation to consider is that the strategic analysis is being based on sales obtained for the year 2023 in Spain, without taking into account future growth forecasts, nor that the German and French markets may be different from the Spanish one. By using historical data from a single year, the model does not take into account changes in the consumption patterns, which may affect the analysis, as Worten aims for a growth scenario. Market behaviour and sales can vary significantly, especially if there is a growth in product sales in the German and French markets.

In a growth scenario, FBA costs would increase in proportion to sales volume, since Amazon's service fee is applied per product. However, as sales increase, Worten could take advantage of economies of scale in the FBM model, significantly reducing operating and logistics costs, since the unit cost of storage tends to decrease with larger volumes. In terms of transport, greater optimisation of vehicle capacity and more frequent shipments would allow costs per unit to be reduced, which could bring the studied scenario of shipping 15 units per shipment, closer to the real situation, since higher volume of sales could justify more frequent shipments with this quantity.

A factor that may also affect the obtained results is that the storage and operating costs, as well as transport costs between the DC and the customer were modelled on the basis of cost of living percentages in Germany and France, adapting the values of Portugal. These percentages may therefore not accurately reflect the reality of the costs in these countries, resulting in estimates that may overestimate the real transport and operating values.

In the FBA scenario, since the algorithm that Amazon uses to decide the allocation of products to its FCs, taking demand into account, was missing, the same ratio was used for the distribution of products throughout Amazon's FCs, as explained in Subchapter 5.3.3. This did not allow the model to allocate the products to their final destination in a very realistic way, which translates into a poor utilisation of the pallets sent per trip to the various destinations. This, has therefore had a direct impact on the total cost of this scenario, which requires a maximum of eight pallets for the quarters with the highest demand (Q1 and Q4), and a maximum of two pallets for the low season quarters (Q2 and Q3), which translates into a mandatory journey for each FC, every month. By using Amazon's allocation algorithm, more efficient shipping routes could have been created for the selected FCs, leading to a better optimisation of pallet capacity. This would have reduced the number of trips needed and, in turn, lowered transport costs, as pallets were underutilised.

The fact that the model did not consider the capacity of the DCs may not have had a major impact, since in the FBM scenario, the choice to open many DCs, means that the total demand is well distributed between them. This means that no single DC needs to handle a large number of units, eliminating the need for a very high capacity at each one. If only one DC were open, it would need to have enough space to accommodate all the demand for the quarter, but with several DCs operational, this requirement is softened. Furthermore, in a real scenario, where the period to be considered would be shorter than a quarter, the number of units would also be reduced, which further diminishes the importance of DC capacity. This means that the effective capacity of the DCs would probably be sufficient to meet demand, making this factor less critical to the model's performance.

7.3 Future Work

Based on the limitations identified, it is clear that the most relevant next step would be to integrate the time on a monthly scale, rather than relying on several quarterly micro-simulations, as done in this study. By modelling logistics and operating costs on a monthly basis, it would be possible to obtain a more detailed and accurate view of the supply chain's behaviour throughout the year, allowing for a continuous and more realistic understanding of logistics flows, as well as better capturing seasonal variations, peaks in demand and market fluctuations. Through an annual overview, the number of DCs to open given by the model, would take these variations into account, allowing the DC network to be adjusted consistently throughout the year.

Once this variable has been accounted for in the objective function, the next step would be the integration of France and Germany into a single distribution model. Currently, the model has been tested separately for each country, which limits the strategic vision to each territory. By expanding the model to cover both countries, it would be possible to obtain a more holistic view of the distribution network in the region, allowing for broader and more effective optimisations.

This would give the model more freedom to choose between different locations, in order to obtain a configuration that minimises the total costs for both countries. The model would probably be able to reduce the number of DCs to open (compared to the sum of the results obtained for the two countries separately) by strategically dispersing them to cover both regions. In this way, it would be possible to take advantage of economies of scale in shipments from the warehouse, since the quantity to be shipped would be greater, in order to supply the DCs that fulfil the shared demand. In addition, the joint distribution of products between the two countries could reduce the need to frequently send smaller sets of shipments needed to serve each country separately, thus reducing transport costs.

Another potential benefit of an integrated approach would be the added flexibility of the distribution network, since it would be able to utilise DCs that can serve both countries, depending on regional demand.

Since the strategy is considering subcontracting DCs in the German and French regions, the fixed costs of having operational DCs are diluted in the operational and storage costs. Thus, the fact that there are no fixed costs associated with opening DCs allows the model to minimise total costs, by opening a large number of DCs. However, this freedom results in unrealistic and unstable decisions, where the model chooses to open different DCs for different quarters, in response to variations in demand. Thus, in order to minimise the cost of transport between the DC and the customer, the model does not take into account the operational complexity that comes from managing too many DCs. To this end, it would be interesting to consider a penalty associated with the number of open DCs, in order to encourage a more balanced and realistic choice about the number of DCs to be used. This penalty could also discourage frequent changes in DC locations throughout the year, promoting a more stable distribution network in line with the reality of the operations.

As a future research, the model could integrate the LIRP into an unified model. The problem studied in this dissertation offers valuable insights into the structure of the distribution network of Amazon, allowing for a strategic and more general view of the problem, as well as the variables to be taken into account, serving as the basis for a more robust and integrated implementation. Integrating the LIRP would allow, not only for an optimisation of DC locations, that takes into account efficient customer allocation, but also for inventory management, and transport and routing decisions. This integration involves taking into account new variables that are essential for an effective logistic model. Among these variables are replenishment lead times, service levels, which have been little addressed in this study, reordering levels, as well as the lateral transhipment of stock between the chosen DCs. Taking all these important aspects into account, enables the logistics distribution network to be agile and flexible in responding to changes in demand, while maintaining a balance between cost and stock availability.

By incorporating these variables into an integrated LIRP model, will not only provide more accurate optimisation of logistics costs, but will also allow for a more strategic and adaptive supply chain management. In this way, it will be possible to design a more efficient distribution network, capable of responding proactively to fluctuations in demand and changes in market conditions, guaranteeing a significant competitive advantage.

Another potential area for future research is the development of a more comprehensive model that integrates all the scenarios explored in this study. Currently, the way the model was developed, it separates the different fulfillment models, where each scenario is tested independently. However, combining these scenarios into a single, unified model would allow for a more holistic optimisation process, as it considers a broader set of decision-making factors.

Since everything is limited to one space, including the capacity of facilities as a parameter that could influence the choice of DCs to open would be an important study to make when considering the strategic positioning of DCs.

This study focused mainly on analysing the comparative costs of FBA and FBM, highlighting the impacts of each model on Worten's logistics operations. However, in future approaches, it would be interesting to explore the potential of outsourcing fulfilment process costs, considering the use of external logistics partners. The inclusion of this type of model could offer a broader and more realistic view of the options available for optimising operations, especially if more detailed information on these alternatives were accessible. Big Buy, for example, is a third-party logistics provider that offers a comprehensive range of services for expanding online sales, by supporting brands and retailers through its Full-service Marketplace Operations, including logistics, stock management, and Direct-To-Consumer (DTC) shipping, while also aiding in international sales on platforms like Amazon.

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A

Appendix A1

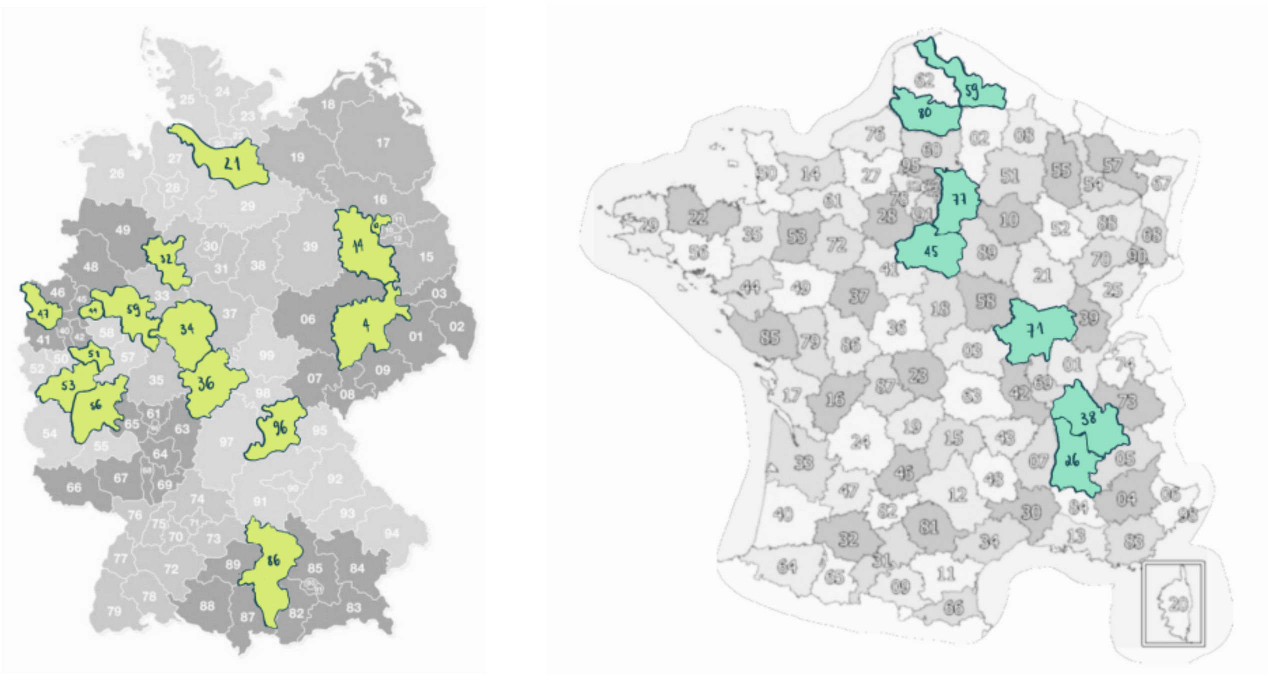

Figure A.1: a) Amazon's FCs distribution in Germany b) Amazon's FCs distribution in France

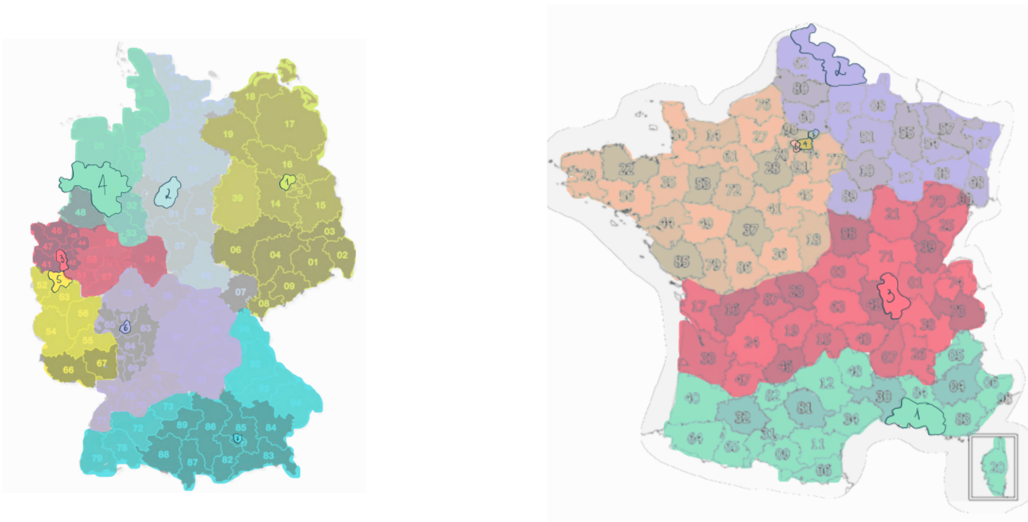

Figure A.2: a) DCs distribution and allocation proposed for Germany b) DCs distribution and allocation proposed for France

Table A.1: Average Product Family Volume

Product	Average Volume (m^3)
1	0.019
2	0.012
3	0.016
4	0.037
5	0.027
6	0.007
7	0.160
8	0.051
9	0.003
10	0.071
11	0.093

Table A.2: Average Product Family Price

Product	Average Price (€)
1	55.00
2	32.50
3	30.00
4	50.00
5	53.33
6	40.00
7	90.00
8	170.00
9	15.67
10	78.33
11	54.55

Table A.3: Amazon's Costs for Germany

Table A.4: FBM Commission Costs for Germany

Product	Commission Cost (FBM) (€)
1	24.62
2	11.21
3	10.64
4	19.38
5	21.10
6	9.74
7	56.56
8	50.55
9	9.05
10	29.46
11	23.10

Table A.5: FBA Service Costs for Germany

Product	FBA Fee for Q1, Q2 and Q3 (€)	FBA Fee for Q4 (€)
1	33.04	34.39
2	17.00	17.17
3	17.58	17.82
4	28.60	28.94
5	28.80	29.05
6	15.39	15.97
7	72.47	73.65
8	63.91	64.29
9	13.87	13.91
10	37.99	38.51
11	35.85	36.05

Table A.9: Extrapolation of data for Germany and France, obtained from the values for Portugal

	Portugal 2024	France	Germany	
Reception Cost	1.54	2.08	2.17	per pallet
Storage Cost	0.17	0.23	0.24	per day per pallet
Expedition Cost	1.54	2.08	2.17	per pallet

Table A.10: Reception and Expedition Costs for each Product, based on their volume, for all DCs, for Germany

#DC \ Product	1	2	3	4	5	6	7	8	9	10	11
1	0.032	0.019	0.027	0.062	0.045	0.011	0.272	0.085	0.005	0.118	0.151
2	0.032	0.019	0.027	0.062	0.045	0.011	0.273	0.085	0.005	0.119	0.152
3	0.026	0.016	0.023	0.051	0.037	0.009	0.225	0.070	0.004	0.098	0.125
4	0.031	0.019	0.027	0.061	0.044	0.011	0.267	0.083	0.005	0.116	0.148
5	0.027	0.017	0.023	0.053	0.038	0.009	0.234	0.073	0.004	0.102	0.130
6	0.037	0.022	0.032	0.072	0.052	0.013	0.316	0.099	0.006	0.137	0.175
7	0.031	0.019	0.027	0.061	0.044	0.011	0.267	0.083	0.005	0.116	0.148

Table A.6: Amazon's Costs for France

Table A.7: FBM Commission Costs for France

Product	Commission Cost (FBM) (€)
1	25.58
2	12.58
3	14.22
4	20.86
5	22.81
6	11.93
7	59.18
8	50.55
9	10.03
10	32.47
11	27.82

Table A.8: FBA Service Costs for France

Product	FBA Fee for Q1, Q2 and Q3 (€)	FBA Fee for Q4 (€)
1	36.26	36.84
2	21.00	22.17
3	21.08	21.93
4	34.18	35.02
5	32.95	33.87
6	17.46	18.21
7	87.73	88.46
8	63.91	64.84
9	15.07	15.91
10	38.03	48.91
11	36.43	37.13

Table A.11: Storage Costs for each Product, based on their volume, for all DCs, for month, for Germany

#DC \ Product	1	2	3	4	5	6	7	8	9	10	11
1	0.305	0.186	0.262	0.596	0.430	0.105	2.623	0.820	0.047	1.141	1.457
2	0.306	0.187	0.263	0.599	0.432	0.106	2.634	0.823	0.047	1.145	1.463
3	0.300	0.183	0.258	0.585	0.422	0.103	2.576	0.805	0.046	1.120	1.431
4	0.354	0.216	0.304	0.692	0.499	0.122	3.044	0.951	0.054	1.323	1.691
5	0.299	0.182	0.257	0.584	0.421	0.103	2.570	0.803	0.046	1.118	1.428
6	0.410	0.250	0.352	0.801	0.578	0.142	3.524	1.101	0.062	1.532	1.958
7	0.327	0.199	0.281	0.639	0.461	0.113	2.812	0.879	0.050	1.222	1.562

Table A.12: Reception and Expedition Costs for each Product, based on their volume, for all DCs, for France

#DC \ Product	1	2	3	4	5	6	7	8	9	10	11
1	0.030	0.018	0.026	0.058	0.042	0.010	0.257	0.080	0.005	0.112	0.143
2	0.018	0.011	0.016	0.036	0.026	0.006	0.158	0.049	0.003	0.069	0.088
3	0.019	0.012	0.016	0.037	0.027	0.007	0.164	0.051	0.003	0.071	0.091
4	0.027	0.016	0.023	0.052	0.038	0.009	0.230	0.072	0.004	0.100	0.128
5	0.030	0.018	0.026	0.059	0.043	0.010	0.261	0.081	0.005	0.113	0.145
6	0.079	0.048	0.068	0.154	0.111	0.027	0.676	0.211	0.012	0.294	0.376

Table A.13: Storage Costs for each Product, based on their volume, for all DCs, for month, for France

#DC\Product	1	2	3	4	5	6	7	8	9	10	11
1	0.297	0.181	0.255	0.580	0.418	0.102	2.551	0.797	0.045	1.109	1.417
2	0.266	0.162	0.229	0.520	0.375	0.092	2.288	0.715	0.041	0.995	1.271
3	0.301	0.184	0.259	0.589	0.425	0.104	2.590	0.809	0.046	1.126	1.439
4	0.781	0.476	0.672	1.526	1.101	0.270	6.715	2.099	0.119	2.920	3.731
5	0.572	0.349	0.492	1.118	0.806	0.198	4.919	1.537	0.087	2.139	2.733
6	0.206	0.126	0.177	0.402	0.290	0.071	1.771	0.553	0.031	0.770	0.984

Table A.14: Parameters Used

Parameters Assumed	Values
Cost of Living when compared to Portugal - Germany	41%
Cost of Living when compared to Portugal - France	35%
ckm for Germany	1.00 €
ckm for France	0.96 €
dcf	1.35
$ifee$	1.18 €
$irate$	0.23%
max	10 and 15 $units$
pc	33 $pallets$
pv	1.63 m^3
sl	95%
tw	48 h