

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

A Case Study of Worten

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## 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 analyzes 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

## 1. Introduction

The continuous evolution of the world's population and the increased connectivity that comes from it, have made global access to products easier for consumers, allowing companies to explore international markets with fewer barriers. Globalisation has facilitated market expansion beyond national borders, driving the internationalisation of companies as a key strategy for growth [1]. The rise of e-commerce and digital platforms has further encouraged internationalisation, with companies relying on these channels to reach a larger network of customers and offer consumers a seamless shopping experience [2]. The pandemic only accelerated the growing need for the efficient distribution of goods around the world, especially through e-commerce [3]. This increase in online demand has led companies to adapt their strategies, integrating physical and digital channels to create a seamless omnichannel experience, where customers can interact with brands through multiple touchpoints [4].

Marketplaces, such as Amazon, have emerged as a pivotal tool for companies seeking rapid international growth, by providing businesses with guaranteed visibility and global reach, transforming not only how consumers shop but also how companies manage their supply chains, from the order fulfillment to stock management [5]. The efficient management of Amazon's distribution and logistics is critical to maintain a high level of service and customer satisfaction.

In this context, Worten, a Portuguese retailer, is looking to

expand beyond its mature Iberian market into key European marketplaces, such as Germany and France. As such, this study aims to develop a methodology that helps Worten strategically enter these markets through Amazon, analysing different fulfilment options to meet customer demand and minimise delivery costs.

The main challenge addressed is to design a logistics distribution model that minimises costs while maintaining high levels of service in Worten's expansion. This includes decisions on the location of Distribution Centres (DCs), the allocation of demand between them, and the choice of fulfilment model, with the aim of maximising operational efficiency and customer satisfaction.

## 2. Literature Review

### A. Facility Location Design Problems

The strategic location of Distribution Centres (DCs) is a critical decision for supply chain efficiency [6]. The Facility Location Problem (FLP) is a widely studied area of literature that addresses the best placement of facilities to minimise total costs, which include transport and operating costs, while meeting customer demand efficiently [7].

The classic facility location problem was first proposed by Alfred Weber in 1909, with the aim of minimising the distance between facilities and demand points [8]. Over time, the problem has evolved, but its core objective remains the same: determining the ideal location of facilities, such as DCs or warehouses, in order to optimise the flow of products from

the points of origin to the end customers, meeting demand effectively and at reduced costs [9]. The strategic importance of FLP lies in its ability to affect various dimensions of business logistics, where a strategically inappropriate location can result in high transport costs, prolonged delivery times and, consequently, loss of competitiveness and customer dissatisfaction [10]. This trade-off is expressed by the number of facilities to open, which can reduce transport costs and improve delivery times, but also raises the operating costs of maintaining more units. The challenge is therefore, to identify the optimum number of facilities and their locations in order to maximise the efficiency of the logistics network [11].

However, with the growth of supply chains, FLP has gained even greater importance in strategic distribution decisions, becoming more complex and evolving to include several additional parameters, such as facility capacity, inventory policies and transport restrictions [12][11]. Various sub-problems have emerged from the traditional FLP, such as the Location Inventory Problem (LIP), the Location Routing Problem (LRP) and the Location Inventory Routing Problem (LIRP) [13].

- LIP (Location Inventory Problem): Combines facility location decisions with inventory management, focusing essentially on optimising inventory levels at different facilities, seeking to minimise inventory and transport costs while ensuring that demand is met [14] [15].
- LRP (Location Routing Problem): Integrates vehicle routing and facility location decisions, considering factors such as vehicle capacity and delivery time windows, optimising transport routes with the aim of reducing total costs, while ensuring an efficient service to customers [16].
- LIRP (Location Inventory Routing Problem): Combines location, inventory and routing decisions in a single model. In this way, it seeks to optimise the location of facilities, inventory levels and transport logistics simultaneously, in a more comprehensive approach, offering an integrated view of the entire supply chain, ensuring that decisions on the location of DCs, inventory management and route planning are taken together to minimise total costs and improve operational efficiency [17].

These problems are interdependent, and their effective solution can significantly reduce operating costs, improve customer service levels and optimise a company's logistics network [13].

#### B. Order Fulfillment

Order fulfilment is one of the pillars of success in e-commerce and refers to all the steps involved from the moment the customer places an order, until the product is delivered. With the growing popularity of e-commerce platforms and marketplaces, customer expectations regarding the speed and reliability of deliveries have increased significantly. Therefore, optimising the order fulfilment process has become essential in order to remain competitive and guarantee customer satisfaction [18]. In highly competitive markets such as e-commerce, the ability to reduce delivery times can be a decisive factor in customer satisfaction and loyalty. As such, the design of the distribution network significantly impacts order fulfilment performance and plays a crucial role in controlling business costs [19].

By using FLP in fulfillment network models, companies can optimise order allocation, reduce transport costs and deliv-

ery times, improve facility locations, and enhance their ability to respond to market fluctuations.

By studying the existing literature on these problems, this study fills a gap by exploring how these theoretical frameworks can be applied to a real-world scenario involving marketplaces like Amazon, particularly in the context of international expansion.

### 3. Methodology

The developed model considers a multi-tier logistics network for distributing products from a warehouse to final clients, via an online marketplace, indicating the 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.

In both scenarios, the aim is to optimise the flow of products, minimising total costs and meeting demand efficiently.

The notation used in the model, as well as its description, are presented in the following tables 1, 2, 3 and 4.

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 1. The objective function corresponds to minimise the transport costs associated with shipping from Warehouse  $i$  to the Marketplace's FCs,  $m$ , and the fee associated with using the Marketplace's fulfilment services. The transportation cost from the Warehouse  $i$  to the Marketplace's FC  $m$ , is presented in equation 2, and the cost of the Marketplace's fee for using the Fulfillment Service for Product  $p$ , is given by equation 3.

$$\text{Min} (ship1_{im} + fec_{imp}) \quad (1)$$

The transportation cost is presented in equation 2, and refers to the costs between the Warehouse  $i$  and the Marketplace's FCs  $m$ .

$$ship1_{im} = \sum_{i \in W} \sum_{m \in M} (FTLC_{im} + LTLC_{im} + ins1_{im}) \quad (2)$$

$$fec_{imp} = \sum_{i \in W} \sum_{m \in M} \sum_{p \in P} (fee_p \times a_{imp}) \quad (3)$$

For scenario 2, the objective function is described by equation 4, which corresponds to minimise total costs, which include 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.

$$\text{Min} (ship1_{ij} + ship2_{jk} + stc_{jp} + opc_{ijkp} + commc_{jkp}) \quad (4)$$

The transportation cost from the Warehouse  $i$  and DC  $j$  is presented in equation 5, while the Transportation Cost between the DC  $j$  and the Client  $k$  is given by equation 6.

$$ship1_{ij} = \sum_{i \in W} \sum_{j \in DC} (FTLc_{ij} + LTLc_{ij} + ins1_{ij}) \quad (5)$$

$$ship2_{jk} = \sum_{j \in DC} \sum_{k \in C} ((adjd_{jk} \times ckm \times ntrip_{jk}) + ins2_{jk}) \quad (6)$$

The Storage cost of the Product  $p$  at the DC  $j$  is given by equation 7, and the operating costs can be seen in equation 8.

$$stc_{jp} = \sum_{j \in DC} \sum_{p \in P} (stor_{jp} \times I_{jp}) \quad (7)$$

$$opc_{ijkp} = \sum_{j \in DC} \sum_{p \in P} \left( \sum_{i \in W} (recept_{jp} \times x_{ijp}) + \sum_{k \in C} (exp_{jp} \times u_{jkp}) \right) \quad (8)$$

The cost of using the Marketplace's customers is represented through a commission by product, and can be represented by equation 9.

$$commc_{jkp} = \sum_{j \in DC} \sum_{k \in C} \sum_{p \in P} comm_p \times u_{jkp} \quad (9)$$

To obtain the main equations, it was necessary to do some intermediate calculations, described from equation 10 to 16.

Since transport data from Warehouse  $i$  to Destination  $D$  depends on the number of pallets and the destination's zip code, the model converts product units into pallets. This conversion considers the products' average volume,  $vol_p$ , and the fixed pallet capacity,  $pv$ .

Equation 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,  $M$ . Once the number of pallets is known, it is necessary to determine how many complete journeys are needed to transport these pallets, since the maximum capacity of a truck for a Full Truck Load (FTL) is 33 pallets.

Equation 11 divides the total number of pallets,  $N_{id}$ , by the maximum pallet capacity per trip,  $pc$  (in this case, 33 pallets). Equation 12 calculates the cost of the FTLs needed to ship the demand, from Warehouse  $i$ , to Destination  $d \in \{DC, M\}$ , whether this is the DC or the FC of the Marketplace, when the number of pallets being transported is 33 ( $N = pc$ ).

$$N_{id} = \frac{\sum_{p \in P} inP(x_{idp} \times vol_p)}{pv} \quad \forall i \in W, \forall d \in \{DC, M\} \quad (10)$$

$$ctrip_{id} = \frac{N_{id}}{pc} \quad \forall i \in W, \forall d \in \{DC, M\} \quad (11)$$

$$FTLc_{id} = ctrip_{id} \times tc_{idN} \quad \text{with } N = pc, \quad \forall i \in W, \forall d \in \{DC, M\} \quad (12)$$

However, there are still some pallets that are not enough to completely fill a truck (33 pallets), known as Less than Truck Load (LTL).

Equation 13 calculates the number of remaining pallets, which are not being accounted for in the complete journeys. And then, the cost of the LTL is calculated, in equation 14.

$$addp_{id} = N_{id} - (ctrip_{id} \times pc) \quad \forall i \in W, \forall d \in \{DC, M\} \quad (13)$$

$$LTLc_{id} = tc_{idN} \quad \text{with } N = addp_{id}, \quad \forall i \in W, \forall d \in \{DC, M\} \quad (14)$$

The 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. In this way, it is necessary to first calculate the value of the commodities (15) in order to then, calculate the value of the insurance (16):

$$vog_{id} = \sum_{p \in P} (x_{idp} \times pp_p) \quad \forall i \in W, \forall d \in \{DC, M\} \quad (15)$$

$$ins1_{id} = vog_{id} \times irate \quad \forall i \in W, \forall d \in \{DC, M\} \quad (16)$$

In order to obtain the total cost of transport from Warehouse  $i$ , to Destination  $d \in \{DC, M\}$ , all these costs are added, represented by equation 17.

$$ship1_{id} = \sum_{i \in W} \sum_{d \in \{DC, M\}} (FTLc_{id} + LTLc_{id} + ins1_{id}) \quad (17)$$

This is a generic formula, which covers the various destinations to which goods can leave from the Warehouse  $i$ , depending on the scenario being used (the Destination  $d \in \{DC, M\}$  can be the DC  $j$  or the Marketplace's FC  $m$ ).

Given that the value of the transport costs between the DCs and the end customers is given by  $km$ , the Haversine formula is used, to determine this distance, accounting for the Earth's curvature, to which is added a Distance Conversion Factor,  $dcf$ , in order to adjust the calculated distances between the two geographical points, so as to reflect actual traveling conditions. Haversine uses the latitude and longitude of the two points.

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

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 18 calculates the number of journeys required to transport all the products. For each journey, a fee is charged, and equation 19 calculates the total cost of insurance, associated with the number of journeys.

$$ntrip_{jk} = \frac{\sum_{p \in P} u_{jkp}}{max} \quad \forall j \in DC, \forall k \in C \quad (18)$$

$$ins2_{jk} = ntrip_{jk} \times ifee \quad \forall j \in DC, \forall k \in C \quad (19)$$

Equation 20 calculates the total transport cost between DC  $j$  and the end customer  $k$ , including both the transport cost and the insurance cost.

$$ship2_{jk} = \sum_{j \in DC} \sum_{k \in C} ((adjd_{jk} \times ckm \times ntrip_{jk}) + ins2_{jk}) \quad (20)$$

### Constraints for the model

Scenario 1 only needs a restriction to ensure that the total demand is met, and sent to the Marketplace's FCs, and is given by constraints 21.

**Table 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 2: Parameters**

Parameters	Description
$adj_{jk}$	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 ( $m^3$ )
$ppp$	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, $N_{pallets_{id}}$ (€)
$tw$	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 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
$feec_{omp}$	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: 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)

$$\sum_{i \in W} x_{imp} \geq \overline{dem}_{kp} \quad \forall m \in M, \quad \forall k \in C, \quad \forall p \in P \quad (21)$$

Scenario 2 constraints are defined from equation 22 to 31.

$$\sum_{i \in W} x_{ijp} = \sum_{k \in C} u_{jkp} + I_{jp}, \quad \forall j \in DC, \quad \forall p \in P \quad (22)$$

$$\sum_{j \in DC} u_{jkp} \geq \overline{dem}_{kp}, \quad \forall k \in C, \quad \forall p \in P \quad (23)$$

Constraint 24 ensures that at least one DC is open.

$$\sum_{j \in DC} z_j \geq 1 \quad (24)$$

$$x_{ijp} \leq \text{big}M \times z_j, \quad \forall i \in W, \quad \forall j \in DC, \quad \forall p \in P \quad (25)$$

$$u_{jkp} \leq \text{big}M \times z_j, \quad \forall j \in DC, \quad \forall k \in C, \quad \forall p \in P \quad (26)$$

$$w_{jkp} \leq z_j \quad \forall j \in DC, \quad \forall k \in C, \quad \forall p \in P \quad (27)$$

$$\sum_{j \in DC} w_{jkp} = 1 \quad \forall k \in C, \quad \forall p \in P \quad (28)$$

$$u_{jkp} \leq \text{big}M \times w_{jkp}, \quad \forall j \in DC, \quad \forall k \in C, \quad \forall p \in P \quad (29)$$

$$\frac{\text{adj}_{jk}}{\text{vel}} \times w_{jkp} \leq \text{tw}, \quad \forall j \in DC, \quad \forall k \in C, \quad \forall p \in P \quad (30)$$

$$\overline{dem}_{kp} \times \text{sl} \leq \sum_{i \in W} \sum_{j \in DC} x_{ijp}, \quad \forall k \in C, \quad \forall p \in P \quad (31)$$

$$w_{jkp}, z_j \in \{0, 1\} \quad \forall j \in DC, \quad \forall k \in C, \quad \forall p \in P \quad (32)$$

$$a_{imp}, I_{jp}, x_{ijp}, u_{jkp} \geq 0 \quad (33)$$

Constraints 22 are the conservation of flow, and 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 DC. Constraints 23 ensure that each customer's demand for each product is satisfied by the quantity dispatched from the DC. Constraints 25 and 26 ensure that DCs can only be

used to ship products if they are open. Constraints 27 ensure that the respective DC can only serve a customer if it is in operation. Constraints 28 ensures that each customer is allocated to only one DC, avoiding multiple allocations.

Constraints 29 ensure that the flow of products from the DC  $j$  to Customer  $k$  only occurs if the customer is allocated to the DC. The delivery time constraints (30) guarantee that the time taken to transport the products from the DCs to the customers does not exceed the limited time window,  $\text{tw}$ , ensuring that the products are delivered on time. The service level agreement constraint (31) ensures that customer demand is met at a specified minimum level. Finally, the last two constraints, 32 and 33 are variable domain constraints.

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

## 4. Case Study

### A. Worten

Worten is one of the leading electronics and home appliance retailers in Portugal, and is part of the renowned Sonae Group. With an omnichannel strategy, the company operates in both

physical shops and e-commerce, offering a wide range of technological products, from consumer electronics to specialised services. Having consolidated its presence in the Iberian market, the next step is to expand into other European markets, especially through well-established marketplaces such as Amazon. This international expansion brings new challenges, especially in the logistics area where, in order to compete in markets such as Germany and France, Worten needs to ensure that its products reach customers quickly and efficiently, while keeping costs under control.

### B. Amazon

Amazon is one of the largest global e-commerce platforms, connecting sellers from various sectors to millions of consumers around the world. Through this platform, companies like Worten can expand their international presence without the need for a robust physical infrastructure in each market. Amazon offers sellers two main fulfilment options: Fulfillment by Amazon (FBA), where Amazon manages the entire logistics process, and Fulfillment by Merchant (FBM), where the seller is responsible for storing and delivering the products themselves, using Amazon only as a Marketplace [20].

In the FBA model, Amazon controls the storage, packaging and shipping of products, using its vast network of distribution centres to guarantee fast deliveries. One advantage of FBA is the access to the Prime programme, which offers accelerated deliveries, increasing product visibility [21]. However, this entails significant additional fees, which can affect profit margins, especially for low-value products. In contrast, FBM offers Worten greater control over the logistics process, allowing for personalisation in shipments and returns management, but requires a robust logistics infrastructure to guarantee competitive delivery times [22].

### C. Scenarios

The scenarios analysed in the study aim to assess the two logistics approaches that Worten can adopt in its expansion into the German and French markets. In the first scenario, FBA is analysed as a distribution solution, where products are sent from Worten's warehouse directly to Amazon's Fulfillment Centres (FCs) in Europe, with costs including transport and FBA fees. In the second scenario, Worten chooses to manage the fulfilment process directly, using intermediary DCs, which gives it greater control over logistics and allows it to decide on the location of DCs, with a view to efficiently allocating products to customers.

### D. Assumptions

The main assumptions made were summarised:

**Product Families:** Products were grouped into 11 families based on similarities in type, volume, and weight to simplify logistical analysis. This data was provided by Worten.

**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 represented by a unique zip code.

**Transport Costs from the Warehouse to the DC:** The transport costs provided by Worten for the products leaving the warehouse were for the *Schenker* carrier, and were per pallet, from the warehouse to 95 postcodes of each Germany and France.

**Transport Costs from the DC to the End Client:** These transport costs were calculated based on the taxed cost per kilometer used in Portugal, adjusted to the cost of living of these countries. A rate of 41% and 35% was used for Germany and France, respectively.

**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.

**DC's 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.

## 5. Results and Discussion

### A. 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.

Due to computational and data limitations, the model had to be split into two different models, one for each scenario - FBA and FBM - , instead of an integrated one, allowing for a separate analysis of operating and transport costs, which was essential to reduce processing time and make the runs feasible.

Also due to computational limitations, the model was divided into quarterly micro-tests, allowing to reduce execution time, but simplifying some aspects. This approach provides insights into seasonal demand, but lacks a single optimal solution of DCs to open for the year, requiring strategic, qualitative analysis of quarterly trends.

Another important simplification is that, regardless of the variation in the Service Level Agreement (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, without any inventory accumulation, which would mean that storage costs are not being accounted for, which is totally unrealistic, especially when analysing a three month period. For this reason, the storage cost had to be adjusted to reflect the continuous flow of products, changing from the storage cost, equation 7, the variable regarding the inventory,  $i_{j,p}$ ,  $x_{i,j,p}$ . 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 also does not reflect reality. In this way, storage costs end up being inflated, since the model does not consider fluctuations in demand throughout the quarter.

In the absence of the algorithm that Amazon uses to distribute the products to its FCs, the same reason was used to distribute the products to the DCs. In this way, it doesn't allow the best use to be made of the capacity of the trucks, which should also be taken into account for the lack of precision in the result obtained.

### B. Presentation and Discussion of Results

To evaluate the logistical feasibility of the FBA and FBM scenarios for France and Germany, tests were conducted

across all four quarters, to capture seasonal demand fluctuations. In the FBA scenario, costs were estimated based on shipping costs to Amazon's FCs and FBA service fees, with limited flexibility to study different cost variations. In contrast, the FBM scenario allowed the model to decide which DCs to open based on transport, operating, storage, and commission costs. As it is made up of more costs, it was possible to explore the impact that variations in these costs have on the strategy. Thus, the FBM scenario was the focal point for optimising logistics distribution costs, across both countries.

#### B.1 Observed Global Patterns: Germany and France

The analysis of the FBM scenario reveals consistent logistical patterns between Germany and France, as both countries exhibit similar trends.

To deepen the analysis, three scenarios were tested: one with a single DC open, another with two DCs open, and a third, where the model optimises both the number and location of DCs to operationalise. This comparison highlights the impact that a centralised versus distributed structure, has on transport and operating costs.

In the case of both Germany and France, the increase in the number of operational DCs is accompanied by a drop in transport costs between the DC and the customer. 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.

The transition from opening one to two DCs has a very steep negative slope, which reflects the impact that a geographically distributed network has on logistics costs, where this expansion makes it possible to substantially reduce the distance between the DC and the customer, offering the greatest benefit in terms of transport costs.

It can also be seen that, as the number of DCs to be opened increases, the transport costs between the DC and the customer tend towards the same value for the different quarters, despite opening a different number of DCs. Thus, the solution that minimises transport costs, tends to open fewer DCs, for quarters with lower demand. This shows 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, the model opens more DCs, in order to optimise geographical coverage, and reduce these distances as much as possible.

As for total costs, it is possible to identify the same reduction in costs with the increase in the number of operational DCs, although this reduction is less marked than the one seen for transport costs between the DC and the customer. This indicates that, although opening more DCs allows the model to reduce total costs, this reduction does not have such a high weight in total costs, as it does in transport costs. As increasing the number of DCs reduces the cost of transport to the end customer, it also increases other logistics costs, especially in quarters of high demand, where total costs increase due to volume. This balance reflects the trade-off between reducing distances and the additional operating, storage and transport costs of opening more DCs, which the model takes into account, to identify the most economical configuration.

For France, the costs of Amazon's fulfilment service are considerably higher than for Germany, covering both the FBA fee and the commissions charged when using only Amazon's marketplace (FBM). On average, there is an increase of around 4% in FBM commissions, and 14% in the FBA fee per product, for the French market, compared to the German market. So, although the input data for transport, operating and storage costs are lower for France (as they have been modelled according to the cost of living in that country), this increase directly impacts the total costs, as it applies to each product, making the operation in France a bit more expensive.

Knowing that the cost used per kilometre between the DC and the customer is lower for France, it would be expected that the model would not need to open as many DCs as for Germany, in order to minimise total costs. However, this is not the case, as more DCs are opened for all quarters. The transport costs between the DC and the customer obtained are also more expensive for France, than for Germany, when only one DC is opened. 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, increasing the number of DCs in France is the model's response to mitigate the high transport costs incurred in travelling between the DC and the customer. By opening more DCs, the model manages to reduce the average delivery distances through the strategic distribution of DCs, allowing the transport costs obtained for the different quarters, to be very similar to those obtained for Germany.

When comparing the relative weights of the costs obtained for the scenario in which only one DC is opened, or an excessively large number of DCs are opened (given by the model's solution), the model's aim of minimising costs that are variable per quarter becomes clear. Thus, there is a reduction in their weight, increasing the relative weight of commission costs (costs that are fixed to the demand for the quarter) from around 50% to around 80%. As might be expected, this cost is higher for the quarters with the highest demand, which is justified by the volume of sales in these quarters.

#### *B.2 Sensitivity Analysis on Transport Costs between the DC and the Client*

As identified by the relative weight of the cost of transport between the DC and the customer, for the scenario where only one DC is opened, this is the the main variable to be studied in order to draw conclusions about its influence on total costs, and on the efficiency of a distribution network.

##### **Number of units allowed per shipment**

It was necessary to set a limit on the number of units allowed per shipment between the DC and the customer, given that demand is analysed on a quarterly basis, and will not be delivered in a single trip, nor in an excessive number of individual journeys. For a more precise comparison, the impact of this limitation on transport costs and total costs was analysed, considering a reduction in the limit from 15 to 10 units per trip. The aim was to understand how this variation would affect logistics costs.

This reduction, by allowing less aggregation of orders, increases the number of journeys needed to meet quarterly demand, which directly affects the cost of transport between the DC and the end customer. It was therefore expected that this

change would result in an increase in transport costs, since by reducing the capacity of each consignment, more deliveries would be required for the same demand. However, this impact was not observed in transport costs, which decreased with the reduction in aggregation. This reduction can be explained by the increase in the number of DCs that the model suggests to open: by limiting to fewer units allowed per journey, the model requires more DCs, in order to reduce the proximity between them and the demand points, avoiding high transport costs per unit, that result from the increase in journeys needed to meet demand.

It can also be seen that, in the quarters with the highest demand, transport costs between the DC and the customer are lower, regardless of the limit of units allowed per shipment. This is due to the greater efficiency gained in consolidating a larger volume of orders.

Total costs have remained practically stable, with a very subtle increase as the number of units allowed per shipment decreased, a fact that can be explained as the total cost is not just about transport between the DC and the customer. Thus, an increase in the number of open DCs, in order to reduce the cost of transport between the DC and the customer, that comes with the lower aggregation of shipments, results in an increase in other logistics costs.

##### **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, the initial cost per kilometre used for each country was gradually reduced by 36%.

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.

The analysis showed, as might be expected, that despite the reductions in the transport cost per kilometre, the total costs remained practically unchanged, with only slight decreases. This stability in total costs 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 the DCs closer to customers, resulting in a trade-off between all the 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.

In this way, as the cost per kilometre increases, the model tends to decrease the cost of transport between the DC and the customer, by increasing the number of DCs open, with this variation being more marked for the quarters with the highest demand. Thus, by having the DCs more distributed across the regions, the model manages to reduce the costs associated with shipping products from the DC, justifying the negative slope. This variation is more marked for quarters with higher demand, as by increasing the number of open 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 increase in the number of DCs operating is more evident, which is justified by the strategy of meeting the high demand efficiently. 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.

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. 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 showed an increase in operating and storage costs, especially in the quarters with the highest demand, as the number of open DCs increases, a reflex of the increase in the cost per kilometre. This is because, for a few DCs, the model has the freedom to choose the cheapest ones, but with more DCs, this flexibility decreases, requiring the inclusion of higher-cost units, which proportionally increases storage and operating costs.

For France, the same results were found, although the variations in costs were less marked, as the cost per kilometre increased. 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. Since the reduction in transport costs between the DC and the customer is not so pronounced with the increase in the cost per kilometre, as it is for Germany, the increase in the other logistics costs could not be expected to be as pronounced. As might be expected, the number of DCs to be opened increases with the rise in the cost per kilometre, more than for Germany, a fact justified by the disperse distribution of demand across this region.

### *C. Analyse by Country*

For the analysis for each country, 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.

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, for Germany, 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).

However, for France, instead of offering the model the seven DCs located in the zip codes with the highest demand, only four were given as an option. This can be justified because, for this country, 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 the pallets from the warehouse to neighbouring zip codes, resulting in an increase in unnecessary journeys, it was decided to opt for four, rather than seven locations, for possible DCs.

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 (4, for France), varying the number of units allowed to be sent from the DC to the customer, between 10 and 15, for a fixed number of open DCs.

The analysis of the data shows that the cost of the FBA scenario is, for both countries, consistently higher than that of the FBM scenario, when the number of DCs to be opened, is given by the model. However, while for Germany, the FBM scenario where 7 DCs are opened, and the aggregation of 15 units per shipment is used, is also lower than the FBA scenario, for all quarters, for France it is not. In this country, the FBM scenario, opening 4 DCs and using the same shipment aggregation, outperforms the FBA scenario, for the quarters with the lowest demand. This can be explained by the high FBM rates which, for low volumes of demand, the costs associated with opening fewer DCs, handling the fulfilment process and paying FBM commissions, may not be worth it.

The difference between the FBA and FBM scenarios is more pronounced for the quarters with higher demand, which can be explained by the high fees charged for the FBA service, which has a larger relative weight in the total cost of this scenario, discouraging this fulfilment strategy, especially for higher sales volumes.

Furthermore, by setting a number of DCs to open, it was possible to infer the impact that aggregating shipments between the DC and the customer has on costs, especially for higher demand. The increase in total costs registered was of 10%, for the lowest demand for Germany, and 15% for France; and an increase of 12% for highest demand for Germany, and 17% for France. In France the increase in costs is greater, due to the dispersion of demand across the country, as well as the fact that for France, the number of operating DCs considered is three DCs less.

### *E. Cost Comparison*

Although the cost of living is higher in Germany, which leads to higher operating and transport costs, total costs are surprisingly higher in France, although this difference is not significant. This is due to the fact that FBM rates are 4% higher per product, which is reflected in the total costs, making France a more costly market to operate in, despite the relatively lower living and transportation costs. The difference in fees between the countries suggests that Amazon, as a marketplace, is more efficient in Germany (corroborated by the number of FCs in this country, compared to the number of FCs in France), which may reflect a higher degree of brand recognition.

However, the proximity between the costs of the two countries suggests that logistics cost structures are similar, reflecting alignment in operating costs.

### *F. Managerial Insights*

Given the model's simplifications, the results were analysed from a strategic perspective, without seeking exact conclusions for the real world. In this way, the model requires the

results to be interpreted in a qualitative way, by comparing the different scenarios. This approach makes it possible to visualise how variations in factors, such as fluctuations in demand and operating and transport costs, can impact decisions in the distribution network. The patterns identified offer strategic direction, serving as a basis for informed decisions at a high level, rather than detailed operational planning.

In this way, the analyses carried out revealed some important strategic insights that can help in decision-making about the best logistics approaches for Worten's expansion in these markets.

**Weight of transport costs between DC and customer:**

This cost is proportional to distances, weighing more heavily on concentrated DC networks, which require longer deliveries. Opening more DCs reduces distances and costs, but increases operating and storage expenses.

**Operational efficiency for high demand:** In quarters of high demand, the FBM model is more economical than FBA, since the high FBA rates outweigh the FBM logistics costs when sales volumes are high.

**Adapting the network to the market and demand profile:** In Germany, where logistics costs are higher and demand is distributed, centralising operations helps control storage and operating costs. In France, with a more dispersed demand and lower logistics costs, opening more DCs minimises the total cost, indicating the need for personalised strategies.

**Importance of a well-distributed network:** Sensitivity analysis revealed that opening more DCs can keep total cost stable by reducing average delivery distances, mitigating impacts from cost per kilometre increases.

**Impact of Amazon service fees:** FBA fees in France are significantly higher, driving up total costs, especially in the FBA scenario, and making the French market more expensive to operate, possibly due to Amazon's smaller infrastructure in the country.

In summary, to ensure an efficient logistics operation and keep costs under control, it is essential that the choice of fulfillment strategy takes into account the seasonality of demand, the location of DCs, the fees charged by Amazon and transport costs. A hybrid approach, combining FBM and FBA according to fluctuations in demand throughout the year, may be a viable solution for Worten in the French market.

## 6. Conclusions, Limitation and Future Work

### A. Conclusions

The study concludes that the success of a retail company in its international expansion is directly related to the efficiency of its logistics operations. As a company seeks to adapt to the challenges posed by internationalisation and e-commerce, it is crucial to align its logistics operations with consumer expectations. This requires an agile and efficient operation that can offer fast deliveries and a high level of customer convenience.

This dissertation aimed to create a model to support companies like Worten in strategising their internationalisation through marketplaces, particularly Amazon. A literature review provided theoretical insights into distribution challenges, informing the construction of a mathematical model that encompasses the key logistical processes in fulfillment.

Despite substantial methodological limitations and simplifications, the study met its goal by establishing a foundation for understanding Amazon's operational framework and offering broad insights into possible distribution strategies. The research highlighted which logistics costs are most impactful

and how they interact with demand fluctuations, to affect network efficiency. While the quantitative results may lack precise practical application, they offer a strategic perspective on optimising logistics operations. In this way, the study may be used as a tool for strategic decision-making, supporting Worten's optimised growth and competitiveness in new markets.

### B. Limitations

The limitations identified in the study mainly involve the simplifications necessary to make the analyses and the tests feasible, which had an impact on the accuracy of the final results.

One of the main limitations was the simplification of time in quarterly analysis. While these analysis allow for a clear view of costs and demands over the course of each quarter, they do not fully capture fluctuations in demand and logistical behaviour over shorter periods, such as monthly or weekly. This can lead to a less accurate analysis of how sales volumes and transport costs vary, according to seasonal peaks or changes in consumer behaviour. As the model aims to optimise costs quarterly, it adjusts the number and locations of DCs, based on demand and transport costs. However, changing DC numbers and locations each quarter results in an unrealistic, inconsistent distribution network, making it difficult to establish a stable and predictable logistics setup throughout the year.

In addition, the model does not build up stock over the quarter, meeting demand immediately, which doesn't reflect the real dynamics of logistics operations, where planning is based on forecasts. This approach can result in under-utilisation of pallets and increased storage costs, as it does not optimise shipments continuously over time.

Another important limitation of the study is related to the assumption that all customers are represented by specific zip codes and that each shipment to the zip code takes a total of 15 units. By representing each customer as a single zip code, the model does not take into account the actual geographical dispersion of consumers within a specific area, failing to capture the complexity of the logistical costs, involved in serving customers spread over larger areas. Furthermore, by imposing a limit of 15 units per shipment, the model does not reflect real variations in demand between different types of customers or over time. In this way, the model simulates the reality that products are not shipped all at once, but in a staggered and continuous manner, throughout the quarter. The assumption of uniform demand can distort the results, as peaks in demand and seasonal fluctuations are not properly taken into account.

The study uses Worten's 2023 sales data from Amazon Spain as a demand forecast, assuming constant demand across Germany and France, without considering market differences or growth projections. Additionally, transport and operating costs were estimated based on cost-of-living adjustments between Portugal, Germany, and France, which may inflate costs, as cost-of-living differences are diminishing.

### C. Future Work

To address current limitations, the study's first next step should be to integrate the time on a monthly scale, offering a more accurate and continuous view of the operations. Monthly modeling would better capture seasonal demand peaks and market fluctuations, allowing for more realistic logistics flows and consistent DC adjustments throughout the year.

Furthermore, integrating France and Germany into a single distribution model, rather than analysing each separately,

would provide a holistic view of the regional network. This approach could reduce the total number of DCs by strategically positioning them to cover both regions, leveraging economies of scale in shipments and reducing the need for frequent, smaller shipments from the warehouse to the DC.

Since the strategy is considering subcontracting DCs in Germany and France, fixed costs are included within operational and storage expenses, which leads the model to minimise costs by opening numerous DCs. However, this leads to unrealistic and unstable decisions where DCs change each quarter, based on demand shifts. To address this, introducing a penalty for the number of open DCs could help the model favor a more stable and realistic network, reducing operational complexity and discouraging frequent location changes.

Furthermore, after this integration, including the LIRP in an unified model would provide a richer and more complete view of the entire process, since the model would optimise customer allocation, inventory management and transport decisions, in a single approach. Incorporating essential variables, such as replenishment times and vehicle routing, would make the distribution network more agile and flexible, obtaining a more strategic view and allowing Worten to respond proactively to fluctuations in demand, and changes in the market.

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.

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