Locating Logistic Hubs

The Case Study of Worten

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Abstract

Nowadays is vital for a company to differentiate itself from the competition. For Worten, the solution is to offer a service capable of delivering online orders throughout Portugal's Mainland within a two-hour window. Currently, this is already being in some Worten's stores, only serving customers which are within a limited covering radius. To reach all of Portugal's demand, it is necessary to implement several logistic hubs to serve the 278 municipalities spread along Portugal with the purpose of serving online orders.

With the information provided by Worten, it was possible to design several scenarios that could meet the company's requirements. Based on the location and operational cost of each order; the coordinates, demand and cost per square meter of each municipality; and other factors, such as covering radius, hub capacity and percentage of demand covered, it was possible to reach interesting results.

From the different scenarios, it was possible to conclude that multiple allocations can be more cost-effective than single. In addition, the 25 km radius is the most realistic model but can easily be the most expensive due to the short covering area. Finally, with 5 logistic hubs, and depending on the covering radius, it is possible to cover between 51% and 88% of online orders.

To conclude, several scenarios will be presented in this project, providing several courses of action when implementing logistic hubs.

Keywords: Logistic Hubs, p-Hub median, Single Allocation, Multiple Allocation, Location Problems.

1. Introduction

Worten's online channel has been growing in the past years, and with the pandemic, an increase in online orders was perceptible. Consequently, all the operations in the warehouse were adapted partially due to this new reality of sales, and with this, Worten needs to distinguish itself from the competition. A way of differentiating in the retail sector is by offering shorter delivery times, which nowadays represent a strong challenge to these types of supply chains while trying to optimise the transportation cost. With the implementation of a logistic hub, Worten will have the possibility of freeing up space in the main warehouse by having inventory distributed among these hubs, reducing transportation costs. Also, the hubs will have the purpose of making possible deliveries within 2 hours to draw more future customers.

2. Case Study

2.1. Problem Definition

Worten is a company that operates in the retail sector, where it sells large home appliances, to all types of electronics goods and recently expanded to the health and fitness sector, products that can be found in today's gyms. Since 2018, the company has been building an important journey in its Marketplace, where Worten was able to offer a broader range of products by allowing trusted partners to sell their products on the website, granting Worten the possibility to enter new retail categories and the objective is to keep growing in this area of business. Furthermore, the services areas also expanded and after the acquisitions of iServices, a smartphone company operating in Portugal in 2020, Worten acquired Zaask, which is an online platform for contracting home services, and Satfiel, a company mainly focused on the repairment of household appliances and other electronic devices, in 2021. It is essential to refer to omnichannel-based operations and the evolution of different ways a customer can purchase a product by integrating the online store with the physical stores. Services such as Click&Collect, which allows consumers to pick up their order within 15 minutes, Express Delivery, which delivers online orders within 2 hours, and finally, next-day home delivery and the possibility of knowing if a certain store has in stock a specific product.

In the context of the Covid-19 pandemic, the e-commerce sector had a substantial increase in online orders and the need to satisfy customers became the main concern for many online retailers. In this new reality of online shopping, companies are now adopting an approach of Customer Centricity, where customers' needs and preferences are the starting point of all major decision-making within each company. As a way of responding to this approach, many organisations have been focused on offering a wide variety of products and shorter lead times to distinguish themselves from competitors and gain more market share. The higher uncertainty, now resulting from recent events, also impacted the storage space of Worten's warehouse. One strategy implemented by Worten was to increase its safety stock, which also affected its storage space. Looking at Worten's supply chain and the current hubs that have been implemented, one can say that the hubs appeared as a response to the high transportation cost of some SKUs and to serve as a smaller warehouse where it is possible to store several products since stores have limited storage space and the main warehouse is running out of space due to the current situations that were already mentioned. The Logistic hubs already in operation are in Madeira and Coimbra, and both supply the Worten stores in the respective areas. However, when they were implemented, the purpose was to serve a necessity, and they have not reached their maximum efficiency.

It is relevant to add that, due to the pandemic, Worten used some stores to operate as a fulfilment centre for online orders and as a warehouse for other stores. But still, this operation is far from being optimised, and situations such as shipping an order from a Worten store to a customer must be analysed because it will result in higher transportation costs while impacting the service level and delivery time.

The main focus of this thesis is to help Worten with the implementation of logistic hubs. Therefore, the optimal solution will be presented with the different locations for each hub, depending on the covering distance, followed by a more suitable and realistic solution. Regarding the location of the logistic hub, some concepts will be considered, such as Network Design, Last-Mile Deliveries and Hub Location Problems. To identify the municipalities in Portugal which have more online orders, it was decided to use clusters to help simplify the problem.

It is worth mentioning that there are two flows to obtain a product from Worten, which will help to understand the Logistic Hub's purpose better. The first one is the offline flow, the traditional pick-up at the store, which greatly impacts Worten's sales volume. The next is the online flow, where the customers have two options, HD or SD. By choosing the HD option, the customers receive the online order at home on the next business day or within two hours if the order meets specific parameters (supplied by a pilot "HD 2 hours" store). The SD option, known as Click&Collect, allows the customer to pick up the order at a nearby store on the next business day or within 15 minutes if the respective stock has stock available for that product.

The objective is to implement logistic hubs within Worten's supply chain to expand the

"HD 2 hours", currently in pilot phase, to cover all the demand in Portugal's Mainland or partial coverage depending on the results obtained from this study and Worten's strategic decision. In Worten's operation, there are three options to transport the SKUs to the stores or logistic hubs. The first one is the box aggregating the small SKUs that can fit inside this container. The SKUs with larger dimensions that still belong to 708 are shipped individually in pallets. The last one is 701 SKUs that are shipped individually to the sites but will not be considered in this study since they are not eligible for "HD 2 hours".

Requirements for the implementation of the logistic hubs:

- Be able to meet the 2 hours lead times within the respective covering distance.
- Have the capacity to fulfil online demand autonomously.
- The area of a logistic hub must be the minimum possible to fulfil the orders allocated to it to ensure the minimum cost without comprising the service level.
- The logistic hub location must be the one that minimises the cost per square meter without compromising the optimal solution
- The distance travelled between nodes must be minimised to reduce transportation costs.

KPIs considered:

- Demand covered.
- Minimum and Maximum Capacities.
- Cost of each Hub.
- Transportation Cost.
- Total Cost.
- Cost per order.
- Cost per one percentual point of coverage.

Problem Statement and Objectives

To understand where to place a hub, based on demand, lead time restrictions, transportation costs optimisation and other factors, the model must be designed to provide the best possible results to Worten. This model will have, as inputs, the demand aggregated by municipality, the cost per square, covering distance of the hubs and the respective number of hubs to implement. Other inputs that must be considered is the percentage of orders covered. The main objective is to determine the number of logistic hubs, their location and the costs to implement them to cover 100% and 90% of Worten's online orders.

3. Literature Review

3.1. Logistic Hubs

Hubs are facilities that offer several operations like consolidation, connection and switching points for flows between demand points. [1] In addition, they provide super-fast order deliveries, allow companies to be closer to major cities, and ensure the efficiency of last-mile deliveries. [2] **Last-Mile deliveries** are essential to providing the best customer service at an affordable price for the customer. The order delivery to the customer is logistically changeling because of the various factors involved and can become very expensive. [3] [4] **Same-day deliveries** are a powerful tool for online retailers and serve as a strategy to increase sales. SDD, as the name implies, offers the possibility for the customer to order goods online and receive them the same day. [5] Several authors refer to it as being the most common delivery mode. [6] This strategy has seen massive growth with the pandemic, which provides convenience to the customer by eliminating the need to go to the store to pick up their product(s). [5]

"The growth in e-commerce has led to an increase in door-to-door, same-or next-day delivery services within the courier, express, and parcel (CEP) sector, in particular for home deliveries" [7]. Consequently, **Instant Deliveries** are a growing market segment where consumers can buy products online and receive their delivery within less than one or two hours. This new service comes from the fact that customer demands are becoming more sophisticated, meaning a fast delivery at a low price.

3.2. Network Hub Location Problems

Over the years, several authors performed studies to solve the problem of Hub Location. The first authors to begin the study of this problem were Morton E. O'Kelly [8] and James

F. Campbell in 1986. [9] Since then, several other researchers have been studying and investigating this problem, thus arising variants of the Hub Location Problem (HLP) with different objective functions and constraints as well. [10] The hub location problem consists of which nodes should become hubs, followed by the allocation of these hubs to a set of different nodes with different demands associated with them. Hub location problems (HLPs) provide several models based on real-world transportation and telecommunications systems. HLPs mainly address the location of hub facilities but also include network design decisions. The location of hub facilities, hub network design, determining routes of the flows and optimisation of the total costs are some of the objectives that the HPL are focused on. [8] In 2008, Alumur and Kara [11] mentioned in their paper that they reviewed over 100 papers related to the network hub location problem, and it was clear that the location literature influenced the hub location literature. The authors also mention that the p-hub location problems with more publications were p-hub median, followed by fixed cost, p-hub centre and hub covering problem.

Moving on, the different types of HLPs that one may encounter during the literature review will be presented next. Starting with the p-hub median problem, O'Kelly was the first author to study this problem, but these models had a single allocation. The number of hub nodes is known (exogenous), and there are no costs associated with the installation of each hub nor capacity restrictions. [8] On the other hand, Campbell studied the same problem but with multiple allocations. [9] [12] [13]

The p-hub centre location problem (LP) was also first studied by Campbell, with similar characteristics to the p-hub median problem. The purpose of a hub centre problem is to implement a set of hubs that minimise the maximum travel time (cost) of each node pair. [1] [12] [13]

The p-hub covering problem is an extension of the classical covering LP and is more suitable for products with time-sensitive deliveries. One may add that the objective is to minimise the number of hubs to implement so that the maximum distance/cost does not exceed a certain limit. [10] This type of HLP was first proposed by Campbell. [14] [1] [13]

The Hub Maximal Covering LP is a special case of hub covering LP. , the objective function of this type of HLP is to maximise the total flow between nodes. When compared to the p-hub median problem, they are very similar, except that the number of hubs is known as exogenous), and the fixed cost of hub location is disregarded. [1] [12] [13]

Lastly, the capacitated p-hub median problem selects an exact p among a set of candidate hubs so that the total hub flow must be less than or equal to a fixed value. And the transportation cost is minimised. This problem's formulation is similar to the p-hub median LP plus the capacity constraint. [14]

The several authors that present the Hub Location Problems mentioned above also include the respective formulations, which will not be shown in this paper. In their place, will be given the formulation in chapter 4, adapted to the current problem being discussed.

4. Model Proposal

4.1 Model Characterisation

Regarding the implementation of this model, the production and delivery of the products from the suppliers will not be analysed. The model will focus on the connections between the hub nodes and non-hub nodes as well as providing the best possible locations for the hub nodes taking into consideration several restrictions. Within each non-hub node is where the orders belonging to a certain municipality are located.

Data:

- Demand aggregated by municipalities.
- Coordinates of each municipality.
- Coordinates of all possible locations of the logistic hubs, which will be in the centre of a municipality.
- Distance between every hub and non-hub node.
- Transportation cost between the hub and non-hub nodes.
- Cost per square meter for each municipality.

- Covering distances of the logistic hubs, with the appropriate number of hubs require to cover all demand.
- Formula relating the number of orders with logistic hub capacity

4.2 Mathematical Formulations

4.2.1 Parameters

The models' formulations use the following parameters:

- P – the number of logistic hubs to implement.
- R – Earth's radius.
- Rad – Constant to change degrees to radians.
- Disth – Maximum distance that each Hub can cover in kilometres.
- Cap – capacity of the logistic hubs.
- Tdem – Total demand of Portugal Mainland.
- Cob – Percentage of Demand Covered by the logistics hubs.
- Costkm – Fixed cost per kilometre travelled.
- Karea - Constant value represents the relation between the number of orders and area.
- Latn and Latm – Latitude of each municipality and hub, respectively.
- Longn and Longm – Longitude of each municipality and hub, respectively.
- DEM – Demand of each municipality i.
- Costm – Cost of a square meter of a logistic hub.
- d_{ij} – The linear distance between each municipality and logistic hub.

4.2.2 Variables

Table 1 presents the different variables which will be used in the various models, with the corresponding domain, purpose and type of allocation that will be used in.

Table 1 Variables' Characteristics

Variable	Domain	Description	Allocation
x_{ij}	Binary	If a connection between node i and j exist, then is equal to 1	Single
y_j	Binary	It is equal to 1 if the logistic hub is located at municipality j	Single
t_i	Binary	Restricts variable X_{ij}, the sum of this variable must be equal t_i	Multiple
v_{ij}	Binary	Represent the variable X_{ij}, is equal to 1 if a connection between node i and j exist	Multiple
X_{ij}	Positive	Allows node i to be connected to more than one node j	Multiple
F_{ij}	Positive	Flow of orders between nodes i and j	Multiple

4.3 Formulations

In this sub-chapter, the different formulas used in this project will be presented. For each model, the number of hub nodes is known.

P-Median LP – Single Allocation

The objective of this model is to find the most appropriate location for the p logistic hubs to serve the demand nodes so that the total weighted distance between nodes i and j is minimised. For this model, each non-hub node is connected to one hub node, and two non-hub nodes cannot be connected directly. The hubs do not have capacity limitations. No fixed costs are considered. The objective function and constraints are as follows:

$$(1)\ \text{Min} \sum_i \sum_j DEM_i \times d_{i,j} \times x_{i,j}$$

Subject to,

$$(2)\ \sum_j x_{ij} = 1\ \forall\ i\ \in I,$$

$$(3)\ \sum_j y_j = p,$$

$$(4)\ x_{ij} \leq y_j\ \forall\ i,j\ \in I,$$

$$(5)\ x_{ij} = 0,1\ \forall\ i,j\ \in I,$$

$$(6)\ y_j = 0,1\ \forall\ j\ \in I.$$

The objective function (1) minimises the travelled distances between logistic hubs and municipalities, considering the existence of a connection between nodes. Regarding the restrictions, equation (2) ensures that one node can only be served by one logistic hub. Equation (3) guarantees that the sum of all the p-median nodes equals the value p, predetermined in the model. Equation (4) points out that the connection between a logistic hub and a municipality only exists if the p-median exists. Finally, the last two equations, (5) and (6), refer to the domain of both variables, in other words, the values they can assume in the model.

P-Median LP – Fixed Costs

This model is very similar to p-median LP(SA), but now a rental cost per square meter of each possible logistic hub location is introduced. This will also impact the objective function, equation (7), and the constraint remains the same as presented in the previous model. The objective function considers the demand in each logistic hub, which then multiplies by the constant of obtaining the respective area and the fixed rental cost mentioned. The cost of the distance travelled is also placed in the objective function.

$$(7)\ \sum_i \sum_j (x_{i,j} \times DEM_i \times Karea \times CostM_j) + (x_{i,j} \times CostKM \times d_{i,j}).$$

P-Median LP – Covering Radius

The assumptions of these models are equal to the p-median LP(SA), with the difference that now it is introduced a maximum covering distance for each hub, allowing them only to serve the municipality within that radius. The outputs will say unchanged compared to the first model, and the KPI will be introduced in the model to understand if this restriction is being fulfilled. The objective function can now be equal to the one presented in the p-medial problem (1) or to the one from which includes the fixed costs (7), but there is one more constraint added to the model, equation (8):

$$(8)\ d_{ij} \times x_{ij} \leq DistH\ \forall\ i,j\ \in I.$$

P-Median LP – Capacity Limitations

In these models, the assumptions, inputs, outputs, objective function and constraints are similar to the p-median LP(SA), with the only difference that now a constraint regarding the hubs' maximum capacity is introduced. That constraint is equation (9), stating that the demand allocated to each hub cannot exceed the maximum capacity determined.

$$(9)\ \sum_i x_{ij} \times DEM_i \leq Cap,\ \ \forall\ j.$$

P-Median LP – Partial Coverage of Demand

Compared to the p-median LP(SA), in this model, the hubs are not required to cover all the orders received by Worten. It is introduced as an input where the percentage of demand covered is defined. Equation (2) now is equal or lower to 1, which allows a specific municipality not to be covered by hubs and equation (10) will be added, stipulating that the sum of the municipalities which are served by hubs divided by the total number of orders must be equal or greater to the percentage defined at the start.

$$(10)\ \frac{\sum_i DEM_i \sum_j x_{ij}}{TDEM} \geq Cob\ \forall\ j\ \in I.$$

P-Median LP – Multiple Allocation

Lastly, the multiple allocations models will introduce 4 new variables, X_{ij} , f_{ij}, v_{ij} and t_i. The objective function of this model will remain the same. Focusing on the constraints, in addition to the equations (3), (4) and (10), 9 new constraints will be added.

$$(11)\ \sum_j x_{ij} \leq 1\ \forall\ i,j\ \in I,$$

$$(12)\ \sum_j x_{ij} = t_i\ \forall i\ \in I,$$

$$(13)\ f_{ij} = x_{ij} \times DEM_i\ \forall\ i,j\ \in I,$$

$$(14)\ \sum_j f_{ij} \leq\ DEM_i \times \sum_j x(i,j)\ \forall\ i\ \in I,$$

$$(15)\ \sum_i f_{ij} \leq\ Cap\ \forall j\ \in I,$$

$$(16)\ v_{ij} \geq x_{ij}\ \forall\ i,j\ \in I,$$
$$(17)\ \sum_{j} v_{ij}\ \leq 4\ \forall\ i\ \in I,$$
$$(18)\ v_{ij} \leq y_j\ \forall\ i,j\ \in I,$$
$$(19)\ d_{ij} \times v_{ij} \leq DistH\ \forall\ i,j\ \in I.$$

Starting with equation (11), it says that the variable x_{ij}, is now a positive variable and varies between 0 and 1. Equation (12) states that the sum of the variable x_{ij} will be equal to t_i. Equation (13) ensures that the flow from i to j related to the demand of the municipality i must be equal to variable x_{ij}. Equation (14) refers to the sum of the flow of the several hubs j to municipality i, which must be equal or lower to that municipality's demand. The following equation (15) says that the sums of the flows must be equal to the total demand of that municipality. In equation (16), the variable v_{ij} is greater or equal to X_{ij}, since v_{ij} will transform the value of x_{ij} into a binary value, in other words, if x_{ij} assumes values such as 0.63 or 0.092, that will be changed into 1. Equation (17) stipulates that the sum of variable v_{ij} for node *i* can have a maximum of four allocations to logistic hubs. In addition, for equation (18), the variable v_{ij}, need to be higher than a y_j, since, in MA models, the total number of municipalities that will be selected will exceed the 278 municipalities. And the last equation, (19), focuses on complying with the distance restriction, but in this case, for the v_{ij} variable instead of the x_{ij}.

5 Results Analysis

This chapter will present the most relevant assumptions made in this project, the different scenarios studied, with the respective purpose, and the comparison between these scenarios.

Regarding the data and assumptions, starting with the demand, which was provided by Worten, and then treated to be allocated each order to the corresponding municipality, and in total, there are 278 in Portugal's Mainland. From this, it was established that the different covering radii, the 25 km which Worten is currently using to serve online orders, and the 50 and 60 km, which are based on the average speed of a delivery truck. Each hub can be located in the centre of any municipality, and the number of hubs will depend on the covering radius. These numbers were obtained via calculations and GAMS, which is presented in table 2. The area of each hub is based on the area of Worten's warehouse and the orders that each one fulfils.

Concerning the logistic hub's cost, it was considered a rental cost that depends on the m^2 of each hub and the respective location. It is also considered a fixed cost per order and a transportation cost that also considers a fixed value per kilometre.

Table 2 ***Covering distances and the respective number of logistic hubs***

Hub Radius (KMs)	25	50	60
Number of Hubs	53	17	12

Table 3 shows the respective objective function(s) used in the different scenarios studied.

Scenario 1 – By running eight instances, for the 5, 12, 17 and 53 logistic hubs, with both objective functions, distance minimisation and costs minimisation. It is easily concluded that cost minimisation offers better results in terms of the investment required. And focusing on the second objective function, the instance that provides the best results is the 53 hub. In addition, if Worten wants to deliver the orders within the two hours window, a constraint regarding the distance between hubs and municipalities must be added.

Scenario 2 – This scenario is very similar to Scenario 1 with the difference that now a constraint regarding the distance between the hub and non-hub nodes is implemented. And based on the values in table 2, it was possible to run 3 instances with different covering radii for both objective functions. Once more, the cost minimisation OF achieves better results, and the total costs for the covering distances are very similar, but the 12 hubs instance will be the less expensive one.

Scenario 3 – With this third scenario, a maximum hub capacity constraint was implemented to restrict the capacity of the logistic hubs. For this scenario, it was decided that Worten's focus should be on cost minimisation. Therefore, this will be the only objective function considered for this and future scenarios. In addition, this scenario will also be analysed the multiple allocations. By running the different instances, for single and multiple allocations, it was possible to observe in the objective functions for each covering distance the multiple allocation model is more beneficial for the inputs introduced in the model. But implementing multiple allocations can involve another management level, which can become more costly to Worten. The instance with the lowest total costs and cost per order belongs to the 50-kilometre radius. In this instance, single and multiple allocations are the lowest of each type of allocation, but the MA costs are lower than the SA.

Table 3 Description of each Scenario

Scenarios	Purpose	Objective Function
1	Run the model without restrictions (SA) -Total Coverage	Dist Min and Cost Min
2	Implement a covering radius so that logistic hubs can comply with the time window (SA) -Total Coverage	Dist Min and Cost Min
3	Logistic hub capacity restriction and multiple allocations (SA and MA) -Total Coverage	Cost Min
4.1	Partial coverage of demand (90%) (SA and MA) -Partial Coverage	Cost Min
4.2	Optimises the number of logistic hubs based on scenario 4.1 (SA and MA) -Partial Coverage	Cost Min
5	Fixed the number of logistic hubs. Studies the impact that the covering radius and hub capacity on coverage percentage (SA and MA) - Partial Coverage	Cost Min

Scenario 4.1 – Having in mind Scenario 3, now it will be studied the partial coverage of online orders, where the logistic hubs will cover only 90% of the demand. The comparison between the single and multiple allocations will also be analysed. In this scenario, contrarily to what happened in Scenario 3, the maximum hub capacity will be the same, independently of the covering radius of the logistic hubs. This capacity will be equal to 128k orders since the municipality of Lisbon has a demand of 127k orders, and it represents 10.4% of the total demand. As seen in Scenario 3, multiple allocation instances provide less expensive solutions for the same inputs. Having multiple hubs serving municipalities helps to decrease the area of hubs with a higher cost per square meter. It also reduces transportation costs by placing demand on more strategic hubs closer to a specific municipality. And, from the three different covering distances, the 50 km instances have the lowest total costs and cost per order.

Scenario 4.2 – For this scenario, the objective is to reach the minimum number of logistic hubs and respective capacity/area to cover 90% of the orders while allowing feasible solutions. For the single allocation models, each model was run without the capacity restriction to achieve the minimum number of hubs, depending on the covering distance. For the multiple allocation models, the initial idea was to run with the same number of hubs obtained in the single allocation models and with a restriction equal to the maximum capacity retrieved from the SA as well. Using these inputs, it was not possible to have multiple allocation solutions since SA was the most advantageous, so the maximum hub capacity restrictions had to decrease slightly. Comparing the results obtained in the three different covering distances, overall, the SA models were somewhat less expensive than the respective MA models, meaning that, as the number of hubs decreases, multiple allocations are less attractive for the model.

Scenario 5 – In this scenario, the model will be run for 5 logistic hubs for the three different radii. This number of hubs reflects a more realistic number of hubs to implement as suggested by Worten, and it will compare three maximum hub capacities in each radius, impacting the overall coverage percentage of Worten's orders throughout Portugal's

Mainland and hub costs. The allocation will be single for the 25, 50 and 60 kilometres covering distances because the 5 hubs will be located distantly from each other. Therefore, running the model for multiple allocations does not make sense.

For each covering radius, three different maximum capacities will be studied to study their impact on the percentage of demand covered by the hub and analyse the changes in transportation costs and hub costs. The three maximum capacities will be 128k, 200k and 500k orders. By running the various instances, it was possible to conclude that the 25 km radius has the highest total cost and cost per order for each capacity restriction. And the most expensive is the instance of the 500k order. In terms of the percentage of demand covered, the lowest percentage obtained belongs to the 25 km with 128k orders (51%), while the highest percentage was registered in the instance of the 60 km radius with 500k orders (88%). It is also relevant to mention that for the 128k and 200k orders instances, as the covering radius increases, the average cost of m2 decreases, meaning that as the distance increases, the logistic hubs tend to be located further from city centres, lowering the cost per m2. In contrast, the same does not happen for the 500k instances where the 25 km has a higher average cost than the 50 km, and the 60 km has the highest cost of the three distances.

Comparison between scenarios

Scenarios 1 and 2 – Due to the lack of constraints, these are the two less realistic scenarios. For the Dist Min OF, scenario 1 is the most expensive, whereas, in the Cost Min, scenario 2 requires a higher investment.

Scenarios 2 and 3 – Comparing the total costs from Cost Min OF of scenario 2 and the MA of scenario 3, it was concluded that S3 was more expensive. In contrast, the hub capacity and transportation costs decreased.

Scenarios 3 and 4.1 – A comparison between cost per order was made for the multiple allocation instance, which provides the best results, since scenario 3 covers all of the demand, while 4.1, only 90% of the orders. By doing this, it was concluded that 4.1 achieved lower costs per order. The difference in investment cost between the two scenarios is around 21M€.

Scenarios 4.1 and 4.2 – Although scenario 4.2 optimises scenario 4.1 by reducing the number of hubs and increasing the hubs' capacities, scenario 4.1 obtains better results by having lower total costs and cost per order in the three covering distances.

6 Conclusions

To conclude, the cost per order is relatively high throughout the different scenarios, covering distances and types of allocations. That happens due to the large scale that some logistic hubs assume and the location where the hubs are placed since the cost per square meter significantly impacts the hubs' cost and the total costs as well. Throughout scenarios 3 and 4, the multiple allocation models provide better results in terms of cost per order. Still, these types of allocations can be complicated to implement in a supply chain.

At the end of the project, it was possible to gather some limitations that impacted the results for the different scenarios. Starting with a fixed cost of opening and maintaining a logistic hub that should have been considered, besides the rental cost of the hubs and the operational cost of each order. One way of analysing this impact is by comparing Scenarios 4.1 and 4.2, where the number of hubs reduces by more than 50%, and scenario 4.1 still provides lower investment costs than scenario 4.2. Another factor to consider is a more accurate position for the logistic hubs since this project assumed that they would be placed in the centre of the municipality, and a fascinating study would be analysing the best possible location within that municipality.

The products there are limitations and future work regarding this topic. For the limitations, it was assumed that each order received by Worten was represented by one product, and that this product was generic, with the exact physical dimensions for all orders. This assumption does not reflect the reality within Worten's Warehouse, but since there were more than 1 million orders, this assumption was made. Moreover, it would be interesting to study which product Worten should place in each logistic hub while applying the 20/80 strategy, analysing the 20 SKUs representing 80% of the online orders. Lastly, another study that could be conducted is related to the design and layout of each logistic hub based on the product that will be allocated to them. The different areas for each operation can be determined. Also, the storage solutions must be analysed to reduce the floor space and be suitable for fast-moving operations and material handling equipment.

In terms of future work, the other purposes of the logistic hubs can also be studied. For this project, the goal was to be able to fulfil all the online orders received by Worten. Still, they can also have the ability and flexibility to serve some Worten stores, not only to provide inventory but also to store it. There is also the possibility of instead of implementing logistic hubs in a new location. It can be studied the possibility of transforming Worten stores with higher storage capabilities into hubs.

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