Sales Territories Allocation and Establishment of Routes

The Case Study of Würth Portugal

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Abstract

Markets nowadays are characterized by a demand gradually more challenging. Aware of this reality, companies develop their strategies by focusing on customer satisfaction, focusing on providing quality products and services that meet or even exceed customer expectations. Würth Portugal differentiates itself with a strategy based on three business areas: direct sales conducted through teleshopping service or sales team to contact directly with the customer; domestic sales triggered at the level of Würth's stores around the country; and technical assistance where equipment repair services are provided by the company. It is in the context of the sales team, which incorporates the area of direct sales, that the present study arises. This analysis affects Würth's vendors with activity in Alentejo to new sales areas so as to minimize the distances traveled and therefore reduce their associated costs.

Keywords: Sales Network, Sales Territories Restructuring, Route Optimization, Cost Reduction

1. Introduction

An efficient and customer oriented management is the basis for business success in today's world. Over the years, the demand satisfaction moved to the top of the goals to achieve by a company, requiring the development of a management that allows to offer the right product in the right quantity at the right time. Reconcile customer requirements with an increasing number of supply alternatives to compete in the market and also seek to reduce costs, are tasks that require cohesion and communication over all integral parts of the development of a product or service.

Among the activities that aim to create value, the direct contact between seller and customer is one that goes back more to the early days of sales transactions. It is also the one in customer satisfaction based, since the seller can interpret and acquire immediately what are the real needs and reactions of demand in relation to a particular product.

Würth Group is present in the worldwide market, with more than 400 companies across 80 countries, and standing out as a leader in the production and marketing of products for professional use in the construction area. In 2009 the group was awarded by the Federal Association for Logistics with the German premium logistics due to the concept adopted by the company in this area based on the modular system. Nationally, the company has a network of stores throughout the mainland and islands territory.

Würth Portugal, as part of the Würth Group, aims above all to exceed the expectations and needs of its customers and meet their demand, relying on a network of more than 400 vendors. Commercial activity implies that a direct monitoring of customers is maintained, often weekly and attendance, highlighting thus the importance of client portfolios allocated to the sellers as well as the geographical areas they cover.

The present study comes as part of the daily activity of selling of this company, trying to determine the structure of a sales territory that allows each vendor to achieve their daily goals in terms of its portfolio customers and the lowest cost in travel.

1.1. Research Objective

This research aims to contribute to current academic literature by presenting an approach that can both help to find out which sales territories' structuring fits best to a company considering its strategy and also assuring a cost reduction by identifying within the sales territory built, which route minimizes the total distance to go. Würth Portugal stands out as a supplier of a wide range of products, and its concerns with the quality and service to customers. Part of its success comes from a strong organizational culture oriented to the satisfaction of customer needs, focusing on the formation of a specialized sales network. With the ultimate goal of determining a solution to reduce the distances currently traveled, and aiming to reduce time and costs in fuel, it is intended the development of a model that fits this purpose. This model will receive input data that reflects the current reality of the company and present a solution for each of the vendors, setting a sales territory and a route covering all that territory.

The remainder of this paper is organized as follows. Section 2 presents a literature review on significant topics for this study, such as sales and their importance for a company, the territory design problem, and the traveling salesman problem. Section 3 presents the models selected to be applied to Würth Portugal case study, which is developed in section 4. Finally, section 5 concludes this paper.

2. Literature Review

2.1. Sales

The process of forming a company is based on the definition of the business model that will guide the entire organization in order to create value for its customers. In this model are designed hypotheses associated with what the customer wants and how a company wants to be structured to meet these needs while generating profit simultaneously [1].

Whatever the type of business of a company, the sales are the main source of revenue generation, which means that this area has special attention in planning processes and definition of the organization. After the identification of the target market requirements there must be defined, among others, the inherent sales process issues and organized the sales training activities to ensure customer satisfaction [2].

Sales success depends in large part on the activity of vendors who represent the "engine" of this essential component in the corporate bosom. These players are the first point of contact with the customers [3] and their key role relates to the two irreplaceable aspects that are the basis of their function: identifying/analyzing consumer needs and provide support towards finding solutions to their issues [4].

In the present work, and in general, geographical organization has special relevance, so this component will be analyzed in greater detail. A growing number of studies shows that sellers inserted into a well-organized sales network geographically present higher levels of motivation and satisfaction and therefore better performance and dedication ([5, 6, 7, 8]). Zoltners and Lorimer [7] further argue that decisions relating to the territory of the sales network is one of the most important factors in the improvement of vendors' performance.

The optimization of already existing geographic distribution of sales network is another key aspect for success. This practice usually finds some resistance in the implementation process, since it results in changes to the level of client portfolios, which the sellers do not always accept the best. It is important that companies conduct periodic analysis to the geography of their sales networks in order to avoid incurring unnecessary expenses [7].

2.2. Territory Design Problem (TDP)

The concept of territory design arises from the need to bundle small geographic areas (basic areas) into larger assemblies (territories) according to predetermined criteria and constraints [9]. Given the dynamic component of markets, the decisions associated with this type of planning are always subject to improvements. A good sales territory planning can increase sales, reduce transportation costs, improve performance evaluation systems and reward, and improve coverage of demand [7].

Literature on this matter is diverse, since it may be introduced a large number of applications. Table 1 presents studies in the commercial and sales areas and the respective methods applied (the description of each of these techniques is beyond the scope of this work).

Table 1: TDP Literature in commercial and sales fields

Reference	Applied Method
[16]	Location-allocation
[17]	Location-allocation
[18]	Heuristic
[19]	GRASP
[20]	Location-allocation
[21]	Reactive GRASP
[22]	Exact Resolution Procedure

Source: [23]

2.2.1. A TDP Model

In this section an overview of a TDP resolution mathematical model will take place. The version presented was proposed by Ríos-Mercado and López-Pérez [10]. In this case, the TDP is defined by a graph $G = (V, E)$, comprising a set of nodes given by V and a set of edges given by E and where a basic unit (BU - *basic unit*) i is associated with a node and an edge connecting two nodes i and j there if i and j are adjacent. Each node $i \in V$ is characterized by a parameter set comprising the geographic coordinates (c_i^x, c_i^y) and three measurable activities designated $a \in A = \{1, 2, 3\}$ representing the number of clients, demand and workload, respectively, representing w_i^a the value of activity a in the node i.

A TDP can be decomposed in a hierarchical problem with two distinct phases: in the first phase, corresponding to the tracking phase, the centers of the territories are defined; in the second phase, where affectation happens, nodes are assigned to the centers defined in the previous phase.

Ríos-Mercado and López-Pérez [10] developed a way to simplify the model that passes through the default of the centers of the territories, so the focus is to be on allocation phase. In the allocation model proposed by these authors balance restrictions are addressed simultaneously with connection constraints and restrictions of disjunction which prevents the application of a typical model of location-allocation. Thus, typical strategies are used for a branch-and-bound model for solving the assignment problem. An even simpler way to approach this problem is by relaxing the connection constraints.

The excerpt from the model described is an alternative proposed in [10] for the resolution of a TDP. There are methods developed and tested by other authors, but this is the one that has the highest suitability for the problem under consideration in this study since it has a reduced complexity and allows to consider all the variables relevant to the context in which the problem is inserted.

2.3. Traveling Salesman Problem

The Traveling Salesman Problem (TSP) has been intensively studied. On one hand, it is very simple to understand but on the other hand, it is very difficult to solve [11]. On the basis of this problem is a salesman starting from a given city with a task to visit a group of cities and return to the starting city traveling a route that allows him to visit all these cities only once minimizing the total distance traveled.

Graphically the structure of the TSP is based on a diagram consisting of nodes that represent the cities that the salesman has to visit and arcs that connect pairs of nodes. One solution is achieved when the seller can visit all the cities and return to the node which started the path. The length of this route results from the sum of the lengths of the arcs contained in it.

2.2.2. TSP Resolution Methods

The Traveling Salesman Problem belongs to the class of NP-hard problem, which means that no algorithm has the ability to solve it in polynomial time [12]. In general, the various methods presented in the literature can be divided into two classes: exact resolution models; and approximate resolution models. The latter can also be divided in two subclasses: heuristics; and meta-heuristics.

2.2.2.1. Exact Resolution Models

These methods seek an optimal solution respecting all the restrictions. According to [13], the branch-and-bound algorithms are the most used to solve the TSP accurately. A disadvantage of this type of algorithms is its complexity. In addition to that, large-scale problems of high computational execution time become impractical the application of this class of algorithms [14].

2.2.2.2. Approximate Resolution Models - Heuristics

Generically, heuristics result from the combination of two components: construction methods and improvement methods. The former are based on the gradual construction of a solution, on the other hand, the latter start from a solution and try to improve it by applying a series of exchanges to achieve an improved version of the original input.

Within the construction methods, the simplest is based on a vendor who always travels to the nearest town in the node neighborhood (nearest neighbor method). Regarding improvement methods, the best known is the 2-opt [12] however, the Lin-Kernighan's [12] algorithm has shown better results.

2.2.2.3. Approximate Resolution Models – Meta-heuristics

The large deployment inherent in this subclass methods is to introduce concepts in other areas such as resolution aids in this type of problems. Among the existing meta-heuristics, [12] include the following: genetic algorithms, which adapt the reproduction of the species; Simulated Annealing, that adjusts the behavior of materials under certain conditions; tabu search, that adjusts the social concept associated with a taboo.

2.2.3. Lin-Kernighan Algorithm

This algorithm, developed by Lin and Kernighan [15] considers a T route generated randomly, and the algorithm searches, at each iteration, in sets $X = \{x_1, \dots, x_k\}$ and $Y = \{y_1, \dots, y_k\}$ if there is a connection in X that, if replaced by a connection in Y produces an optimized version, T', of the initial route T. Initially, the X and Y assemblies are empty, being filled gradually with each iteration i.

The following criteria, applied to the links of X and Y sets, have the main objective to ensure the algorithm efficiency [24]:

- Sequential exchange: Any pair of connections (x_i, y_i) and (y_i, x_{i+1}) must share a node. Another condition necessary to ensure that the replacement assembly X by Y linked together links results in a closed path is $y_k = (t_{2k}, t_1)$, where t is a node.
- Viability**:** The edge x_i connecting nodes (t_{2i-1}, t_{2i}) should be selected so that, when connecting the nodes t_{2i} and t_1, it results in a closed path.
- Positive profit: Considering G_i as the profit realized by replacing a link from set X by another of set Y, the y_i edge should be chosen if, and only if, generates a positive profit. Regarding $g_i = c(x_i) - c(y_i) \Rightarrow G_i = g_1 + g_2 + \dots + g_i$, where $c(x_i)$ and $c(y_i)$ represent the costs of the connections x_i and y_i, respectively.
- Disjunction: This criterion expresses the need for the sets X and Y to be disjoint.

The presented algorithm has been proposed by [15] for solving the TSP. There are other methods developed and tested, as described, however, this is a simple model that fits the problem analysis in this work.

Given the dynamic nature of sales, caused by retention and customer acquisition, it is necessary to study and periodically plan geographic areas of focus of vendors. This planning is based on two optimization measures for the seller - structuring and allocation of sales territory and determine the best coverage path planning. The key idea of the territories structuring literature, Territory Design, is based on the creation of areas composed of small geographic areas for assignment to each vendor. Commercial and sales environments have been studied and developed various methods of resolution to this problem but, recalling the methods in Table 1 the one that stands out is the location-allocation. An adapted version of this method [21] was a prominent target for its suitability to the case of Würth-PT. In the literature definition of routes, the Traveling Salesman Problem is presented as an object of study to several authors. Extensions of the original problem in order to adapt it to various areas have been developed. Among the approximate resolution methods, the algorithm developed by Lin and Kernighan [15] prevailed for many years as the procedure with better results. Given the reduced complexity of the problem that motivated this study, these were the methods selected for further implementation.

3. Models

This section describes in detail each of the previously selected models for solving the problem under study – Territory Design Problem and Traveling Salesman Problem.

3.1. Territories Restructuring Model

The aim of this model is to identify independent sales territories for Würth salesmen. Thus, the network is made up by vendors and customers entities. These entities are defined by their geographical location and related through the business sector to which they belong and the distance that separates them. The model takes into account parameters such as the business sector, and the total number of clients for each sector in order to create balanced territories. It considers a pre-defined number of areas based on the number of sellers. The purpose of the model is set, for every seller, a sales territory consisting of customers who are nearest to the seller's home address in order to minimize the distances traveled on visits to customers.

The problem can be summarized based on the following:

Data

- Residence addresses from different vendors
- Customer Locations
- Distances between all pairs of entities

- Business sector of each vendor and each client
- Number of territories to generate
- Number of customers by territory.

To determine:

- The sales network structure defining the number of sales territories
- Customers' allocation to every sales territory
- Planning of daily visits to each vendor.

In order to minimize the distances traveled by the seller guaranteeing coverage of the entire sales territory.

3.1.2. Mathematical formulation

This section presents the mathematical formulation of the model. The superstructure of the sales network is defined by sets. The constraints to be satisfied are defined by a set of linear equations and inequalities. Indexes are defined as follows:

- n for the number of entities
- v, c for the entities indexes; $v, c \in V = \{1, 2, \ldots, n\}$

3.1.2.1. Parameters

$d_{v,c}$ – distance between vendor v and client c; $v, c \in V$

3.1.2.2. Variables

In this model only binary variables are considered.

$$x_{v,c} = \begin{cases} 1, client \text{ c } affected\ to\ territory \text{ c, v} \in \text{V} \\ 0, otherwise \end{cases}$$

Based on the characteristics of the problem in study and through the sets, parameters and variables the model formulation is presented:

$$Min\ Z = \sum_{\substack{v \in V_c \\ c \in C}} d_{vc} x_{vc} \qquad (1)$$

subject to:

$$\sum_{v \in V_c} x_{vc} = 1 \qquad c \in V \qquad (2)$$

$$\sum_{c \in V} x_{vc} \leq \frac{\sum_{c \in V} c}{\sum_{v \in V_c} v} \qquad v \in V \qquad (3)$$

$$x_{vc} \in \{0, 1\} \qquad v, c \in V \qquad (4)$$

The model objective function (1) minimizes the total distances associated with the sales network in study. These distances are traveled by vendors during their visit activities to their clients.

The first constraint (2) ensures that each client c is allocated to one and only one vendor v.

The second constraint (3) ensures the formation of balanced territories considering the maximum number of clients per territory. To calculate the maximum number of clients for each territory, the sum of all clients of a given sector is divided by the number of resources (vendors) available on that sector.

The last constraint (4) shows that variable x_{vc} is equal to 1 if the seller v and the customer c are associated, and 0 otherwise.

The model presented is based on the method developed by [10] for the construction of sales territories. The aim of this study is not only to restructure the sales territories, but also plan the activity of vendors. In a first implementation of the model sales territories were calculated for each salesperson based on the municipalities of residence of each vendor. In a second phase, to plan daily visits for each seller sales sub territories were created. To this end, it was accounted how many customers each sub territory would have to so that the number of clients that each seller has to visit every day was equal to 10. This number is justified by what the company believes to be a daily indicator of productivity for a seller, willing, then, that a seller visits a realistic number of customers, taking into account the relatively large distances that characterize Alentejo, and productivity, taking into account sellers' working hours. For the final solution customers were grouped into sub territories based on the distance to the seller of the territory concerned.

After the construction of all sub territories for each seller, representing the planning of their daily visits, it will be possible to set a route that minimizes the total distance to go.

3.2. Routes Establishment Model

After identifying the sales territories of each vendor and respective sub territories, at this stage is identified the route that allows the vendor to visit each client minimizing the total distance traveled. The entities that make up this network are identical to the model presented in the previous section. In this model entities are related only by the distance between them.

Briefly, the problem under consideration seeks the minimization of the distance traveled by the seller in a workday, ensuring coverage of the entire sub territory using the following data:

- Seller's residence address
- Client's location in each sub territory
- Distance between all pairs of entities.

3.2.1. Mathematical formulation

This section presents the mathematical formulation of the model. Indexes are defined as follows:

- i, j for entities
- m for total number of clients to visit.

3.2.1.1. Parameters

d_{ij} – distance between entities i and j

3.2.1.2. Variables

In this model only binary variables are considered.

$$x_{ij} = \begin{cases} 1, & \text{if edge } i \rightarrow j \text{ is inside the route} \\ 0, & \text{otherwise} \end{cases}$$

Model formulation comes as follows:

$$\text{Min } Z = \sum\nolimits_{j=1}^{m} \sum\nolimits_{i=1}^{m} d_{ij} x_{ij} \qquad (5)$$

subject to:

$$\sum_{j=1}^{m} x_{ij} = 1 \qquad i = 1, \ldots, m \qquad (6)$$

$$\sum_{i=1}^{m} x_{ij} = 1 \qquad j = 1, \ldots, m \qquad (7)$$

Objective function (5) minimizes the total distance of the route each vendor has to travel in order to visit all the clients in his sub territory.

Constraints (5) and (6) ensure that each node (entity) is connected to another node inside the route.

This model was implemented through Microsoft Excel using Solver software. The following example shows how the method was applied.

Table 2 presents a sub territory created for vendor V3 composed by 10 clients. This sub territory was obtained through the division of the total number of customers allocated to vendor V3 during the territories' construction phase into smaller territories (sub territories) of 10 clients each. Table 2 shows a sub territory created for vendor V3 composed with 10 clients.

Table 2. V3 Sales Sub Territory

Entity	Distance (in km)
V3	0
C25	0
C26	12
C27	3
C28	0
C31	10
C32	11
C34	2
C38	8
C40	18
C42	0
V3	-
Total Distance	**65**

Table 2 was designed in order to simulate a daily route for vendor V3. On the first column the actual route by which the vendor visits his clients, starting and ending at his home address (here represented by V3), the remain entities (C25, C26, …, C42) represent all the clients that V3 has to visit. And, based on the information presented in Table 2, it goes as follows: V3 leaves his home address and visits client C25, then, he visits client C26, after visiting C26 he goes to C27 address, and so on. The second column represents the distance between every two entities of the first column. For example, client C32 is at a distance of 10 km from client C31 and at 11 km distance of client C34. By applying Solver to this case, the algorithm will minimize the total distance that V3 has to travel to visit all the clients presented on the first column (the total distance in this particular case is 65 km) and readjust the order by which V3 will visit the clients considering that the nodes on the final and optimized route must be different among each other. The algorithm also takes into account that the route must start and end at V3's home address.

Table **3** shows the final result after applying Solver to data in Table 2.

Table 3. Optimized Route for V3 sub territory

Entity	Distance (in km)
V3	0
C40	8
C27	1
C34	2
C38	0
C31	0
C28	10
C25	0
C32	0
C26	5
C42	0
V3	-
Total Distance	**26**

By the results obtained in Table **3** we can conclude that there's a minimization of 39 km comparing the final distance traveled on the initial route (Table 2) with the one traveled on the optimized route (Table **3**). This method was applied to all the sub territories of all vendors.

4. Case Study

Identified the problem that motivated the present study and the method that better suits to it, now the procedure to achieve the proposed objectives will be described in more detail. Starting by the strategies that helped to deal with data complexity.

4.1. Data processing

One of the main obstacles to the implementation of models is the complexity of the data. To overcome this difficulty, some simplification strategies were applied to input data. On the first part of this section some of the results obtained after implementing the simplification strategies will be presented.

4.1.1. Clients' addresses aggregation

The high number of clients to consider in the analysis (1482 customers) and the lack of precision in the respective addresses making this problem difficult to solve from a computational perspective. Thus arose the need to aggregate those addresses.

Since, in this study, it is only to be considered vendors operating in the districts of Évora and Beja, it became necessary to the aggregate customer addresses by municipality. This aggregation resulted in a total of 28 clusters (each of these districts has 14 municipalities). The demand in the context of this problem is represented by each customer, so the demand for municipality is given by the sum of the clients that make up the same municipality.

Table 4 presents the results obtained for each of the districts.

Table 4. Demand by council

Beja	Demand	Évora	Demand
Aljustrel	52	Alandroal	16
Almodôvar	47	Arraiolos	38
Alvito	11	Borba	33
Barrancos	6	Estremoz	66
Beja	168	Évora	243
Castro Verde	33	Mte-o-Novo	113
Cuba	10	Mora	16
Ferr. Alentejo	43	Mourão	10
Mértola	44	Portel	16
Moura	55	Redondo	27
Odemira	141	Reg. Mons.	50
Ourique	36	Ve. Novas	45
Serpa	76	Vi. Alentejo	25
Vidigueira	18	Vila Viçosa	44

4.1.2. Business sectors aggregation

A key aspect for vendors' allocation to sales territories is based on the business sector (from now on designated "division") to which the seller and the customers of the territory belong. Consequently the model was applied independently to each division, thus allowing the creation new territories respect that criterion.

For the aggregation of different divisions were considered the number of sellers and the number of customers. This strategy identified which vendors and respective customers to include in the model for each division.

Table 5. Data by division

Division	# of Vendors	# of Clients
D1	5	484
D2	3	229
D3	4	481
D4	2	140
D5	1	148

As shown in Table 5, division D5 is composed by only one vendor, therefore, this division was not considered during the territories' construction phase, since the only vendor in D5 is not able to acquire customers from another division and vice versa. This division was re-included in the study during the construction of sub territories for each vendor.

4.2. Data and assumptions used

Another important aspect prior to the implementation phase regards the identification of prior assumptions.

4.2.1. Territory's design

An extremely important aspect to achieve the final solution to the problem in question is the design of sales territories. The construction of these universes was always based on the minimization of distances.

To calculate the number of sales territories to form, as mentioned before, was considered the total number of vendors, in order to obtain a territory for each vendor. But there has been another point to consider that has had considerable weight throughout the analysis – the division. To achieve sales territories balanced among all vendors the key factor is the number of customers, so it is a simple calculation to split all customers by the number of sellers. However, the sector/business division should guide this estimate ensuring that customers are reallocated to specialized vendors in their division.

Thus, for each division it was amounted the total number of customers and divided by the corresponding number of vendors to get an average, establishing, then, approximately the maximum number of customers for each salesperson. Table 6 shows the values obtained for each division.

Table 6. Territories Design

Division	No. of Clients	No. of Vendors	Territory Design
D1	484	5	100
D2	229	3	76
D3	481	4	120
D4	140	2	70

Note that, at this stage, division D5 was excluded from the analysis which is justified, as mentioned before, by the fact that this division is composed of only one vendor.

The design of sub territories strongly depends on the value obtained for the sizing of territories. Although it has been defined a restriction of the number of customers per vendor for the formulation of the problem, the model turned out to assign different numbers of customers to vendors although always respecting the maximum number of customers.

At this phase, it is not relevant to present the values obtained for sub territories design, since it strongly depends on the type of scenario considered – which will be presented below. As for the design of the territories, the calculated values are sealed, they only account as restrictions on the applied models varying on the respective scenario, as some of the scenarios analyzed did not include the design of the sub territories in order to test the impact of the presence/absence of this constraint.

4.3. Problem Resolution

In order to solve the problem in study, four different scenarios were analyzed to identify which method lead to the best solution considering Würth's strategy. In each of the scenarios it was studied the variation of the results taking into account the existence of equilibrium restrictions – maximum number of customers per seller and maximum distance between the vendor-client peers.

4.3.1. Initial scenario – C0

The initial scenario (C0) corresponds to the current situation in the activity of Würth's vendors, with special focus on the parameters analyzed in this model. Thus, the current values for the parameters as a basis for comparison with the results obtained in other scenarios will be presented.

As mentioned, the idea is to get a solution that minimizes the total distance traveled by a seller in his daily activity visiting customers. Thus, the parameter on the basis of the analysis, both in this scenario as in the other, is based on the calculation of total kilometers that the vendor must travel in order to visit the entire customer portfolio in his territory. For other scenarios where sales sub territories were built, the total distance parameter will be analyzed at the level of sub territory.

Table 7 presents the initial data used as input for the study of this problem and that will be used as starting point to the rest of the analysis.

Table 7. Data for scenario C0

Vendor	No. of of Clients	Total distance (km)
V1	86	924
V2	37	1417
V3	133	4078
V4	101	5561
V5	127	2274
V6	79	3441
V7	171	7507
V8	88	4746
V9	52	5017
V10	169	5188
V11	103	3282
V12	54	3399
V13	96	2998
V14	38	4038
V15	148	10463

In Table 7 the distances analysis was not made at the level of the business sector. Except in situations where it was considered the alternative of seeking closer sellers to some customers who have distances considered distant for current vendors of the business sector.

It is important to note that these distances were obtained considering the vendor-client peers and not the client-client peers. Once in their activity the seller mainly covers distances between customers and for the calculation of total distances in Table 7 considered only the sum of the distances between vendors and their different customers, the results obtained should be relativized. In the present scenario, the daily planning of each seller is not constant so it was not possible to obtain this type of information to be used in the analysis.

The high distances shown are the main motivation for this study, there are large discrepancies between the distances traveled by vendors considered, which seeks to balance this analysis.

4.3.2. Built Scenarios

Next, there will be presented and compared the results of the tested scenarios. These scenarios result from the application of the model to initial data and sought to address variants of the considered parameters.

4.3.2.1. Scenario with maximum number of customers per vendor – C1

In this scenario it was studied the construction of sales territories and respective sub territories based on a maximum setting of clients allocated by vendor. The objective of the analysis of this scenario is to realize the possibility of creating within each business sector, sales territories balanced for several vendors, where balance in this case represents a number of clients allocated to a vendor approximately equal to the average number of customers per vendor, and each vendor travels the minimum distance in his sales' activity to customers that have been allocated.

The existence of business sectors with specialized vendors in a particular area, enabled the study of the relocation of clients of a particular vendor to another vendor in the same industry (division). Thus, based on the total customers by business sector was calculated the approximate maximum size that the sales territories of each sector could have (Table 6).

The algorithm for construction of sales territories took into account the scaling parameter and was applied at the level of the business sector, so the analysis was also performed at the level of the business sector, since in this scenario are not considered the chances of exclusion sellers territory. This is the first step of the model, followed by construction of sales sub territories. Next will be presented the results for one business sector as an example, since the application of the model to the remain divisions were built on the same basis.

Business Sector D1

In order to begin, Table 8 shows the results obtained for the design of each vendor's territory.

Table 8. Territory design for division D1

	Vendor	Territory Design
Limit for the territory design (maximum number of customers), **t=100**	V1	100
	V2	84
	V3	100
	V4	100
	V5	100

Given the total number of customers in the territory, the parameter was calculated based on an average customer for each seller. As can be seen from the results shown in Table 8 the created territories have very little variability. The difference in size observed for the seller V2 face the other is justified by the distance from this seller to customers considered in this sector. This is a seller whose home address is in Elvas and the algorithm to run begins by allocating customers to the seller who is closer and when it reaches the maximum number of clients per vendor goes to the second closest vendor. Once the model has a constraint that ensures the allocation of a customer to one and only one vendor and one constraint that prevents the allocation of more customers after the territory of a vendor already has reached its maximum size, the assignment may occur a particular customer to a vendor despite presenting closeness to another vendor.

After obtaining the territories for each seller, the moment to build the respective sub territories has arrived, by forming groups with 10 clients based on the criterion of distance from customer to vendor – which means, the clients in each sub territory will present a distance to the respective vendor similar to the other clients in the same sub territory, as it can prove that the distance among clients of a given sub territory is less than the distance for clients of other sub territories. After constructing the sub territories for each vendor, the model is applied to calculate the route that minimizes the distance traveled by the vendor to visit each client of a given sub territory. Table 9 presents the total distance to be traveled by the vendor in its sales territory for business sector D1. These distances were calculated from the sum of the distances traveled by each vendor in his respective sub territories.

Table 9. Total distance for each territory for D1

Vendor	Municipality of residence	Total distance (in km)
V1	Évora	949
V2	Elvas	1036
V3	Évora	926
V4	Beja	1343
V5	Beja	847

As expected, there are three sellers whose total distance traveled presents results of reduced variability. In Table 9, column "municipality of residence" identifies a relevant factor for this analysis. By comparing the residence municipalities of sellers with the distances given it is possible to conclude that there is a strong correlation between the address of the seller and distances traveled. Another factor which influences the results is the customer's address. To facilitate the analysis, Figure 3 presents a graph with the volume of clients by county.

For the analysis of this scenario will be considered the results obtained for the distances traveled by the sellers presented in Table 9 along with the number of clients by county in Figure 3 and the map that is in Figure 1 that allows to have a geographical notion of this scenario for D1 business sector.

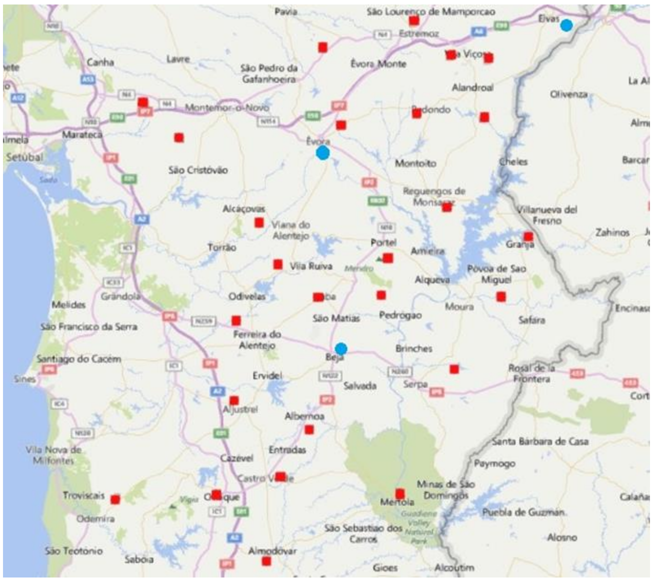

Figure 1. Geographic location of vendors and clients in D1

In Figure 1 are identified geographic locations of vendor entities – blue circles, and customer entities – red squares. It follows, then, that the distances obtained for each of the vendors are justified by the number of customers by municipality and the distances between the municipalities in question. For V1 and V3 vendors, who have a very small variation in the distances involved in this scenario, this result is justified because their municipality of address is Évora – the municipality with the largest number of customers and also the one with location relatively central comparison with other municipalities. Vendor V2 is farthest from the epicenter of demand since his municipality of residence is Elvas which does not have any client, so V2 will eventually be relatively distant to customers. For V4 and V5 sellers, both residing in the municipality of Beja, which is the second municipality with the largest number of customers, we observe a certain variability in the results for the distance. This result is justified by the existence of customers out of a desirable radius distances, fact that can be seen on the map by the presence of customers in the municipalities of Almodovar and Odemira. These customers are closest to Beja municipality and, as in this model each customer has to be allocated to a vendor, end up being assigned to a distant vendor although the distances that separate them are high.

The results for the remain business sectors will be presented in the end of this section.

4.3.2.2. Scenario without maximum number of customers per vendor – C2

In scenario C2 is studied the construction of sales territories excluding the constraint of the maximum number of customers per vendor. This analysis allowed to understand how customers would be allocated based solely on proximity to the vendor. As will be seen later on the presentation of the results, this scenario shows no viability as it would lead to an excessive stress load for some vendors instead of other vendor who would be with few or no customers. It was concluded that effectively restricting the sizing of territories (maximum number of clients per vendor) allows the creation of balanced territories, though often can also assign to a particular vendor a customer who is closest to another vendor. For this analysis remained the constraint that ensures that each client is allocated to one and only one vendor to ensure that no customer would be excluded from the analysis.

Similar to what happened in the previous analysis, also in this analysis algorithm was applied at the level of the business sector in order to ensure that each vendor would be able to meet the needs of customers who they were assigned to. Sales sub territories for each vendor were also built.

As mentioned before, the results obtained for this scenario will only be presented at the end of the section together with the results of the other scenarios allowing to compare and identify which scenario suits best to the particular case of Würth Portugal salesforce.

4.3.2.3. Scenario maximum distance limit between the vendor-client peers – C3

For scenario C3 presented in this section, it was studied the possibility of building sales territories restricting the maximum number of kilometers separating the vendor of each customer to him allocated. The distance was limited to 50 km, considering this as a reasonable distance taking into account the demographic and industrial dispersion that characterizes the region of Alentejo.

The introduction of this constraint in the analysis led to a variation in the method used for the construction of the territories compared to previous scenarios.

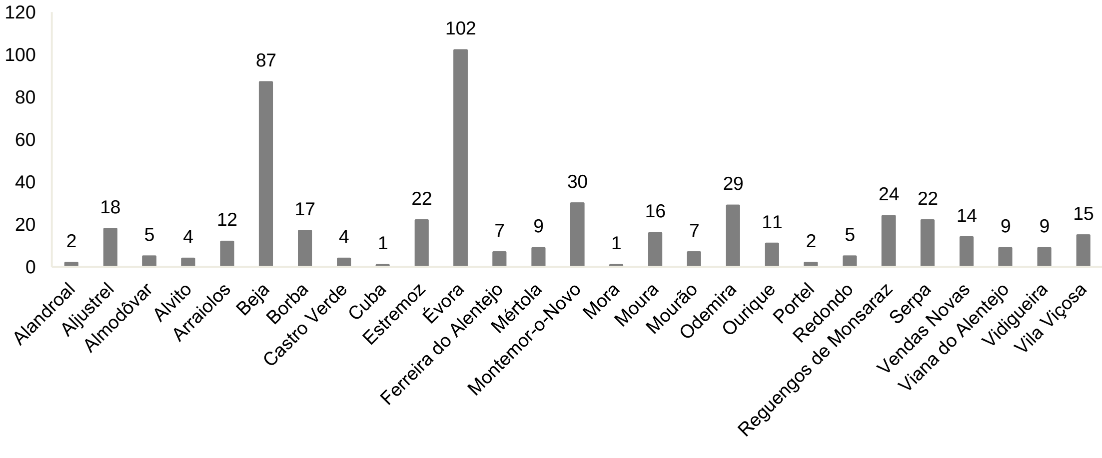

Figure 2. Volume of clients per county for D1

Before the construction of territories the process began by deleting, for each business sector, all customers who did not respect the constraint avoiding also that the algorithm was overloaded with unnecessary data. It should be noted that customer exclusion alternative does not mean that these clients are no longer served by Würth, but it is considered that in cases where there is a high number of customers who currently do not have less than or equal to 50 km distances from the resources that Würth has on the ground should be considered the possibility of strengthening the resources in this region.

This scenario introduced, again, the constraint of the maximum number of clients to allocate to each vendor. As found in C2 scenario, the omission of this constraint leads to observation of strong differences in the territories' design of each seller. So, this restriction was reintroduced in order to ensure that the created territories are balanced at the customer volume level and at the level of total traveled distances for each vendor's activities.

Since the first part of the method implemented already excludes all customers who do not respect the constraint of distance, it was also considered the constraint that ensures that each client is allocated to one and only one vendor. It is believed that this scenario is probably the one that represents the closest solution of reality that led to the realization of this study, however, a more thorough review and comparison will take place at the end of this section.

4.3.3. Scenarios comparison and conclusions

This section seeks to not only to make a comparative analysis based on the key elements studied in different scenarios, but also identify whether there is any scenario that is close to the optimum situation for the activity of the 15 vendors analyzed. Table 10 is a summary of the most relevant parameters in this analysis - the size of territory, i.e., the total number of customers in the territory of each seller ("Desi"), and total distance to travel ("Dist", in km).

Table 10. Results for the analyzed scenarios

Div	Vend	C0		C1		C2		C3	
		Desi	Dist	Desi	Dist	Desi	Dist	Desi	Dist
D1	V1	86	924	100	949	204	1370	82	709
	V2	37	1417	84	1036	56	535	56	481
	V3	133	4078	100	926	0	0	100	454
	V4	101	5561	100	1343	0	0	100	586
	V5	127	2274	100	847	224	2281	54	409
D2	V6	79	3441	80	1454	86	1360	50	579
	V12	54	3399	69	2038	27	321	21	178
	V13	96	2998	80	762	116	1269	97	701
D3	V7	171	7507	125	1145	207	2286	116	883
	V10	169	5188	125	1231	206	2001	150	1191
	V11	103	3282	125	1147	68	329	68	332
	V14	38	4038	106	3191	0	0	0	0
D4	V8	88	4746	75	1693	111	2532	51	692
	V9	52	5017	65	2636	29	594	0	0
D5	V15	148	10463	148	2204	-	-	62	477
TOTAL		**1482**	**64333**	**1482**	**22602**	**1334**	**14878**	**1007**	**7672**

As shown in Table 10 the values obtained for the total distance in the baseline scenario (C0) are in sharp disagreement over all other scenarios, so these will not be considered as a basis of comparison since the calculation method used was not the same.

Considering the total results, the scenario that reveals better output for the parameters considered – territory design and traveled distance, is C3. Not only this scenario displayed better results but it also warned for an alternative to consider – the exclusion of clients that do not fit to any of the vendors available in their business sector considering the purpose to minimize the total distance that each vendor must travel. It is important to recall that it is not an objective of this study the exclusion of clients – it works as an advice for Würth to consider the hypotheses of reinforce its salesforce by engaging more resources.

4.3.4. Sensitivity Analysis

This section makes up a sensitivity analysis to the most uncertain parameters and with greater weight in the model results.

The distance restriction that was introduced in scenario C3 with a maximum value of 50 km, was studied considering two variations: for 25 km and for 75 km. Similarly to the process in scenario C3, the sensitivity analysis started with the exclusion of clients that did not respect the respective distance restrictions. Table 11 presents the results obtained for this analysis.

Table 11. Results for sensitivity analysis

Vend	Max dist = 50 km		Max dist =25 km		Max dist = 75 km	
	Desig	Dist	Desig	Dist	Desig	Dist
V1	82	709	100	355	100	816
V2	56	481	0	0	56	481
V3	100	454	14	42	100	551
V4	100	586	95	245	99	545
V5	54	409	0	0	100	913
V6	50	579	10	20	76	1063
V12	21	178	0	0	35	442
V13	97	701	54	243	100	1052
V7	116	883	63	351	180	2029
V10	150	1191	80	347	180	1851
V11	68	332	63	256	79	518
V14	0	0	0	0	0	0
V8	51	692	8	34	78	1440
V9	0	0	0	0	26	423
V15	62	477	31	89	76	1071
TOTAL	**1007**	**7672**	**518**	**1982**	**1285**	**12124**

The performed sensitivity analysis aimed to evaluate the model results from the change of boundary distances. It was found previously that the scenario that showed better results compared to the current situation of Würth Portugal and compared to other scenarios was the one where it was introduced a constraint on the maximum distance between customers and vendors (C3 scenario), whereby the sensitivity analysis focused directly on the distance.

Initially, it was studied the introduction of this parameter to a maximum of 50 km, i.e., all customers and vendors with longer distances would be automatically excluded from the analysis. It was concluded that the results were significantly better compared to other so it became important to see if the territories and distances obtained would vary with the change in this value.

This variation was studied for 25 km and 75 km. It was concluded finally that the values of the variables size of the territory and total distance traveled varied substantially when changing the restriction value. This variation is quite predictable simply because the sample size that is considered in the implementation of the model vary with different limits imposed by the restriction and, from there, the remaining changes are obvious.

It follows, therefore, that the model results are very sensitive to changes in the limit established for the maximum distance.

5. Conclusions and Future Work

To conclude this paper it is important emphasize that the objective of build sales territories that minimizes the total distance traveled by each vendor was achieved. The application of the model described to the problem of Würth allowed to compare the current situation with different scenarios. Among the scenarios studied, the one that showed significant improvements on the current situation was the scenario with the constraint of the maximum distance between the vendor-client pairs (scenario C). In this scenario it was included the possibility of both customers and sellers to be excluded from the solution precisely because they present distances greater than the limit defined. Scenario C1 also showed acceptable results in comparison with the current situation, but for issues related to the specialization of vendors in individual business areas, the currently constraints held up (remember the particular case the seller with V14 address of origin Setúbal). Scenario C2 was, from the three worked, the one that presented worst results against the objective of the study.

With regard to future development, there are some opportunities that Würth Portugal can consider in order to improve the current situation:

| Raise the awareness of vendors in order to comply with planning visits a day divided by regions or aggregators areas of neighboring customers (sub territories) in order to consolidate the business relationship with their customers and easily allocate new customers to a sub territory.

| Enter a maximum distance between vendor-client that fits the demographic and business reality of the region and use this distance as the maximum radius of the territory of the seller. This value should also serve as guidance for the seller in customer acquisition activity.

In conclusion, it is expected that this study will prove to be a useful tool to support Würth Portugal in the restructuring of the sales territories of its salesforce.

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