ISCTE Business School
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# ROUTING OPTIMIZATION: GEFCO PORTUGAL

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*Rise and rise again, until lambs become lions.*

Russell Crowe, in *Robin Hood.*

## Summary

Transport is considered a crucial area of a Supply Chain since it is responsible for bonding all the agents that are part of it.

To obtain maximum profit in distribution, it is necessary to optimize 3 variables which are referred as the vertices of the Logistics Triangle: Cost, Time and Quality, which means that products must arrive at the final customer at the right time, with the minimum cost for the company and with the maximum quality for the customers.

Routing optimization is one of the most complex areas to apply since there are a lot of variables that cannot be measured and controlled, depending on each scenario.

This project was developed to study how could this company reach the maximum quality of the service while influenced by external and internal factors which influence directly the distribution of orders placed by customers, along with restrictions associated to each scenario. Therefore, the main objective is to optimize several routes of distribution that daily supply the customers of the company.

This project is inserted in the Vehicle Routing Problems (VRP) and started by, firstly, understand the business of the company and then collecting various types of data which were treated and analysed by using Microsoft Excel and its functionalities, such as with formulas and Pivot Tables. Solutions and scenarios were analysed and presented using an Excel Spreadsheet (VRP Spreadsheet).

**Key-words:** Routing Optimization, Supply Chain, Logistics, Vehicle Routing Problem.

## Resumo

O Transporte é considerado uma parte crucial de qualquer Cadeia de Abastecimento, visto ser responsável por interligar todos os agentes que fazem parte da mesma.

Para obter máximo proveito na distribuição, é necessário otimizar as 3 variáveis que são referidas como os vértices do Triângulo Logístico: Custo, Tempo e Qualidade, o que significa que os produtos têm de chegar ao consumidor final no tempo certo, com o mínimo custo para a empresa e com a máxima qualidade possível.

A otimização de rotas é uma das áreas de maior complexidade por haver diversas variáveis que não são mensuráveis nem podem ser controladas, dependendo sempre de cada cenário.

Este projeto foi desenvolvido para estudar como a empresa consegue atingir a máxima qualidade de serviço enquanto existem fatores externos e internos que influenciam diretamente a distribuição dos pedidos dos clientes, além de restrições associadas a cada cenário. Assim sendo, o principal objetivo é otimizar várias rotas de distribuição que fornecem diariamente os diversos clientes da empresa.

Este estudo está inserido nos Problemas de Rotas (VRP) e começou, primeiramente, por analisar o negócio da empresa e recolher os diversos tipos de dados que posteriormente foram tratados e analisados através do Microsoft Excel e das suas funcionalidades como, por exemplo, fórmulas e tabelas dinâmicas. Por fim, foram analisadas e apresentadas soluções e cenários através de um programa específico do Microsoft Excel (VRP Spreadsheet).

**Palavras chave:** Otimização de Rotas, Cadeia de Abastecimento, Logística, Problema de Rotas.

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## Glossary

3PL – Third Party Logistics

4PL – Fourth Party Logistics

ARP – Arc Routing Problem

CARP – Capacitated Arc Routing Problem

CCPP – Capacitated Chinese Postman Problem

CVRP – Capacitated Vehicle Routing Problem

FTL – Full Truck Load

LLP – Lead Logistics Provider

LTL – Less than Truck Load

NRP – Node Routing Problem

SVRPD – Vehicle Routing Problem with Stochastic Demand

VRP – Vehicle Routing Problem

WRP – Warehousing and Reusable Packing

# Chapter 1: Introduction

The purpose of this project is to study the different distribution routes GEFCO, a fourth-party logistics company (4PL) which offers transport and logistic solutions to companies with a wide range of different sectors, has to deliver car parts to the PSA Group car manufacturers. One of the main issues is GEFCO orders preparation, since demand is variable and customer' orders change every day, they need to be prepared and quickly adapt its distribution routes to adjust to internal and external factors which may have a great impact in their distribution task. This study emerges from this issue in order to maintain the quality of the GEFCO service.

The study focuses on transport management and is anchored in the concepts of logistics and supply chain management since transportation is an essential part of this theoretical framework. To develop the study, some restrictions had to be taken in consideration, such has time windows of the different rotations each vehicle has, time windows in which customers are opened to receive orders and the need to deliver orders in a certain sequence, among others as we will see in the following chapters. Although the maximum quality of the service would be traduced by the delivery of all orders in every run, we will see that sometimes it is not possible to accomplish, since there are a lot of factors which influence negatively the delivery of the orders.

Although routing problems may be associated to capacitated vehicles, we will see that solutions presented assure the delivery of every order in the times established by the company, regardless of the capacity of each vehicle.

To determine the optimal route for each vehicle and rotation, there are restriction and factors which, as it has been mentioned, can be internal and external to the company and had to be taken in consideration and analysed separately since their impact is significant to the routes suggested. One of the major issues to deal with was the variable demand of the customers, which can cause changes in terms of distance, time and quantity of products distributed.

In Chapter 2 a theoretical background will be presented with references to papers and articles of study of the same nature.

In Chapter 3 the methodology and data collection to this study will be presented, mentioning how all the procedures and data presented in this project were collected and selected to achieve the results.

In Chapter 4 a brief description of the company will be made to frame the business of the company. Also, the problem description will be presented with the questions and issues that need to be analysed and answered, along with how the data was analysed to solve the problem.

Chapter 5 will be dedicated to the analysis of every result obtained, along with suggestions to every scenario.

In the final chapter conclusions and recommendations will be presented.

# Chapter 2: Literature Review

The importance of freight transportation started when the first commercial trades took place. In the early days, the transport of every type of goods between villages and cities was made using wagons pulled by horses through road and later by ships through sea. Later, the development of this activity conducted to the need to adopt new solutions to face the upcoming issues and challenges. Consumers started to be more rigorous and producers had to adapt to the changing environment so that they could fulfil the customers' needs. One of the solutions adopted by some producers was moving their production to near rivers and roads to easily export their products. Over the years, technology advanced fast and new means of transport appeared, such as the train, which in the Industrial Age was chosen as the main way to transport merchandise. After World War II, road and air transport gained tremendous importance and started being used for short and long distances.

Guedes *et al.*, (2012) defines transportation in a Supply Chain as the movement of products from the producers until the final consumer. Products can either be raw materials, parts or finished products, depending on the stage of the Supply Chain where they are inserted in. It is considered a crucial area of any Supply Chain since it is responsible for bonding the various stages of the whole Supply Chain, adding value through placing the products in the right place at the right time. The definition of the distribution routes supply chains has to assure that products arrive to the final consumer depends on several variables, such as distance, number of destinies or quantity of products transported, among others. Each of these variables may define a new problem for routing decision, such as **shortest routing problem** (minimizing the total distance travelled), **transportation problem with intermediate deposits** (transport is assured by an intermediate warehouse which may function as storage or cross-docking[1] platform), **traveling salesman problem** (origin and depot are the same and each place can only be visited once) or, the most common type of problem, **vehicle routing problem (VRP)** (determine the sequence of customers that need to be visited which minimizes the total cost of each vehicle).

[1]Cross-Docking: Instead of storing merchandise from an arrived truck, it is directly put in another truck for transportation or distribution.

There are two types of decision levels depending on the time interval chosen for a VRP:

- **Tactical problem:** this type of decision level is related to routing definition in a medium-high time interval, in which demand and deliveries are regular so it is possible to define regular routes;
- **Operational problem:** this type of decision level is characterized by uncertain demand and customers so routing definition is decided on a daily basis.

Routing problems are represented by a limited number of locations named nodes and a limited number of connections between the nodes, named arcs. According to Toth and Vigo (2014), depending if demand is concentrated on the nodes or regularly distributed along the arcs, there can be two different groups of routing problems: Node Routing Problem (NRP), where VRP is inserted, and Arc Routing Problem (ARP). According to Tirkolaee, Mahdavi and Esfahani (2018), if the problems mentioned have associated restrictions related to the capacity of the vehicles, there can be two different categories of problems, which are **Capacitated Vehicle Routing Problem (CVRP),** in which it is assumed a predefined node series with positive demand and the objective is to determine the best route which cover all nodes with capacitated vehicles, and **Capacitated Arc Routing Problem (CARP)**, in which there are several series of predefined arcs with zero or positive demand and the objective is to find the best route which covers all required arcs (with positive demand) with capacitated vehicles.

According to Khaligh and Mirhassani (2015) VRP is one of the most challenging optimization problems involving great complexity and effort to analyse all the possibilities that can emerge from choosing the best alternative to minimize the total cost associated to the route chosen. They also refer that VRP with variable demand, which the authors refer as “stochastic demand”, are the most studied cases since there are several daily situations that resemble this type of problems, such as waste collection, mail delivery or retail distribution. SVRPD problems are defined by a single vehicle with limited capacity in which it needs to serve a set of customers whose demand is uncertain. Uncertainty implies that, under certain circumstances, the vehicle may need to return to depot before all customers are satisfied.

Ballou (2004) states that there are several aspects which disturb routing optimization, such as time windows, capacity associated to the vehicles used and average speed of the

vehicles, among others. In order to develop efficient routes, there are some principles that should be taken in consideration, such as: using the most capacitated vehicles so that, if it possible, it can serve all the customers in one run, reducing the costs associated to using more than one vehicle; customers which are closer to each other should be agglomerated so that routes can be optimized in order to minimize the total distance and total travel time; aspects which disturb routing optimization should be negotiated with customers when possible, such has wider time windows; stop sequence should never cross paths and the illustration of the optimized route should form, as Ballou mentions, a "teardrop shape".

Jia, Yanqiu and Zhongjun (2014) refer that 4PL providers are supply chain integrators which are responsible for offering supply chain solutions by managing resources and capabilities so that companies can meet the customer's needs. The role of 4PL providers has been increasing in importance since customers are becoming more demanding and companies need to adjust their supply chains to serve the customer with the maximum quality possible. This assumption is traduced in the increase in transportations costs since companies need to assure that products are placed in the right place at the right time and, to do so, companies rely on 4PL solutions that may be traduced in increasing the frequency of transportation and distance covered by vehicles if it results in a quick response and adaption from the companies to customer's needs.

Taking in consideration the introduction of 4PL providers in supply chains and the need to meet the customer's needs referred earlier, the Council of Supply Chain Management Professionals (2013) defines Logistic Management as "part of the supply chain that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirements. Logistics management activities typically include inbound and outbound transportation management, fleet management, warehousing, materials handling, order fulfilment, logistics network design, inventory management, supply/demand planning, and management of third-party logistics (3PL) services providers. To varying degrees, the logistics function also includes sourcing and procurement, production planning and scheduling, packaging and assembly, and customer service. It is involved in all levels of planning and execution-strategic, operational and tactical. Logistics management is an integrating function which coordinates and optimizes all logistic activities, as well as integrates logistics activities

with other functions, including marketing, sales, manufacturing, finance, and information technology".

According to Guedes *et al.* (2012), Logistics Management is defined by three dimensions (cost, time and quality of the service) and the trade-offs between each of them (agility, leanness and responsiveness). The objective of Logistics Management is to optimize each of the variables by effectively managing each one of them in order to obtain low response time, low costs and high quality of the service. The successful management of the variables and the trade-offs influences positively the logistic system of a determined entity. The variables between the three dimensions are: agility, which is the variable between the dimensions cost and time, is the capacity of a logistic system to react and adapt to a new state of stability if it is influenced negatively by an external factor; leanness, which is the variable between cost and quality of the service, is classified as the capacity of managing effectively the logistic system so that costs can be reduced while maintaining the quality of the service; and responsiveness, which is the variable between time and quality of the service, and it is the capacity of the logistic system to give quick responses while maintaining the quality of the service (see Figure 1).

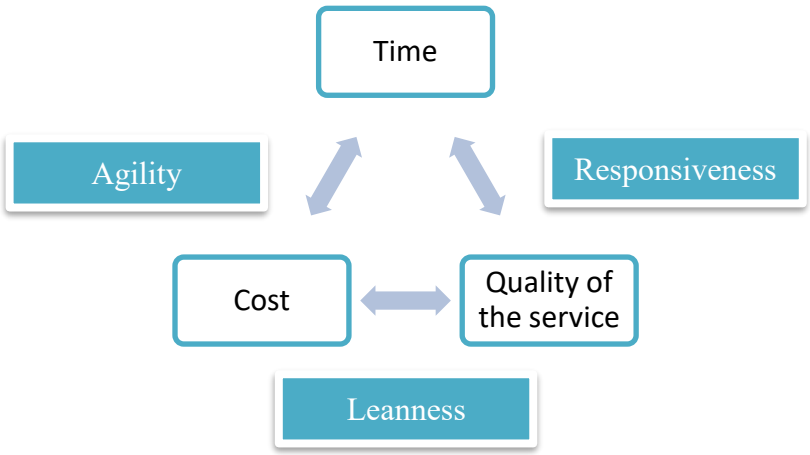


Figure 1: Dimensions and Trade-offs of the Logistics Triangle.

## Chapter 3: Methodology/Data collection

In this chapter the research methods used to obtain the information needed to develop this project will be presented, along with a description for each stage of the project.

Atieno (2009) mentions that, since quantitative data is based on qualitative judgment, both qualitative and quantitative research need to be used to make a good analysis, which means that numerical data cannot be explained if the presumptions that are related to it are not perceived. Based on this information, both types of research can and should be used to study any kind of research problem. While qualitative research is based on description and intuition, involving fieldwork by enquiring people and observing processes, quantitative research is confirmatory and deductive, requiring the analysis of numbers and statistics, being considered the scientific research paradigm. Also, the author mentions that since qualitative data can be coded quantitatively, values can be understood and analysed to help reaching a greater insight into what the data in analysis means.

Ivankova and Plano Clark (2018) introduce the mixed methods research as being a research method which combines qualitative and quantitative research, including personal observation, institutional structure and background knowledge. Although the use of this type of research has been growing in acceptance, several academics in addition to the aforementioned (e.g. Hesse-Biber, 2015) report that this method is not fully studied and developed, meaning that there are subjects and areas where it should not be used.

As it has been mentioned, mixed methods research is characterized by using both qualitative and quantitative research methods. In this project, both research types were used: while the qualitative method was used through personal observation when it was needed to understand and confirm certain values obtained through numerical evaluation (mainly associated to time), the quantitative method was used to analyse every numerical value obtained, regarding the number of deliveries, quantities and other characteristics associated to it.

To elaborate this project, it was divided in 7 stages:

The first stage was choosing the period to analyse. Since February 2018, GEFCO WRP owns a database where the customers' orders and its characteristics are registered. Therefore, data concerning orders previous from February is not available. For that reason

and to obtain a sample that could be representative of the daily deliveries made by GEFCO WRP, this study was based on the data collected through the database of the company corresponding to a period of 3 months: February, March and April.

In the second stage the information mentioned in the stage before was extracted from the database and put in an Excel file, which enabled the use of formulas and pivot tables to organize and analyse the orders delivered in the aforementioned period.

The third stage was doing an ABC Analysis to exclude customers which had insignificant impact in this study.

The fourth stage was attributing to each vehicle of each route a certain number of customers. To do so, it was needed to confirm the location of each customer considered for this study and divide the customers according to their zip code and location.

In the fifth stage, after setting the sample size, there were 2 aspects which were fundamental to define the optimal route: coordinates and work schedule of each customers considered for this study. The coordinates were extracted from the database of the company and verified using Google Maps. The work schedules were obtained by making phone calls to each one of the customers. The information on websites was not enough since there are customers' which workers arrive earlier at the companies and are able receive the orders before opening doors, which was a major factor to determine the optimal route for each vehicle.

The sixth stage was elaborating the optimal route for each vehicle and each rotation using an Excel Spreadsheet program (VRP Spreadsheet). By inserting all the information needed for elaborating the optimal route for each situation, such as coordinates, opening and closing time of the customers and service time, the program would calculate which was the optimal route according to distance. Since the first variable to optimize was time, suggested scenarios had to be adapted to present the intended results. It is important to refer that this program was crucial to the development of this project.

The seventh and final stage was analysing all the results obtained and presenting the conclusions and suggestions associated to each scenario.

# Chapter 4: Problem description and Data Analysis

## The company as a case study

GEFCO Group was founded in 1949 but only opened its first agency in Portugal in 1992. The first agency opened in Portugal was in Setúbal and it is dedicated to the distribution of Peugeot and Citroen finished vehicles (PSA Group). In 1993 a new agency was founded in Porto Alto, which in 2003 moved to Alverca. The focus of this agency is the distribution of general goods and car parts through road vehicles.

On the following years, GEFCO opened 3 more agencies in Porto, Mangualde and Pombal, all dedicated to the distribution of general goods, car parts and finished vehicles (only Mangualde).

In 2005, GEFCO founded in Alverca their first agency in Portugal of warehousing and added value services, named GEFCO WRP. This agency has the purpose to store and distribute car parts to the authorized repairers and independent repairers of PSA Group.

As a LLP-4PL solutions provider, GEFCO is responsible for controlling and managing the whole supply chain, from the moment an order is placed, storage, distribution and, in the end, the delivery to the final customer. Their core freight is road transport, although they also transport goods through air, sea and rails.

While GEFCO Alverca core business lies on national *groupage*[2] (collect and distribute general goods from various customers) and international distribution (export and import through FTL and LTL), GEFCO WRP focuses on warehousing and daily distribution of car parts to PSA Group customers, essentially. The warehouse has an area of storage of 2.700 m² and stores all types of car parts, from tires to engines to the smallest parts that are needed to build a car.

In 2016, PSA Group launched its multi-brand manufacturer's part distributor, named DISTRIGO. This new brand aims to provide to repairers the possibility to buy the best multi-brand products on the market, regardless of the car type, brand and distribution channel chosen by the customer, offering a great variety of products. This investment will

[2]*Groupage*: French word to define the collection of goods from various clients in a single vehicle, which may have different destinations. It is also known as LTL (Less than Truck Load).

allow the group to conquer market share and be a viable and strong alternative to authorized repairers from other brands.

## Problem description

GEFCO WRP is responsible for the storage and distribution of car parts for the PSA Group customers located in Lisboa and Vale do Tejo. There are two types of customers: the subsidiary firms or authorized repairers and the automotive workshops or independent repairers. The total amount of customers surpasses 260 and the average number of orders per day is close to 100.

The information flow of an order starts in the customer, which can place orders through two different channels: online platform or by phone call. If the order is placed through the online platform, it goes straight to the online platform of GEFCO WRP, but if the customer places an order through phone call, a GEFCO operator needs to insert it on the online platform. After this, the system informs the warehouse operators which items are going to be put in distribution and later informs the customer when the orders placed will be put in distribution, being the last stage the delivery of the order.

The material flow of an order may start on two different places, depending on the stock status of all items in the order. If no item is currently out of stock, the material flow starts on GEFCO WRP. Otherwise, the product needs to be ordered from GEFCO PINTO, based in Madrid and responsible for cross-docking all different types of car parts to the different GEFCO European warehouses. The products ordered from GEFCO PINTO are automatically placed by the system, which runs daily scans to verify which products need to be replenished. Every day in the morning a truck from GEFCO PINTO arrives to GEFCO WRP (until 04:00) with products ordered, which may be stored in the warehouse or put in distribution. After the picking process[3], the orders placed by the customers are put in distribution and lately delivered (see Figure 2).

[3]Picking process: It is a logistic warehouse process executed by a warehouse operator which consists in collecting an ordered item from where it is stored and preparing it for expedition.

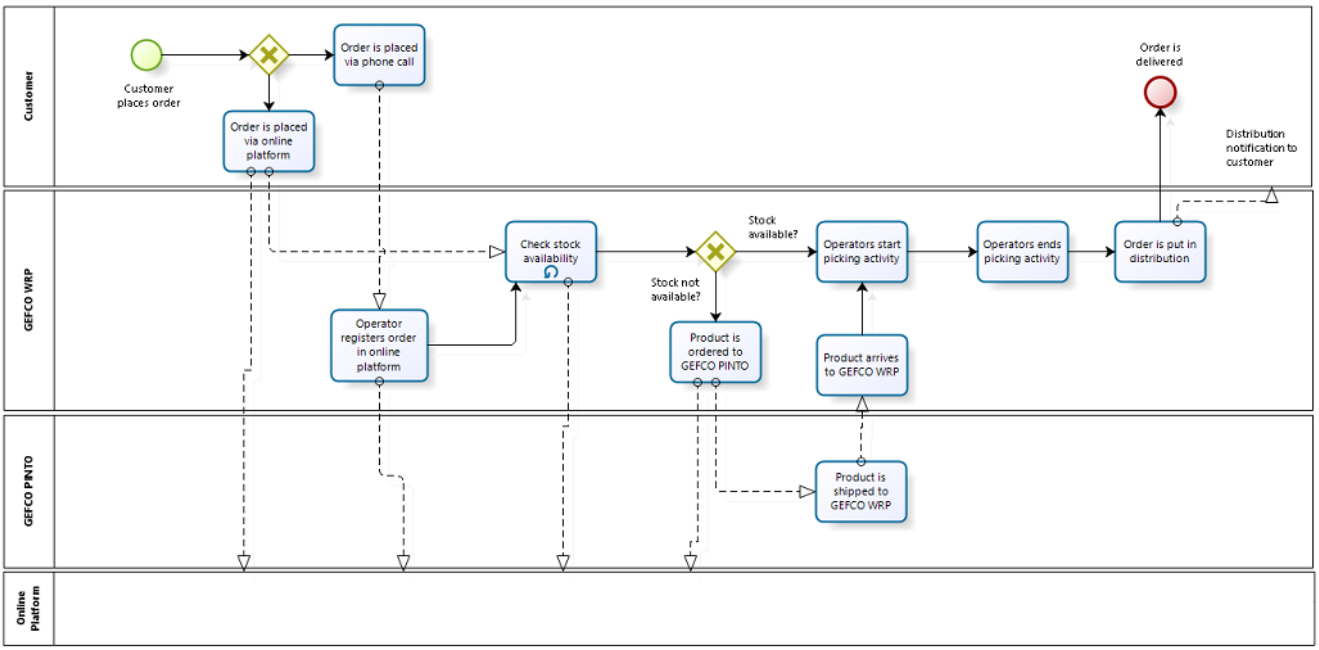


Figure 2: Material and Information Flow of an order placed by a customer.

GEFCO WRP has 6 routes to reach all customer zones where PSA Group customers are distributed. Since customers can place orders during the day, each route has 3 rotations which are defined by time windows that vehicles must respect to assure the delivery of items to every customer at the right time. The last route only has 2 rotations as we will see on the upcoming chapters.

Since demand is variable and customers are irregularly distributed in the customer zones, it may be difficult to assure that all orders are delivered on time, and consequently compromising the quality of the service. According to the Logistics Triangle and its variables (cost, time and quality), the focus of GEFCO is to serve all customers at the right time, with high quality of the service and with the lowest possible costs, although the management of these variables does not allow to maximize all three at the same time.

One other issue is the negative influence of external factors, such as traffic or weather. Since they are very unpredictable, they can influence the entire distribution and cause delays in the delivery of orders.

Considering all the information described above, the aim of this project is to optimize every rotation to maintain high levels of quality, knowing that demand is variable and external factors are unpredictable and may influence negatively the rotations.

## Customers' classification

Based on historical information, namely number of orders placed and billing volume, we can identify 2 types of customers: the U customers (Urgent), which are authorized repairers, and the AU customers (Non-Urgent), which are independent repairers. Every time a new customer places an order, it automatically enters the GEFCO's database. Since it is the first time this customer placed an order, it is considered an AU customer. Afterwards, depending on the regularity and number of orders and billing volume on the following months, it can be considered a U customer.

The customers' classification establishes if the delivery to a given customer can be postponed to a rotation posterior to the one that follows its order. For instance, suppose that a customer X places an order at 09:45. If customer X is classified as being a U customer, its order will have to be delivered in the first rotation that starts after 09:45. On the other hand, if customer X is classified as being an AU customer, its order will have to be delivered as soon as possible, although this does not mean it will be delivered in the first rotation that starts after 09:45. Deliveries from AU customers may be postponed even when they are scheduled for a given rotation. If external factors such as traffic or weather delay deliveries and the driver realizes he will not be able to arrive at depot in time for the next rotation, he has to inform GEFCO WRP so that they can inform the customers that their deliveries will be postponed. As it has been mentioned, since all deliveries from U customers need to be delivered in the first rotation that starts after the time the order is placed, one or more AU customers' deliveries may have to be postponed to assure the delivery of every order from U customers. Despite being possible to postpone the delivery of an AU customer, there is an internal policy to ensure that AU customers must have their orders delivered up to the 2 upcoming rotations that follows the order.

## Rotations, Vehicles and Service Time

Rotations are defined by time windows which vehicles need to respect: there is a time limit for vehicles to leave depot and a time limit for vehicles to return. The time since a vehicle leaves depot until it arrives is called a rotation. Each rotation starts and ends at depot, except the last rotation of each vehicle, which ends in the last customer visited. Orders placed by customers have a specific time to be prepared and to be loaded on

vehicles. Also, there is a time limit for vehicles to make last delivery to maintain maximum quality of service and arrive at depot in time to prepare for the next rotation.

As it has been mentioned on the previous sub-chapters, GEFCO WRP has 6 routes to reach all customer zones where PSA Group customers are distributed, which we will refer as vehicles (V1 to V6). Each vehicle has 3 rotations (R1 to R3) expect vehicle 6, which only has 2 rotations (R1 and R2), since it is the vehicle which travels the longest distance, as we will see in the following chapters.

Table 1: Schedules for each vehicle and placed orders

| Vehicles | Rotations | Cut-off | Preparation ending time | Time limit vehicles leave depot | Time limit for last delivery |
|---|---|---|---|---|---|
| **Vehicles 1 2 3 4 5** | R1 | 18:00 | 06:00 | 06:30 | 09:30 |
| | R2 | 10:00 | 10:30 | 11:00 | 12:30 |
| | R3 | 12:30 | 13:00 | 13:30 | 15:30 |
| **Vehicle 6** | R1 | 18:00 | 06:00 | 06:30 | 11:00 |
| | R2 | 11:00 | 11:30 | 12:00 | 15:30 |

Table 1 contains the time information about the vehicles and the corresponding rotations. The first and second columns list the vehicles and their rotations. The third column, named “Cut-off”, represents the time limit customers can place orders so that they are delivered on the upcoming rotation. Regarding the first rotation, for all vehicles, the time mentioned in this column is from the previous day, which means that orders placed until 18:00 must be delivered on the first rotation of the next day. The fourth column, named “Preparation ending time”, represents the time limit that orders need to be ready so that they can be loaded on each vehicle. The fifth column, “Time limit car leaves depot”, represents the time limit that a vehicle has to leave depot. The interval between the fourth and fifht column is the time in which orders are loaded to each vehicle. The sixth and last column, “Time limit for last delivery” is the time limit vehicles can deliver orders so they can arrive in time at depot to prepare for the next rotations. Regarding the last rotation of every vehicle (R3 to vehicles 1 to 5 and R2 to vehicle 6), it is not necessary to return to depot after delivering the last order. Taking this into account, the driver finishes its service after delivering the last order, so the time mentioned in the last rotation of each vehicle (15:30) concers the time limit all orders must be delivered to achive maxium quality of the service for the customer.

The Service Time is the time since the driver arrives to a customer until he leaves. It depends on the number of items it has to deliver to a given customer. According to

historical data, it is assumed that, for vehicles 1 to 5, the Service Time in the first rotation is 12 minutes, 8 minutes for the second rotation and 10 minutes for the third rotation. For vehicle 6, the service time for the first rotation is 14 minutes while in the second rotation it is 10 minutes. These assumptions were also confirmed by personal observation.

The average speed of each vehicle for each rotation was determined based on the locations each vehicle had to visit, taking in consideration main roads, highways, time of the day and personal observation. In Table 2 we can see the average speed that was considered for each situation:

Table 2: Average speed of each vehicle per rotation

| Vehicle | Rotation | Average Speed (km/h) |
|---|---|---|
| V1 | R1 | 50 |
| | R2 | 40 |
| | R3 | 50 |
| V2 | R1 | 50 |
| | R2 | 40 |
| | R3 | 50 |
| V3 | R1 | 50 |
| | R2 | 40 |
| | R3 | 50 |
| V4 | R1 | 60 |
| | R2 | 50 |
| | R3 | 60 |
| V5 | R1 | 60 |
| | R2 | 60 |
| | R3 | 60 |
| V6 | R1 | 70 |
| | R2 | 70 |

One major factor that needs to be mentioned is that vehicles are outsourced[4] which means GEFCO contacts transportation companies to rent vehicles and drivers to deliver their orders. The cost associated to rent a vehicle is not directly associated with the distance covered by the vehicle. GEFCO pays to the transportation companies a fixed daily value so that they can use the vehicle for daily deliveries. Then, although the price is not directly related to the distance covered on a day, the vehicle that delivers orders for the closest customers' costs less than the vehicle which delivers orders for the furthest customers.

Based on historical information, Table 3 lists the average time that vehicles leave depot on each rotation during February, March and April, and their average (Total Average):

[4]Outsourcing: Business practice in which companies transfer a service or activity to a specialized third-party agent.

Table 3: Average time vehicles leave depot in a 3-month period.

| Vehicles | Rotation | FEBRUARY | MARCH | APRIL | TOTAL Average |
|---|---|---|---|---|---|
| V1 | R1 | 06:26 | 06:24 | 06:22 | 06:24 |
| | R2 | 10:49 | 10:54 | 10:58 | 10:53 |
| | R3 | 13:25 | 13:23 | 13:26 | 13:24 |
| V2 | R1 | 06:20 | 06:10 | 06:18 | 06:16 |
| | R2 | 10:49 | 10:51 | 10:58 | 10:52 |
| | R3 | 13:16 | 13:15 | 13:20 | 13:17 |
| V3 | R1 | 06:27 | 06:22 | 06:23 | 06:24 |
| | R2 | 10:52 | 10:55 | 11:00 | 10:55 |
| | R3 | 13:26 | 13:21 | 13:27 | 13:24 |
| V4 | R1 | 06:19 | 06:12 | 06:22 | 06:17 |
| | R2 | 10:52 | 10:53 | 10:59 | 10:54 |
| | R3 | 13:17 | 13:17 | 13:21 | 13:18 |
| V5 | R1 | 06:23 | 06:14 | 06:12 | 06:16 |
| | R2 | 10:55 | 10:53 | 10:56 | 10:54 |
| | R3 | 13:27 | 13:18 | 13:22 | 13:22 |
| V6 | R1 | 06:33 | 06:18 | 06:30 | 06:27 |
| | R2 | 11:45 | 11:51 | 12:05 | 11:53 |

As we can see in table 3, the total average time vehicles leave depot never surpasses the established times previously mentioned. Since vehicles do not need to wait for the time limit to leave depot, the total average is lower than the time limit because most of the times vehicles leave depot once orders are loaded, although due to technical problems sometimes it can take more time than expected. The time a vehicle leaves depot is influenced by the number of orders to be loaded on the vehicle, number of warehouse operators and technical situation. The last factor mentioned relates to technical issues that may occur with the system used to verify customers' orders.

## Data analysis

Since February 2018, GEFCO WRP owns a database where the customers' orders are registered. Therefore, data concerning orders previous from February is not available. For that reason and to obtain a sample that can be representative of the daily deliveries made by GEFCO WRP, this study will be based on the data collected through the database of the company corresponding to a period of 3 months: February, March and April. During the aforementioned period, a total of 5800 deliveries to PSA Group customers were made, including both authorized repairers and independent repairers. Moreover, 269 different PSA Group customers placed at least one order in the 3 months mentioned.

Since a lot of customers only ordered small quantities in February, April and March, an ABC Analysis was made to select which customers were relevant to GEFCO and to this study. The ABC Analysis showed that, out of the 269 customers that placed at least one

order in the 3 months period in analysis, 197 placed less than 10 orders (classified as C customers), 47 customers placed at least 10 orders and not more than 61 orders (classified as B customers), and 25 customers placed more than 61 orders (classified as A customers) (see Figure 1). In terms of total number of customers, the C customers represent 73% of the total customers, while the B and A customers represent 17% and 9%, respectively.

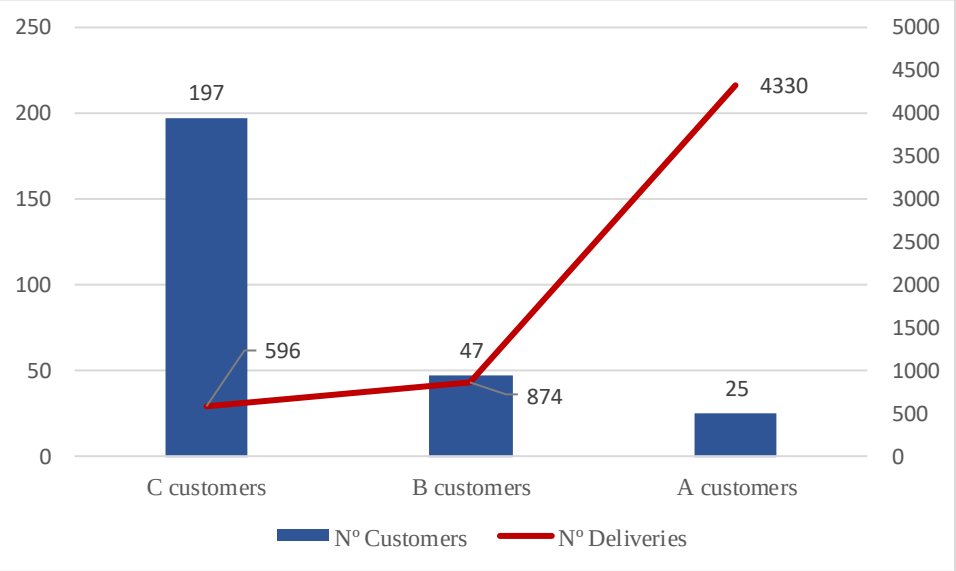


Figure 3: Customer's classification and total number of deliveries in the 3 months period in analysis.

If we consider the total number of deliveries, we can conclude that C customers placed, in total, 596 orders in February, April and March, which represent 10% of the total deliveries. The remaining 90% of placed orders were made by customers classified as B and A. In detail, B customers placed 874 orders in total, which represent 15% of the total orders and A customers were responsible for 4330 orders, representing 75% of the total orders (see Figure 1 for number of deliveries per type of customer).

In conclusion, from the 269 customers, the ones classified as C customers were removed from this study since they had little to no impact to GEFCO. Consequently, this study only includes customers classified as B and A, which represent 72 customers and 90% of the placed orders during the period under consideration.

From the 5800 deliveries registered, it is possible to conclude that 5094 were made by vehicles 1 to 5 and 706 were made by vehicle 6. One other important aspect to mention is that, from the 5800 deliveries, 4563 were placed by customers classified as U while 1237 were placed by customers classified as AU, representing 79% and 21%, respectively.

If we separate vehicles 1 to 5 from vehicle 6, we conclude that, for vehicles 1 to 5, the first rotation has the highest number of deliveries with 2556 deliveries, which represents 50% of the total deliveries. The second rotation has 676 deliveries which represents 13% of the total deliveries and the third rotation has 1862 deliveries, representing 37% of the total deliveries. Regarding the sixth vehicle, the first rotation has 474 deliveries while the second rotation has 232 deliveries, representing 67% and 33% of the total deliveries for this vehicle, respectively. Regarding orders from U and AU customers, we can conclude that, in the first rotation of vehicles 1 to 5, the number of deliveries for U customers was 2083 while for AU customers was 473. In the second rotation, the number of deliveries for U customers was 548 while the number of deliveries for AU customers was 128 and, for the third rotation, the number of deliveries was 1425 and 437 for U customers and AU customers, respectively (see Figure 4). Regarding vehicle 6, the number of deliveries for U customers in the first rotation was 345 while deliveries for AU customers were 129. For the second rotation, the number of deliveries was 157 and 75 corresponding to U customers and AU customers, respectively (see Figure 5).

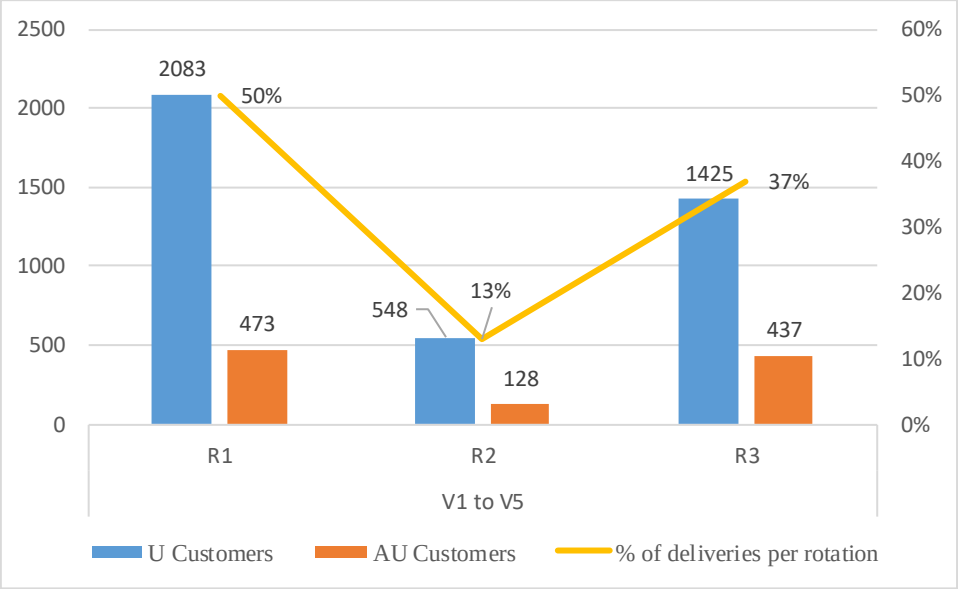


Figure 4: Number of deliveries of U and AU customers per rotation and the percentage of deliveries per rotation, for vehicles 1 to 5.

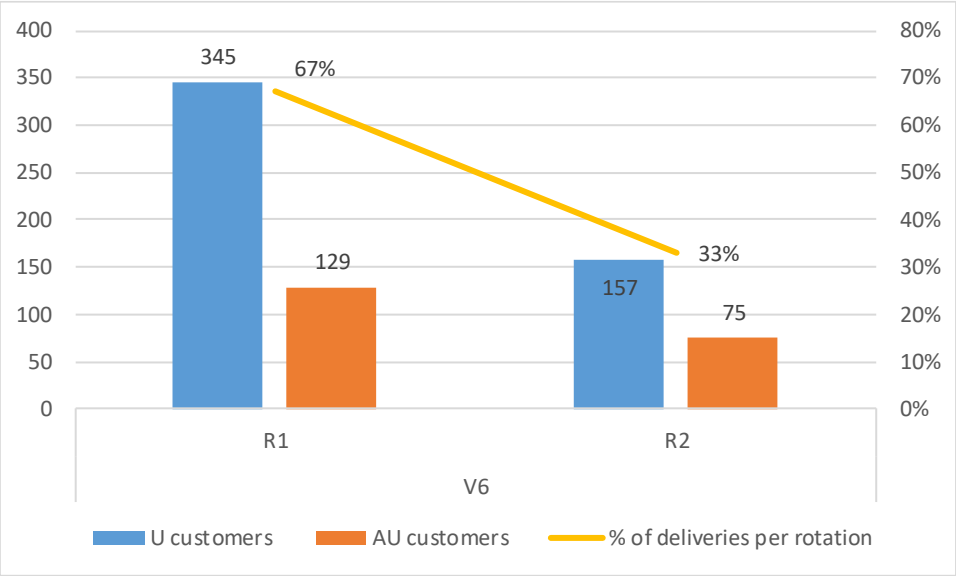


Figure 5: Number of deliveries of U and AU clients per rotation and the percentage of deliveries per rotation, for vehicle 6.

The reason why deliveries from vehicles 1 to 5 and vehicle 6 have been separated is because they do not have the same number of rotations, so they need to be analysed separately.

For each of the 72 customers under study, it was needed to collect information regarding the earliest time someone is at the location to receive the orders, which can be earlier than the opening hours for the public. For example, although some customers only open for customers at 09:00, they do have workers who arrive at work at 08:30, so they can receive the orders earlier than they open doors. This information was obtained by making phone calls to every one of the 72 customers.

The area division for each vehicle was based on the zip code and location of each customer. The customers with zip codes started by 26 were associated to vehicle 1, which corresponds to the areas of Sacavém, Loures and Camarate. The customers from the centre of Lisbon were associated to vehicle 2. These customers have zip codes started by 10, 11, 15 and 17. The customers from Pontinha, Amadora and Carnaxide were attributed to vehicle 3. The zip codes of these areas start in 16, 26 and 27. The customers from Oeiras, Sintra, Mem Martins and S.D. Rana, which zip codes start by 27, were attributed to vehicle 4. Customers from Margem Sul, which zip codes start by 28 and 29, were attributed to vehicle 5 and customers located in Santarém and between Santarém and Alverca (north), were attributed to vehicle 6. These customers have zip codes started by

20, 21, 23 and 25. Although there are customers which zip codes start with the same digits but are attributed to different vehicles is because they are located on different areas. For instance, customers from Amadora and Loures both have zip codes which start by the same zip code number (26) but since they are located on opposite locations, they are attributed to different vehicles.

## Problem formalization

As we have discussed previously, the main situation of this project regards the delivery of orders to customers assuring the maximum quality of the service. To obtain this, GEFCO needs optimized routes for every rotation which assure that orders are delivered to the customers at the right time, considering that there are external factors which are unpredictable and can influence negatively the deliveries, compromising the quality of the service.

Since the cost of the vehicles is negotiated between GEFCO and the transportation companies and is not directly related to the distance covered, the 2 main factors that need to be optimized are time and quality of the service, although, when possible, the routes will be optimized taken the distance travelled in consideration. There are some restrictions which need to be taken in account. While some are applied to all vehicles, others are specific for a determined vehicle. Before the presentation of the optimal route for each rotation, the restrictions will be presented.

Restrictions to vehicles 1 to 5: R1 – vehicles need to leave depot maximum 06:30 and return maximum 10:30; R2 – vehicles need to leave depot maximum 11:00 and return maximum 13:00; R3 – vehicles need to leave depot maximum 13:30 and do not need to return to depot.

Restriction to vehicle 6: R1 – vehicle needs to leave depot maximum 06:30 and return maximum 11:30; R2 – vehicle needs to leave depot maximum 12:00 and do not need to return to depot.

Each rotation and each vehicle will be analysed individually, and the calculations will be put in table format, followed by some justifications.

It is important to mention that every case is variable since external factors, such as traffic or weather cannot be measured and anticipated so time and distance can vary.

# Chapter 5: Problem solving

## Solving the problem: routing optimization

For the following tables, we will have 11 columns which are organized in the following order:

- Stop count: Order of the customers visited by the vehicle;
- Location Name: Name of the customers visited by the vehicle;
- Location ID: ID given to each customer;
- Total distance travelled (km): total distance, in kilometres, travelled by the vehicle, from depot to each one of the customers and finally returning to depot;
- Distance between stops (km): distance, in kilometres, between the location where the vehicle is and to where it will go next;
- Total driving time (km): total time, in hours and minutes, that the driver spent driving, from depot to each one of the customers and finally returning to depot;
- Time between stops (hh:mm): time, in hours and minutes, between the location where the vehicle is and to where it will go next;
- Arrival time (hh:mm): time, in hours and minutes, which the vehicle will arrive at certain location;
- Opening hour (hh:mm): time, in hours and minutes, a customer opens doors to receive their orders;
- Departure time (hh:mm): time, in hours and minutes, which the vehicle will leave a certain location;
- Working time (hh:mm): sum of Total driving time and Service time. It is given in hours and minutes.

<u>Restrictions for vehicle 1:</u>

- Customer **Sucursal Oficina Sacavem** needs to be the first customer visited in every rotation.

Vehicle 1, Rotation 1:

Table 4: Optimized route for vehicle 1 in rotation 1, assuming all U customers place orders.

| Stop count | Location name | Location ID | Total distance traveled (km) | Distance between stops (km) | Total driving time (hh:mm) | Time between stops (hh:mm) | Arrival time (hh:mm) | Opening hours (hh:mm) | Departure time (hh:mm) | Working time (hh:mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | WRP | 0 | 0,00 | | 0:00 | | | | 06:30 | 0:00 |
| 1 | SUCURSAL OFICINA SACAVEM | 5 | 19,79 | 19,79 | 0:21 | 0:21 | 06:51 | 24h | 07:03 | 0:33 |
| 2 | M. COUTINHO - PECAS E REP. AUT | 2 | 27,13 | 7,34 | 0:31 | 0:10 | 07:13 | 07:30 | 07:42 | 1:12 |
| 3 | AUTO SOUSAS, LDA. | 1 | 31,81 | 4,68 | 0:40 | 0:09 | 07:51 | 07:50 | 08:03 | 1:33 |
| 4 | PALOCAR,REPARACOES AUTO | 4 | 36,60 | 4,79 | 0:51 | 0:11 | 08:14 | 08:30 | 08:42 | 2:12 |
| 5 | ODICAR - COMERC AUTO. E PECAS | 3 | 48,52 | 11,92 | 1:03 | 0:12 | 08:54 | 08:30 | 09:06 | 2:36 |
| 6 | WRP | 0 | 72,92 | 24,40 | 1:26 | 0:23 | 09:29 | | | 2:59 |

Table 4 shows us that, assuming all 5 U customers placed orders and if the vehicle left depot at 06:30, it would arrive at his first customer at 06:51. Times in orange mean that the vehicle would arrive before the opening hours and would have to wait for the customer to open. Customer ID 2 opens at 07:30 and the vehicle arrives at 07:13, which means it would have to wait 17 minutes for it to open. Moreover, customer ID 4 opens at 08:30 and the vehicle arrives at 08:14, which means it would have to wait 16 minutes for it to open. After serving all U customers, if the vehicle returned to depot, it would arrive at 09:29, so we can conclude that the total working time is 02:59 hours, as it is mentioned in the last column. Since it has until 10:30 to return to depot, this vehicle still would have around 1 more hour to make deliveries, so we could include AU customers in this rotation if they placed orders. One other important factor to mention is that there are 2 customers which the vehicle would need to wait at until someone from the company arrived to receive the orders. If we sum the waiting time of the two customers, we conclude that the vehicle would be idle for 33 minutes. Also, if we look at the fourth column, we can conclude that the vehicle would travel 72 km and the total driving time would be 01:26 hours.

Vehicle 1, Rotation 2:

Table 5: Optimized route for vehicle 1 in rotation 2, assuming all U customers place orders.

| Stop count | Location name | Location ID | Total distance traveled (km) | Distance between stops (km) | Total driving time (hh:mm) | Time between stops (hh:mm) | Arrival time (hh:mm) | Opening hours (hh:mm) | Departure time (hh:mm) | Working time (hh:mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | WRP | 0 | 0,00 | | 0:00 | | | | 11:00 | 0:00 |
| 1 | SUCURSAL OFICINA SACAVEM | 5 | 19,79 | 19,79 | 0:21 | 0:21 | 11:21 | 24h | 11:29 | 0:29 |
| 2 | ODICAR - COMERC AUTO. E PECAS | 3 | 30,49 | 10,70 | 0:34 | 0:13 | 11:42 | 08:30 | 11:50 | 0:50 |
| 3 | M. COUTINHO - PECAS E REP. AUT | 2 | 37,62 | 7,13 | 0:43 | 0:09 | 11:59 | 07:30 | 12:07 | 1:07 |
| 4 | AUTO SOUSAS, LDA. | 1 | 42,31 | 4,68 | 0:52 | 0:09 | 12:16 | 07:50 | 12:24 | 1:24 |
| 5 | PALOCAR,REPARACOES AUTO | 4 | 47,10 | 4,79 | 1:03 | 0:11 | 12:35 | 08:30 | 12:43 | 1:43 |
| 6 | WRP | 0 | 62,84 | 15,74 | 1:24 | 0:21 | 13:04 | | | 2:04 |

Table 5 shows us that, assuming the car leaves depot at 11:00 and all 5 U customers place orders in this rotation, the vehicle would return to depot 4 minutes after the established time. The vehicle departs from the last customer at 12:43 and it takes 21 min to arrive to depot, meaning that it would arrive at 13:04. On this scenario there are no closed customers, so the vehicle has no idle time. Also, in comparison to the first rotation, the stop count is different, meaning that closed customers influence the stop count. Since all customers are opened, the vehicle can take the shortest route which, in this scenario, is also the route that takes less time. Taken this into consideration, the total distance travelled by this vehicle would be 62 km and the total driving time 01:24 hours, being the total working time 02:04 hours.

Vehicle 1, Rotation 3:

Table 6: Optimized route for vehicle 1 in rotation 3, assuming all U customers place orders.

| Stop count | Location name | Location ID | Total distance traveled (km) | Distance between stops (km) | Total driving time (hh:mm) | Time between stops (hh:mm) | Arrival time (hh:mm) | Opening hours (hh:mm) | Departure time (hh:mm) | Working time (hh:mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | WRP | 0 | 0,00 | | 0:00 | | | | 13:30 | 0:00 |
| 1 | SUCURSAL OFICINA SACAVEM | 5 | 19,79 | 19,79 | 0:21 | 0:21 | 13:51 | 24h | 14:01 | 0:31 |
| 2 | AUTO SOUSAS, LDA. | 1 | 22,29 | 2,50 | 0:26 | 0:05 | 14:06 | 13:30 | 14:16 | 0:46 |
| 3 | PALOCAR,REPARACOES AUTO | 4 | 27,08 | 4,79 | 0:37 | 0:11 | 14:27 | 08:30 | 14:37 | 1:07 |
| 4 | M. COUTINHO - PECAS E REP. AUT | 2 | 35,64 | 8,56 | 0:46 | 0:09 | 14:46 | 14:00 | 14:56 | 1:26 |
| 5 | ODICAR - COMERC AUTO. E PECAS | 3 | 43,05 | 7,40 | 0:57 | 0:11 | 15:07 | 14:00 | 15:17 | 1:47 |

Table 6 shows us that, assuming the vehicle leaves depot at 13:30 and all 5 U customers place orders in this rotation, the car would finish delivering all U customers at 15:07. In comparison to the previous two rotations, the stop count is different since there are customers which close for lunch and open doors at a determined time, so the optimized route must be planned according to this factor. As it has been mentioned in the previous chapters, the vehicle does not return to depot, so the total distance, total driving time and working time are shorter than if it had to return to depot. The total driving distance is 43 km, while the total driving time and working time are 57 minutes and 01:47 hours, respectively. As we have discussed in the previous chapters, all orders from AU customers must be delivered in the two upcoming rotations that follow their order. Since most customers attributed to this route close at 18:00, we can assume that this rotation is the most fit to have orders from AU customers delivered.

<u>Restrictions for vehicle 2:</u>

- No restrictions.

Vehicle 2, Rotation 1:

Table 7: Optimized route for vehicle 2 in rotation 1, assuming all U customers place orders.

| Stop count | Location name | Location ID | Total distance travelled (km) | Distance between stops (km) | Total driving time (hh:mm) | Time between stops (hh:mm) | Arrival time (hh:mm) | Opening hour (hh:mm) | Departure time (hh:mm) | Working time (hh:mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | WRP | 0 | 0,00 | | 0:00 | | | | 06:30 | 0:00 |
| 1 | AUTO MONTES CLAROS LDA | 2 | 23,32 | 23,32 | 0:26 | 0:26 | 06:56 | 07:00 | 07:12 | 0:42 |
| 2 | GARAGEM INTENDENTE DE POMBO | 3 | 26,29 | 2,96 | 0:34 | 0:08 | 07:20 | 07:30 | 07:42 | 1:12 |
| 3 | AUTO BENFICA | 1 | 34,00 | 7,71 | 0:53 | 0:19 | 08:01 | 08:00 | 08:13 | 1:43 |
| 4 | SUCURSAL OFICINA RF | 5 | 38,61 | 4,62 | 1:05 | 0:12 | 08:25 | 08:00 | 08:37 | 2:07 |
| 5 | HUILACAR, LDA. | 4 | 48,88 | 10,27 | 1:20 | 0:15 | 08:52 | 09:00 | 09:12 | 2:42 |
| 6 | WRP | 0 | 70,79 | 21,91 | 1:44 | 0:24 | 09:36 | | | 3:06 |

Table 7 shows us that, assuming all 5 U customers placed orders and the vehicle leaves at 06:30 from depot, it would arrive at his first customer at 06:56. Times in orange mean the vehicle would arrive before the opening hours and would have to wait for the customer to open. Customer ID 2 opens at 07:00 and the vehicle arrives at 06:56, which means it would have to wait 4 minutes for it to open. Moreover, customer ID 3 opens at 07:30 and the vehicle arrives at 07:20, which means it will have to wait 10 minutes for it to open. Regarding customer ID 4, it opens at 09:00 but the vehicle arrives at 08:52 so it would have to wait 8 minutes for it to open. After serving all the U customers, if the vehicle returned to depot, it would arrive at 09:36, so we can conclude the total working time is 03:06 hours, as it is mentioned in the last column. Since it had until 10:30 to return to depot, it means it would have 1 more hour to make deliveries, so we could include AU customers in this rotation if they placed orders. As we can see on Table 7, there are 3 customers which the vehicle would need to wait at until someone from the company arrived to receive the orders, concluding that the idle time of this vehicle in this rotation is 22 minutes. If we look at column 4 we conclude that the total distance covered by the vehicle is 70 km and the total driving time is 01:44 hours.

Vehicle 2, Rotation 2:

Table 8: Optimized route for vehicle 2 in rotation 2, assuming all U customers place orders.

| Stop count | Location name | Location ID | Total distance traveled (km) | Distance between stops (km) | Total driving time (hh:mm) | Time between stops (hh:mm) | Arrival time (hh:mm) | Opening hour (hh:mm) | Departure time (hh:mm) | Working time (hh:mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | WRP | 0 | 0,00 | | 0:00 | | | | 11:00 | 0:00 |
| 1 | AUTO MONTES CLAROS LDA | 2 | 23,32 | 23,32 | 0:26 | 0:26 | 11:26 | 07:00 | 11:34 | 0:34 |
| 2 | GARAGEM INTENDENTE DE POMBO | 3 | 26,29 | 2,96 | 0:34 | 0:08 | 11:42 | 07:30 | 11:50 | 0:50 |
| 3 | AUTO BENFICA | 1 | 34,00 | 7,71 | 0:53 | 0:19 | 12:09 | 08:00 | 12:17 | 1:17 |
| 4 | SUCURSAL OFICINA RF | 5 | 38,61 | 4,62 | 1:05 | 0:12 | 12:29 | 08:00 | 12:37 | 1:37 |
| 5 | HUILACAR, LDA. | 4 | 48,88 | 10,27 | 1:20 | 0:15 | 12:52 | 09:00 | 13:00 | 2:00 |
| 6 | WRP | 0 | 70,79 | 21,91 | 1:44 | 0:24 | 13:24 | | | 2:24 |

Table 8 shows us that, assuming the vehicle leaves depot at 11:00 and all 5 U customers placed orders in this rotation, the vehicle would return to depot 24 minutes after the established time. The vehicle leaves the last customer at 13:00, which is the time limit for this rotation and it takes 24 minutes to return to depot, meaning it would arrive at 13:24. On this scenario there are no closed customers, so the vehicle has no idle time. If we compare this rotation with the first rotation of this vehicle, we can see that the stop count is the same, meaning that not only this route is optimized accordingly to the lowest time possible but also to the shortest distance covered. Taken this into consideration, the total distance covered by the vehicle would be 70 km and the total driving time 01:44 hours, being the total working time 02:24 hours.

Vehicle 2, Rotation 3:

Table 9: Optimized route for vehicle 2 in rotation 3, assuming all U customers place orders.

| Stop count | Location name | Location ID | Total distance traveled (km) | Distance between stops (km) | Total driving time (hh:mm) | Time between stops (hh:mm) | Arrival time (hh:mm) | Opening hours (hh:mm) | Departure time (hh:mm) | Working time (hh:mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | WRP | 0 | 0,00 | | 0:00 | | | | 13:30 | 0:00 |
| 1 | AUTO MONTES CLAROS LDA | 2 | 23,32 | 23,32 | 0:26 | 0:26 | 13:56 | 07:00 | 14:06 | 0:36 |
| 2 | GARAGEM INTENDENTE DE POMBO | 3 | 26,29 | 2,96 | 0:34 | 0:08 | 14:14 | 14:00 | 14:24 | 0:54 |
| 3 | AUTO BENFICA | 1 | 34,00 | 7,71 | 0:53 | 0:19 | 14:43 | 14:30 | 14:53 | 1:23 |
| 4 | SUCURSAL OFICINA RF | 5 | 38,61 | 4,62 | 1:05 | 0:12 | 15:05 | 08:00 | 15:15 | 1:45 |
| 5 | HUILACAR, LDA. | 4 | 48,88 | 10,27 | 1:20 | 0:15 | 15:30 | 14:30 | 15:40 | 2:10 |

If we look at table 9 we can see that, assuming the vehicle leaves depot at 13:30 and all 5 U customers placed orders in this rotation, the vehicle would finish delivering all U customers at 15:30. If we compare this rotation to the previous ones of this vehicle, we can see that the stop count is the same, meaning that not only this route is optimized accordingly to the lowest time possible but also to the shortest distance covered. Since this is the last rotation, the vehicle does not return to depot, so the total distance, total driving time and working time are shorter than if it had to return to depot. The total distance is 48 km, while the total driving time and working time are 01:20 hours and 02:10 hours, respectively. As we have discussed in the previous chapters, all orders from AU customers must be delivered in the two upcoming rotations that follow their order. Despite the last delivery of a U customer is done at 15:30, we can include deliveries for AU customers in this rotation, since most customers close at 18:00.

Restrictions for vehicle 3:

- The first customer to be visited, imperatively and in all rotations, is **Citroverca – Com. e Reparação** and after this customer the vehicle needs to go to **Sucursal Oficina Alfragide.**
- **Citroverca Com. e Reparação** and **Jose Manuel Martins, LDA** are located in the same place (next to each other), so orders are delivered in the same customer, meaning that service time is 00:12 minutes for both customers. Since all orders are delivered on one customer, we will just consider in the following scenarios the customer **Citroverca Com. e Reparação.**

Vehicle 3, Rotation 1:

Table 10: Optimized route for vehicle 3 in rotation 1, assuming all U customers place orders.

| Stop count | Location name | Location ID | Total distance traveled (km) | Distance between stops (km) | Total driving time (hh:mm) | Time between stops (hh:mm) | Arrival time (hh:mm) | Opening hours (hh:mm) | Departure time (hh:mm) | Working time (hh:mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | WRP | 0 | 0,00 | | 0:00 | | | | 06:30 | 0:00 |
| 1 | CITROVERCA - COM. E REPARACAO | 2 | 0,78 | 0,78 | 0:02 | 0:02 | 06:32 | 24h | 06:44 | 0:14 |
| 2 | SUCURSAL OFICINA ALFRAGIDE | 5 | 30,48 | 29,69 | 0:28 | 0:26 | 07:10 | 24h | 07:22 | 0:52 |
| 3 | MARQUES SILVA LDA | 4 | 39,85 | 9,38 | 0:38 | 0:10 | 07:32 | 08:00 | 08:12 | 1:42 |
| 4 | AUTO CONTINENTE 2 - COMERCIO | 1 | 45,59 | 5,74 | 0:47 | 0:09 | 08:21 | 08:30 | 08:42 | 2:12 |
| 5 | VERTEXCAPRICE UNIPESSOAL LDA | 6 | 53,11 | 7,52 | 0:57 | 0:10 | 08:52 | 09:00 | 09:12 | 2:42 |
| 6 | JOSE M.MARTINS FILIPELDA | 3 | 54,92 | 1,80 | 1:01 | 0:04 | 09:16 | 09:00 | 09:28 | 2:58 |
| 7 | WRP | 0 | 80,46 | 25,55 | 1:27 | 0:26 | 09:54 | | | 3:24 |

Table 10 shows us that, assuming all 7 U customers place orders in this rotation, the vehicle leaves at 06:30 from depot, it would arrive at his first customer at 06:32. After leaving the first customer the vehicle must go to **Sucursal Oficina Alfragide**. Times in orange mean that the vehicle would arrive before the opening hours and would have to wait for the customer to open. Customer ID 4 opens at 08:00 and the vehicle arrives at 07:32, which means it would have to wait 28 minutes for it to open. Moreover, customer ID 1 opens at 08:30 and the vehicle arrives at 08:21, which means it would have to wait 9 minutes for it to open. Regarding customer ID 6, it opens at 09:00 and the car arrives at 08:52, meaning it would have to wait 8 minutes for it to open. After serving all the U customers, if the vehicle returned to depot, it would arrive at 09:54, so we can conclude that the total working time is 03:24 hours, as it is mentioned in the last column. Since it had until 10:30 to return to depot, it means it has 36 minutes to make deliveries, so we can include AU customers in this rotation if they place orders. As we can see on table 10, there are 3 customers which the vehicle needs to wait at until someone from the company arrives to receive the orders. We can conclude that the idle time of this vehicle in this

rotation is 45 minutes. If we look at column 4 we conclude that the total distance covered by this vehicle is 80 km and the total driving time is 01:27 hours.

Vehicle 3, Rotation 2:

Table 11: Optimized route for vehicle 3 in rotation 2, assuming all U customers place orders.

| Stop count | Location name | Location ID | Total distance traveled (km) | Distance between stops (km) | Total driving time (hh:mm) | Time between stops (hh:mm) | Arrival time (hh:mm) | Opening hours (hh:mm) | Departure time (hh:mm) | Working time (hh:mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | WRP | 0 | 0,00 | | 0:00 | | | | 11:00 | 0:00 |
| 1 | CITROVERCA - COM. E REPARACAO | 2 | 0,78 | 0,78 | 0:02 | 0:02 | 11:02 | 24h | 11:10 | 0:10 |
| 2 | SUCURSAL OFICINA ALFRAGIDE | 5 | 30,48 | 29,69 | 0:28 | 0:26 | 11:36 | 24h | 11:44 | 0:44 |
| 3 | AUTO CONTINENTE 2 - COMERCIO | 1 | 35,84 | 5,36 | 0:36 | 0:08 | 11:52 | 08:30 | 12:00 | 1:00 |
| 4 | MARQUES SILVA LDA | 4 | 42,66 | 6,82 | 0:46 | 0:10 | 12:10 | 08:00 | 12:18 | 1:18 |
| 5 | VERTEXCAPRICE UNIPESSOAL LDA | 6 | 45,44 | 2,78 | 0:52 | 0:06 | 12:24 | 09:00 | 12:32 | 1:32 |
| 6 | JOSE M.MARTINS FILIPELDA | 3 | 47,24 | 1,80 | 0:56 | 0:04 | 12:36 | 09:00 | 12:44 | 1:44 |
| 7 | WRP | 0 | 72,79 | 25,55 | 1:22 | 0:26 | 13:10 | | | 2:10 |

Table 11 shows us that, assuming the car leaves depot at 11:00 and all 7 U customers place orders in this rotation, the vehicle would return to depot 10 minutes after the established time. The vehicle leaves the last customer at 12:44 but it takes 26 minutes to return to depot, meaning it would arrive at 13:10. On this scenario there are no closed customers, so the vehicle has no idle time. If we compare this rotation to the previous one, we can see that the stop count is different: on this rotation customer ID 1 is visited after customer ID 5, while in the first rotation it was customer ID 4 the customer visited after customer ID 5. This change of order is explained by the opening hours of each customer: since there are no customers closed in this rotation, the route is optimized according to shortest distance covered and lowest time possible. Taken this into consideration, the total distance covered by the vehicle would be 72 km and the total driving time 01:22 hours, being the total working time 02:10 hours.

Vehicle 3, Rotation 3:

Table 12: Optimized route for vehicle 3 in rotation 3, assuming all U customers place orders.

| Stop count | Location name | Location ID | Total distance traveled (km) | Distance between stops (km) | Total driving time (hh:mm) | Time between stops (hh:mm) | Arrival time (hh:mm) | Opening hours (hh:mm) | Departure time (hh:mm) | Working time (hh:mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | WRP | 0 | 0,00 | | 0:00 | | | | 13:30 | 0:00 |
| 1 | CITROVERCA - COM. E REPARACAO | 2 | 0,78 | 0,78 | 0:02 | 0:02 | 13:32 | 24h | 13:42 | 0:12 |
| 2 | SUCURSAL OFICINA ALFRAGIDE | 5 | 30,48 | 29,69 | 0:28 | 0:26 | 14:08 | 24h | 14:18 | 0:48 |
| 3 | AUTO CONTINENTE 2 - COMERCIO | 1 | 35,84 | 5,36 | 0:36 | 0:08 | 14:26 | 08:30 | 14:36 | 1:06 |
| 4 | MARQUES SILVA LDA | 4 | 42,66 | 6,82 | 0:46 | 0:10 | 14:46 | 08:00 | 14:56 | 1:26 |
| 5 | VERTEXCAPRICE UNIPESSOAL LDA | 6 | 45,44 | 2,78 | 0:52 | 0:06 | 15:02 | 09:00 | 15:12 | 1:42 |
| 6 | JOSE M.MARTINS FILIPELDA | 3 | 47,24 | 1,80 | 0:56 | 0:04 | 15:16 | 09:00 | 15:26 | 1:56 |

Table 12 shows us that, assuming the car leaves the depot at 13:30 and all 7 U customers place orders in this rotation, the vehicle would finish delivering all U customers at 15:16. If we compare this rotation to the previous ones of this vehicle, we can see that the stop count is the same as rotation 2, meaning that this rotation is also optimized according to shortest distance covered and lowest time possible. Since this is the last rotation, the vehicle does not need to return to depot, so the total distance, total driving time and working time are shorter than if it had to return to depot. The total distance covered is 47 km, while the total driving time and working time are 56 minutes and 01:56 hours, respectively. As we have discussed in the previous chapters, all orders from AU customers must be delivered in the two upcoming rotations that follow their order. Since most customers close at 18:00, we can assume that this rotation is most fit to have orders from AU customers delivered. The only issue is that they would be delivered after 15:30, compromising the quality of the service offered.

Restrictions for vehicle 4:

- Customer **Sucursal Oficina Oeiras** needs to be the first customer visited in every rotation.

Table 13: Optimized route for vehicle 3 in rotation 1, assuming all U customers place orders.

| Stop count | Location name | Location ID | Total distance traveled (km) | Distance between stops (km) | Total driving time (hh:mm) | Time between stops (hh:mm) | Arrival time (hh:mm) | Opening hours (hh:mm) | Departure time (hh:mm) | Working time (hh:mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | WRP | 0 | 0,00 | | 0:00 | | | | 06:30 | 0:00 |
| 1 | SUCURSAL OFICINA OEIRAS | 7 | 41,20 | 41,20 | 0:30 | 0:30 | 07:00 | 24h | 07:12 | 0:42 |
| 2 | CAMEJO RAMALHO E SILVA LDA | 1 | 43,50 | 2,29 | 0:36 | 0:06 | 07:18 | 07:15 | 07:30 | 1:00 |
| 3 | RAMALHO RAMALHO | 4 | 49,36 | 5,86 | 0:44 | 0:08 | 07:38 | 07:45 | 07:57 | 1:27 |
| 4 | RUGEMPECAS, LDA S.DOMINGOS RANA | 5 | 50,69 | 1,33 | 0:48 | 0:04 | 08:01 | 08:15 | 08:27 | 1:57 |
| 5 | F MARQUES E FILHOS LDA | 2 | 60,58 | 9,89 | 1:09 | 0:21 | 08:48 | 08:00 | 09:00 | 2:30 |
| 6 | RUGEMPECAS, LDA TERRUGEM | 6 | 69,03 | 8,45 | 1:24 | 0:15 | 09:15 | 09:00 | 09:27 | 2:57 |
| 7 | M C D GARCIA LDA. | 3 | 75,03 | 6,00 | 1:36 | 0:12 | 09:39 | 08:30 | 09:51 | 3:21 |
| 8 | WRP | 0 | 121,42 | 46,40 | 2:17 | 0:41 | 10:32 | | | 4:02 |

Table 13 shows us that, assuming all the 7 U customers place orders and if the vehicle leaves at 06:30 from depot, it would arrive at his first customer at 07:00. Times in orange mean that the vehicle would arrive before the opening hours and would have to wait for the customer to open. Customer ID 4 it opens at 07:45 and the vehicle would arrive at 07:38, which means that it will have to wait 7 minutes for it to open. Moreover, customer ID 5 opens at 08:45 and the vehicle arrives at 08:01, meaning that it would have to wait 44 minutes for it to open. After serving all U customers, if the vehicle returned to the depot, it would arrive at 10:32, so we can conclude the total working time is 04:02 hours. Since it had until 10:30 to return to the depot, it means it would arrive 2 minutes after the

established time. One important factor to mention is that there are two customers which the vehicle needs to wait at until someone from the company arrives to receive the orders. If we sum the waiting time of the two customers, we conclude that the vehicle is idle for 21 minutes. Also, if we look at the fourth column, we conclude that the vehicle covers 121 km and the total driving time is 02:17 hours.

Vehicle 4, Rotation 2:

Table 14: Optimized route for vehicle 4 in rotation 2, assuming all U customers place orders.

| Stop count | Location name | Location ID | Total distance traveled (km) | Distance between stops (km) | Total driving time (hh:mm) | Time between stops (hh:mm) | Arrival time (hh:mm) | Opening hours (hh:mm) | Departure time (hh:mm) | Working time (hh:mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | WRP | 0 | 0,00 | | 0:00 | | | | 11:00 | 0:00 |
| 1 | SUCURSAL OFICINA OEIRAS | 7 | 41,20 | 41,20 | 0:30 | 0:30 | 11:30 | 24h | 11:38 | 0:38 |
| 2 | CAMEJO RAMALHO E SILVA LDA | 1 | 43,50 | 2,29 | 0:36 | 0:06 | 11:44 | 07:15 | 11:52 | 0:52 |
| 3 | RAMALHO RAMALHO | 4 | 49,36 | 5,86 | 0:44 | 0:08 | 12:00 | 08:45 | 12:08 | 1:08 |
| 4 | RUGEMPECAS, LDA S.DOMINGOS RANA | 5 | 50,69 | 1,33 | 0:48 | 0:04 | 12:12 | 07:45 | 12:20 | 1:20 |
| 5 | F MARQUES E FILHOS LDA | 2 | 60,58 | 9,89 | 1:09 | 0:21 | 12:41 | 08:00 | 12:49 | 1:49 |
| 6 | RUGEMPECAS, LDA TERRUGEM | 6 | 69,03 | 8,45 | 1:24 | 0:15 | 13:04 | 09:00 | 13:12 | 2:12 |
| 7 | M C D GARCIA LDA. | 3 | 75,03 | 6,00 | 1:36 | 0:12 | 13:24 | 08:30 | 13:32 | 2:32 |
| 8 | WRP | 0 | 121,42 | 46,40 | 2:17 | 0:41 | 14:13 | | | 3:13 |

Table 14 shows us that, assuming the vehicle leaves depot at 11:00 and all 7 U customers place orders in this rotation, the vehicle would return to depot at 14:12, 01:12 hours after the established time. The vehicle leaves the last customer at 13:31, 31 minutes after the established time and it takes 41 minutes for it to arrive at depot. On this scenario there are no closed customers, so the vehicle has no idle time. If we compare this rotation to the previous one, we can see that the stop count is the same Taken this into consideration, the total distance covered by the vehicle would be 121 km and the total driving time 02:17 hours, being the total working time 03:13 hours.

Vehicle 4, Rotation 3:

Table 15: Optimized route for vehicle 4 in rotation 3, assuming all U customers place orders.

| Stop count | Location name | Location ID | Total distance traveled (km) | Distance between stops (km) | Total driving time (hh:mm) | Time between stops (hh:mm) | Arrival time (hh:mm) | Opening hours (hh:mm) | Departure time (hh:mm) | Working time (hh:mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | WRP | 0 | 0,00 | | 0:00 | | | | 13:30 | 0:00 |
| 1 | SUCURSAL OFICINA OEIRAS | 7 | 41,20 | 41,20 | 0:30 | 0:30 | 14:00 | 24h | 14:10 | 0:40 |
| 2 | CAMEJO RAMALHO E SILVA LDA | 1 | 43,50 | 2,29 | 0:36 | 0:06 | 14:16 | 07:15 | 14:26 | 0:56 |
| 3 | RAMALHO RAMALHO | 4 | 49,36 | 5,86 | 0:44 | 0:08 | 14:34 | 14:00 | 14:44 | 1:14 |
| 4 | RUGEMPECAS, LDA S.DOMINGOS RANA | 5 | 50,69 | 1,33 | 0:48 | 0:04 | 14:48 | 08:45 | 14:58 | 1:28 |
| 5 | F MARQUES E FILHOS LDA | 2 | 60,58 | 9,89 | 1:09 | 0:21 | 15:19 | 08:00 | 15:29 | 1:59 |
| 6 | RUGEMPECAS, LDA TERRUGEM | 6 | 69,03 | 8,45 | 1:24 | 0:15 | 15:44 | 09:00 | 15:54 | 2:24 |
| 7 | M C D GARCIA LDA. | 3 | 75,03 | 6,00 | 1:36 | 0:12 | 16:06 | 08:30 | 16:16 | 2:46 |

Table 15 shows us that, assuming the vehicle leaves depot at 13:30 and all 7 U customers place orders in this rotation, the vehicle would finish delivering all orders at 16:06. If we compare this rotation to the previous ones of this vehicle, we can see that the stop count

is the same, so this rotation is optimized according to shortest distance covered and lowest time possible. Since this is the last rotation, the vehicle does not need to return to depot, so the total distance, total driving time and working time are shorter than if it had to return to depot. The total distance covered is 75 km, while the total driving time and working time are 01:36 hours and 02:46 hours, respectively. Although all customers must have their orders delivered until 15:30 so that GEFCO can guarantee maximum quality of the service, the orders from AU customers from this and other rotations should be delivered on rotation 3 since most customers' close doors at 18:00. As we can see, the orders from all U customers are delivered until 16:06, meaning that there are 2 customers which have their orders delivered after 15:30, compromising the quality of the service for the remaining orders it must deliver on this rotation.

Restrictions for vehicle 5:

- **Sucursal Setubal** is not delivered in the first rotation, only on second and third.

Vehicle 5, Rotation 1:

Table 16: Optimized route for vehicle 5 in rotation 1, assuming 5 U customers place orders.

| Stop count | Location name | Location ID | Total distance traveled (km) | Distance between stops (km) | Total driving time (hh:mm) | Time between stops (hh:mm) | Arrival time (hh:mm) | Opening hours (hh:mm) | Departure time (hh:mm) | Working time (hh:mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | WRP | 0 | 0,00 | | 0:00 | | | | 06:30 | 0:00 |
| 1 | AUTO MONUMENTAL DE ALMADA AMORA | 2 | 40,83 | 40,83 | 0:40 | 0:40 | 07:10 | 07:00 | 07:22 | 0:52 |
| 2 | AUTO QUALIDADE LDA | 4 | 55,85 | 15,02 | 1:02 | 0:22 | 07:44 | 08:15 | 08:27 | 1:57 |
| 3 | PAULO ALEXANDRE E MIGUEL GRACA LDA | 5 | 65,56 | 9,71 | 1:17 | 0:15 | 08:42 | 08:50 | 09:02 | 2:32 |
| 4 | AUTO FLORA-MANUEL ANTONIO PAU | 1 | 80,67 | 15,11 | 1:34 | 0:17 | 09:19 | 08:30 | 09:31 | 3:01 |
| 5 | AUTO MONUMENTAL DE ALMADA MOITA | 3 | 80,67 | 0,00 | 1:34 | 0:00 | 09:31 | 08:30 | 09:43 | 3:13 |
| 6 | WRP | 0 | 125,07 | 44,40 | 2:06 | 0:32 | 10:15 | | | 3:45 |

Table 16 shows us that, assuming 5 U customers place orders in this rotation and the vehicle leaves at 06:30 from depot, it would arrive at his first customer at 07:10. Times in orange mean that the vehicle would arrive before the opening hours and would have to wait for the customer to open. Customer ID 4 opens at 08:15 and the vehicle arrives at 07:44, which means it would have to wait 31 minutes for it to open. Moreover, customer ID 5 opens at 08:50 and the vehicle arrives at 08:42, meaning that it would have to wait 8 minutes for it to open. After serving U customers, if the vehicle returned to depot, it would arrive at 10:15, so we can conclude the total working time is 03:45 hours. Since it has until 10:30 to return to depot, it means it would arrive 15 minutes before the established time. One important factor to mention is that there are two customers which the vehicle need to wait at until someone from the company arrives to receive the orders.

If we sum the waiting time of the two customers, we conclude the vehicle is idle for 39 minutes. Also, if we look at the fourth column, we conclude that the vehicle covers 125 km and the total driving time is 03:45 hours.

Vehicle 5, Rotation 2:

Table 17: Optimized route for vehicle 5 in rotation 2, assuming all U customers place orders.

| Stop count | Location name | Location ID | Total distance traveled (km) | Distance between stops (km) | Total driving time (hh:mm) | Time between stops (hh:mm) | Arrival time (hh:mm) | Opening hours (hh:mm) | Departure time (hh:mm) | Working time (hh:mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | WRP | 0 | 0,00 | | 0:00 | | | | 11:00 | 0:00 |
| 1 | AUTO MONUMENTAL DE ALMADA MOITA | 3 | 45,50 | 45,50 | 0:35 | 0:35 | 11:35 | 08:30 | 11:43 | 0:43 |
| 2 | AUTO FLORA-MANUEL ANTONIO PAU | 1 | 45,50 | 0,00 | 0:35 | 0:00 | 11:43 | 08:30 | 11:51 | 0:51 |
| 3 | AUTO QUALIDADE LDA | 4 | 58,11 | 12,60 | 0:48 | 0:13 | 12:04 | 08:15 | 12:12 | 1:12 |
| 4 | PAULO ALEXANDRE E MIGUEL GRACA LDA | 5 | 67,81 | 9,71 | 1:03 | 0:15 | 12:27 | 08:50 | 12:35 | 1:35 |
| 5 | SUCURSAL OFICINA SETUBAL | 6 | 89,70 | 21,89 | 1:29 | 0:26 | 13:01 | 24h | 13:09 | 2:09 |
| 6 | AUTO MONUMENTAL DE ALMADA AMORA | 2 | 119,22 | 29,52 | 1:59 | 0:30 | 13:39 | 07:00 | 13:47 | 2:47 |
| 7 | WRP | 0 | 160,17 | 40,95 | 2:39 | 0:40 | 14:27 | | | 3:27 |

Table 17 shows us that, assuming the vehicle leaves depot at 11:00 and all 6 U customers place orders in this rotation, the vehicle would return to depot at 14:27, 01:27 hours after the established time. The vehicle leaves the last customer at 13:47, meaning that it already should have left depot for the third rotation. The main reason for this to happen is because this vehicle must cover long distances, compromising the arrival of the vehicle in time to depot. On this scenario there are no closed customers, so the vehicle has no idle time. If we compare this rotation to the previous one, we can see that, not only the stop count is different, but also there is one more customer to visit. Taken this into consideration, the total distance covered by the vehicle would be 160 km and the total driving time 02:39 hours, being the total working time 03:27 hours.

Vehicle 5, Rotation 3:

Table 18: Optimized route for vehicle 5 in rotation 3, assuming all U customers place orders.

| Stop count | Location name | Location ID | Total distance traveled (km) | Distance between stops (km) | Total driving time (hh:mm) | Time between stops (hh:mm) | Arrival time (hh:mm) | Opening hours (hh:mm) | Departure time (hh:mm) | Working time (hh:mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | WRP | 0 | 0,00 | | 0:00 | | | | 13:30 | 0:00 |
| 1 | AUTO MONUMENTAL DE ALMADA AMORA | 2 | 40,83 | 40,83 | 0:40 | 0:40 | 14:10 | 07:00 | 14:20 | 0:50 |
| 2 | PAULO ALEXANDRE E MIGUEL GRACA LDA | 5 | 55,99 | 15,16 | 1:02 | 0:22 | 14:42 | 14:00 | 14:52 | 1:22 |
| 3 | AUTO QUALIDADE LDA | 4 | 65,66 | 9,67 | 1:18 | 0:16 | 15:08 | 14:00 | 15:18 | 1:48 |
| 4 | AUTO FLORA-MANUEL ANTONIO PAU | 1 | 78,88 | 13,22 | 1:32 | 0:14 | 15:32 | 14:30 | 15:42 | 2:12 |
| 5 | AUTO MONUMENTAL DE ALMADA MOITA | 3 | 78,88 | 0,00 | 1:32 | 0:00 | 15:42 | 14:00 | 15:52 | 2:22 |
| 6 | SUCURSAL OFICINA SETUBAL | 6 | 94,30 | 15,42 | 1:55 | 0:23 | 16:15 | 24h | 16:25 | 2:55 |

Table 18 shows us that, assuming the vehicle leaves depot at 13:30 and all 6 U customers place orders in this rotation, the vehicle would finish delivering all U customers at 16:15. If we compare this rotation to the previous ones, we can see that the stop count is different from the previous rotations. The main reason for this to happen is because of the opening

hours. Since this is the last rotation, the vehicle does not need to return to depot, so the total distance, total driving time and working time are shorter than if it had to return to depot. The total distance covered is 94 km, while the total driving time and working time are 01:55 hours and 02:55 hours, respectively. Although all customers must have their orders delivered until 15:30 so that GEFCO can guarantee maximum quality of the service, the orders from AU should be delivered on rotation 3 since most customers' close at 18:00 or later. As we can see on the eight column, all orders from U customers are delivered until 16:15, meaning that there are 3 customers which have their orders delivered after 15:30, compromising the quality of the service for the last three U customers and for the remaining orders it still has to deliver on this rotation.

Restrictions for vehicle 6:

- Only 2 rotations.

Vehicle 6, Rotation 1:

Table 19: Optimized route for vehicle 6 in rotation 1, assuming all U customers place orders.

| Stop count | Location name | Location ID | Total distance traveled (km) | Distance between stops (km) | Total driving time (hh:mm) | Time between stops (hh:mm) | Arrival time (hh:mm) | Opening hours (hh:mm) | Departure time (hh:mm) | Working time (hh:mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | WRP | 0 | 0,00 | | 0:00 | | | | 06:30 | 0:00 |
| 1 | MECANICA AGRICOLA LDA BENAVENTE | 3 | 29,99 | 29,99 | 0:24 | 0:24 | 06:54 | 07:00 | 07:14 | 0:44 |
| 2 | VASILPNEUS,LDA | 5 | 45,18 | 15,18 | 0:41 | 0:17 | 07:31 | 24h | 07:45 | 1:15 |
| 3 | MECANICA AGRICOLA LDA VARZEA | 4 | 75,78 | 30,61 | 1:11 | 0:30 | 08:15 | 07:00 | 08:29 | 1:59 |
| 4 | ALVES DA LUZ, LDA | 1 | 118,34 | 42,56 | 1:39 | 0:28 | 08:57 | 08:30 | 09:11 | 2:41 |
| 5 | ANENACLA-COM.PECAS AUTOMOVEIS, | 2 | 134,76 | 16,42 | 1:53 | 0:14 | 09:25 | 08:00 | 09:39 | 3:09 |
| 6 | WRP | 0 | 225,25 | 90,50 | 2:49 | 0:56 | 10:35 | | | 4:05 |

Table 19 shows us that, assuming all 5 U customers place orders in this rotation and the vehicle leaves at 06:30 from depot, it would arrive at his first customer at 06:54. Times in orange mean the vehicle would arrive before the opening hours and would have to wait for the customer to open. Customer ID 3 opens at 07:00 and the vehicle arrives at 06:54, which means it would have to wait 6 minutes for it to open. After serving these customers, if the vehicle returned to depot, it would arrive at 10:35, so we can conclude that the total working time is 04:05 hours. Since it had until 11:30 to return to depot, we can include some U customers in this rotation if they placed orders. The idle time for this vehicle in this rotation is 6 minutes. If we look at the fourth column, we conclude that the vehicle covers 225 km and the total driving time is 02:49 hours.

Vehicle 6, Rotation 2:

Table 20: Optimized route for vehicle 6 in rotation 2, assuming all U customers place orders.

| Stop count | Location name | Location ID | Total distance traveled (km) | Distance between stops (km) | Total driving time (hh:mm) | Time between stops (hh:mm) | Arrival time (hh:mm) | Opening hours (hh:mm) | Departure time (hh:mm) | Working time (hh:mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | WRP | 0 | 0,00 | | 0:00 | | | | 12:00 | 0:00 |
| 1 | MECANICA AGRICOLA LDA BENAVENTE | 3 | 29,99 | 29,99 | 0:24 | 0:24 | 12:24 | 07:00 | 12:34 | 0:34 |
| 2 | VASILPNEUS,LDA | 5 | 45,18 | 15,18 | 0:41 | 0:17 | 12:51 | 24h | 13:01 | 1:01 |
| 3 | MECANICA AGRICOLA LDA VARZEA | 4 | 75,78 | 30,61 | 1:11 | 0:30 | 13:31 | 07:00 | 13:41 | 1:41 |
| 4 | ALVES DA LUZ, LDA | 1 | 118,34 | 42,56 | 1:39 | 0:28 | 14:09 | 08:00 | 14:19 | 2:19 |
| 5 | ANENACLA-COM.PECAS AUTOMOVEIS, | 2 | 134,76 | 16,42 | 1:53 | 0:14 | 14:33 | 08:30 | 14:43 | 2:43 |

Table 20 shows us that, assuming all 5 U customers place orders in this rotation and the vehicle leaves at 12:00 from depot, it would finish delivering all customers at 14:34. If we compare this rotation to the previous one, we can see that the stop count is the same. Since this is the last rotation, the vehicle does not need to return to depot, so the total distance, total driving time and working time are shorter than if it had to return to depot. The total distance covered is 134 km, while the total driving time and working time are 01:53 hours and 02:43 hours, respectively. Although all customers must have their orders delivered until 15:30 so that GEFCO can guarantee maximum quality of the service, the orders from AU from this and other rotations should be delivered on rotation 3 since most customers' close at 18:00 or later. As we can see on the column "Arrival time", the vehicle finishes delivering all U customers' orders at 14:34, almost one hour before the established time to guarantee maximum quality of the service. Taken this into consideration, this vehicle still has one hour to deliver other customers, maintaining the quality of the service.

After interpreting each of the tables on the previous sub-chapter, we can take several conclusions regarding each of the rotations. Starting with the distance covered by each vehicle, figure 7 shows us the distance covered by each vehicle in each rotation. We can conclude that vehicle 5 covers the longest total distance, while vehicle 1 covers the shortest total distance. Also, we can conclude that vehicle 6 is the vehicle which covers the longest distance in a single rotation.

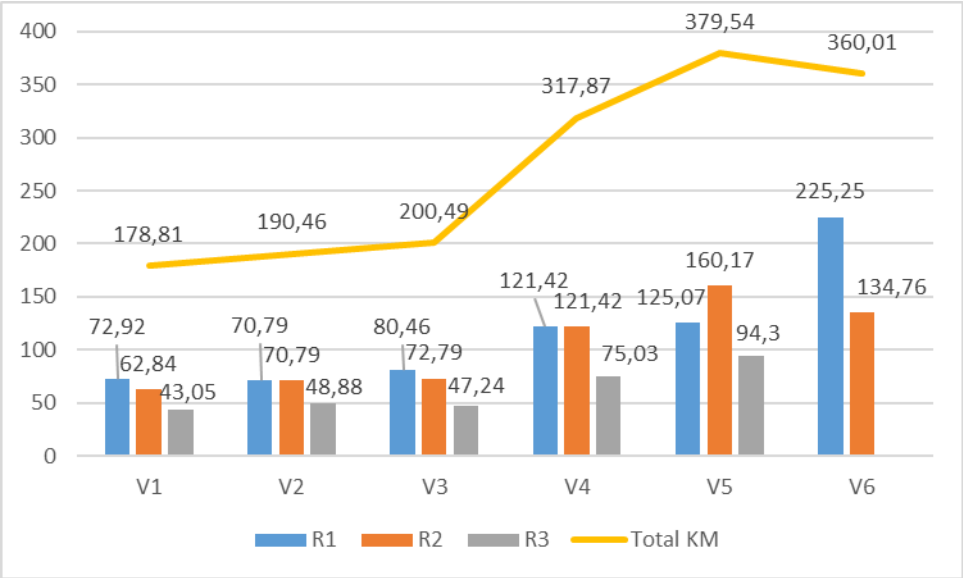


Figure 6: Total distance covered by each vehicle, in each rotation.

Regarding the idle time for the three rotations, the vehicle which has the highest value is vehicle 3, which is 00:45 minutes, followed by vehicle 5 with 00:39 minutes. Then, we have vehicle 1 with 00:33 minutes, vehicle 2 with 00:22 minutes, vehicle 4 with 00:21 minutes and finally vehicle 6 with just 00:06 minutes. The idle time compromises the deliveries from all vehicles since they cannot go to other customers before delivering all orders since it is not advantageous, not only in terms of distance but also in terms of time. Rotations are optimized according to arriving the earliest to depot and, if possible, with the shortest distance possible to cover.

Regarding all the vehicles, vehicle 4 never arrived on the established time in any of the rotations, so we can conclude it is not possible to deliver orders for AU customers, at least in the first and second rotation. In the first rotation, according to the tables, we can see that vehicle 4 in the only which arrives later than the established arrival time to depot (2 minutes after). All the other vehicles arrive on time and some even have time to make more deliveries, like vehicles 1, 2, 3 and 6. Regarding the third rotation, and taking in consideration that in order to maintain the maximum quality of the service, the vehicles needed to deliver all U customers until 15:30, we conclude that only vehicles 4 and 5 still have orders to deliver to U customers after the established time. Also, because most AU customers' close doors at 18:00, this rotation is fit to have remaining orders from other rotations delivered.

Taking in consideration the number of deliveries of U and AU customers per vehicle and rotation (table 21 to 26 in Annex), we can conclude that:

- For vehicle 1, the average number of deliveries per rotation is 6,90, which means, excluding the U customers, there are 2 more AU customers which place orders per rotation. If we consider customers classified as B and A in the ABC Analysis, we conclude that this vehicle has 20 customers in total. Although most orders come from U customers, we can see that there are also some AU customers with high number of orders during the 3 months in analysis (table 27 in Annex);
- For vehicle 2, the average number of deliveries per rotation is 4,63, which means that U customers are the ones that mostly place orders (table 28 in Annex). If we consider customers classified as B and A in the ABC Analysis, we conclude that this vehicle has 9 customers in total;
- For vehicle 3, the average number of deliveries per rotation is 6,19, which means, same as vehicle 2, U customers are the ones that mostly place orders (table 29 in Annex). If we consider customers classified as B and A in the ABC Analysis, we conclude that this vehicle has 14 customers in total;
- For vehicle 4, the average number of deliveries per rotation is 5,99, which means U customers are the ones that mostly place orders (table 30 in Annex). If we consider customers classified as B and A in the ABC Analysis, we conclude that this vehicle has 8 customers in total, meaning there is only 1 customer classified as AU;
- For vehicle 5, the average number of deliveries per rotation is 4,59, which means U customers are the ones that mostly place orders (table 31 in Annex). If we consider customers classified as B and A in the ABC Analysis, we conclude this vehicle has 11 customers in total;
- For vehicle 6, the average number of deliveries per rotation is 3,92, which means U customers are the ones that mostly place orders (table 32 in Annex). If we consider customers classified as B and A in the ABC Analysis, we conclude that this vehicle has 10 customers.

In conclusion and after analysing every scenario obtained, we can say that rotation 2 has the most restrict schedules, since none of the vehicles arrived at the time established. This rotation should be adapted so that only U customers would be inserted in this rotation, while rotations 1 and 3 could have both U and AU customers. Also, as we have mentioned, vehicle 4 is the most troublesome since it never arrived on time in any of the rotations. For this case, we can assume two different solutions: put one more vehicle

which could support this and the other vehicles if there were a lot of customers to visit; partner up with a local distribution company so that it could help distributing orders from a determined rotation.

# Chapter 6: Conclusions

This project was crucial to understand how should GEFCO deal with the distribution of orders for the PSA customers taking in consideration all the factors which could influence the distribution of placed orders. One major issue during this analysis was the quantity of variables that influenced how to determine the optimal route for each rotation and justify why it is not possible to accurately define the optimal route.

As we have seen, there are several factors which cannot be determined with precision that influence the rotations, such as traffic, weather, arrival of employees that can receive orders and demand of the customers, among others. With this said, the optimal route is determined based on the data collected, not only through the database of the company, but also by personal observation since it was crucial to understand how the whole supply chain worked: from the picking activity and preparation of the orders to the distribution and delivery in each of the customers. The personal observation was crucial since it enabled to accurately determine values like average speed of each rotation or service time.

Each of the rotations depends on the demand from each one of the customers: there are some days with more orders than others, as there are days with less. Also, sometimes one customer which is not regular in placing orders decided to do it and the optimal route has to be designed taken that customer into consideration. Since this could happen, the best way to determine which customers were important to include on this study was through the ABC Analysis, which enabled to sort and classify those customers that did not order regularly.

Regarding the rotations of vehicles 1 to 5, the development of this project allowed to understand that rotation 2 is very strict when it comes to schedules, so only U clients should be attributed to this rotation. Also, clients and schedules attributed to vehicle 4 should be reviewed since this vehicle did not arrive on time at depot on the first and second rotation. Also, the quality of the service has been improved since optimized routes enabled vehicles to arrive at the right time at each of the clients.

VRP Spreadsheet was a crucial tool since it enabled to accurately determine the best route according to shortest time or distance covered by analysing the variables inserted. One of the main advantages of this Spreadsheet was the quickness it generated the optimized routes and the precision of each value given. All the data collected, analysed and used to

solve this project was based on the database of the company and personal observation in real time.

The development of this project is expected to, not only have a positive impact on the daily distribution of the several customers GEFCO has, but also allow other projects to be developed related to this matter.

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# Annexes

| Vehicle | Client | Classification | Sum of orders placed | Sum of Nº of volumes | Sum of weight (kg) |
|---|---|---|---|---|---|
| V1 | A.H.ALMEIDA | AU | 21 | 33 | 33,77 |
| | A.S.FERREIRA | AU | 1 | 1 | 0,01 |
| | ACP-SERVICOS RAPIDOS PRIOR VELHO | AU | 10 | 15 | 17,42 |
| | ANA GIL PEREIRA-REP.E COM.AUTO | AU | 12 | 32 | 108,1 |
| | ANTONIO ALCOBIA UNIPESSOA L,LD | AU | 1 | 1 | 0,51 |
| | ANTONIO GUERREIRO DAMAS | AU | 4 | 8 | 14,69 |
| | AUTO AJT UNIPESSOAL LDA | AU | 1 | 1 | 0,02 |
| | AUTO CANICOS UNIPESSOAL,L DA | AU | 7 | 9 | 2,89 |
| | AUTO FORMIOMNIA, LDA | AU | 3 | 5 | 1,23 |
| | AUTO JMS | AU | 20 | 27 | 18,49 |
| | AUTO PAUSACA REPARACOES AUTO, | AU | 1 | 3 | 0,58 |
| | AUTO PIMPAO MARGARIDO | AU | 2 | 3 | 0,61 |
| | AUTO PINHEIROS RODRIGUES | AU | 2 | 3 | 0,21 |
| | AUTO REPARADORA BRAGADENSELDA | AU | 7 | 9 | 4,21 |
| | AUTO REPARADORA MARIO E CARMO | AU | 16 | 52 | 49,89 |
| | AUTO REPARADORA RUNA SILVA | AU | 1 | 1 | 0,15 |
| | AUTO SOUSAS, LDA. | U | 133 | 383 | 774,61 |
| | CARMAGA,LDA | AU | 2 | 5 | 60,07 |
| | CASTRO E CRUZ, LDA | AU | 8 | 10 | 0,53 |
| | CENTRAUTO - COMPONENTES AUTO, | AU | 2 | 2 | 1,06 |
| | CEPRA - CENTRO FORMACAO | AU | 3 | 7 | 19,07 |
| | CITROFIX - OFICINA REP. AUTO | AU | 8 | 9 | 2,7 |
| | COSMIAUTO LDA | AU | 6 | 7 | 6,84 |
| | DIVER - AUTO , LDA. | AU | 1 | 2 | 0,91 |
| | ESTEVES E CRUZ, LDA | AU | 1 | 1 | 1,4 |
| | F. MENDES E SANTOS LDA | AU | 1 | 1 | 1,37 |
| | FLAAUTO-PECAS AUTO LDA | AU | 1 | 1 | 0,15 |
| | FORMULA F, LDA | AU | 15 | 16 | 4,91 |
| | GEFCO PORTUGAL TRANSITARIOS - | AU | 2 | 20 | 40 |
| | GJ CAR-REP. DE AUTO.LDA | AU | 2 | 2 | 1,05 |
| | GONCALVES VICENTES LDA | AU | 2 | 2 | 1,07 |
| | GRANLOURES-COMERCIO PECAS AUTO | AU | 12 | 22 | 20,33 |
| | H2O VISUAL, LDA | AU | 3 | 3 | 1,97 |
| | J.P.A.AUTO REPARADORA,LDA | AU | 11 | 30 | 63,07 |
| | JOEL LUCAS ROQUE | AU | 5 | 5 | 0,41 |
| | JORCARSERVICE-COM.REP.MANUT.AU | AU | 1 | 1 | 0,14 |
| | JOVICAUTO DA RAMADA,LDA | AU | 3 | 4 | 18,25 |
| | LOPES RIBEIRO PINTURAS LDA | AU | 11 | 40 | 16,61 |
| | LOURESFIBRA, LDA | AU | 2 | 2 | 0,88 |
| | LUIS FILIPE DA SILVA SOUSA | AU | 2 | 3 | 21,82 |
| | M. COUTINHO - PECAS E REP. AUT | U | 180 | 994 | 1601,16 |
| | M.C.PECAS | AU | 19 | 22 | 10,74 |
| | MARCO ANTONIO OLIVEIRA NOTA | AU | 1 | 1 | 0,03 |
| | MARLENE SOFIA RODRIGUES TEIXEI | AU | 4 | 6 | 3,37 |
| | MCS- PECAS E ACESSORIOS CAMARATE | AU | 11 | 13 | 10,02 |
| | METALURGICA DE CARRICHE LDA | AU | 2 | 3 | 2,39 |
| | MICROMOTOR LDA. PRIOR VELHO | AU | 10 | 15 | 22,37 |
| | MOTIVOBRIGATORIO, LDA | AU | 3 | 4 | 1,12 |
| | NELSON ARRULO, REPARACO ES A | AU | 5 | 5 | 1,56 |
| | NEVES E CANDEIAS LDA | AU | 1 | 1 | 0,02 |
| | NUELTINA,LDA | AU | 3 | 3 | 6,17 |
| | ODICAR - COMERC AUTO. E PECAS | U | 143 | 631 | 1013,17 |
| | PALOCAR,REPARACOES AUTO | U | 34 | 48 | 35,04 |
| | PAULO MARTINS OFICINA AUTO | AU | 1 | 4 | 8,66 |
| | PECILOURES COM. DE PECAS | AU | 37 | 67 | 57,3 |
| | PEDRO M M GODINHO | AU | 5 | 7 | 0,8 |
| | PINHEIRO SOUSA, LDA | AU | 2 | 2 | 0,55 |
| | RUI PAULO E ALMEIDA | AU | 73 | 114 | 52,17 |
| | SAQUINE SALEM,UNIPESSOAL, LDA | AU | 18 | 35 | 37,06 |
| | SERGIO ANDRADE ELECTRICE REP. | AU | 3 | 4 | 3,11 |
| | STOPCARMO DE ALVERCA LDA | AU | 4 | 4 | 0,35 |
| | SUCURSAL OFICINA SACAVEM | U | 328 | 5542 | 10881,12 |
| | TRAJETORIA DEFINIDA, LDA. | AU | 1 | 1 | 0,02 |
| | VERAUTO DE JOAO RIBEIRO | AU | 4 | 4 | 1,54 |
| | VICAREL- REPARACOES AUTO | AU | 3 | 6 | 9,07 |
| | VOLANTE DE ALVERCA | AU | 1 | 1 | 0,3 |
| TOTAL | | | 1242 | 8318 | 15071,21 |

Table 21: Volume, weight and total number of placed orders by customers attributed to vehicle 1.

| Vehicle | Client | Classification | Sum of orders placed | Sum of Nº of volumes | Sum of weight (kg) |
|---|---|---|---|---|---|
| V2 | ACP-SERVICOS RAPIDOS LISBOA | AU | 3 | 4 | 4,14 |
| | AEROX SERVICE - AUTO REP AIR, | AU | 1 | 5 | 81,15 |
| | AUTO BENFICA | U | 185 | 791 | 1863,49 |
| | AUTO ENCARNACAO | AU | 5 | 5 | 1,03 |
| | AUTO FASCINANTE LDA | AU | 9 | 9 | 2,83 |
| | AUTO MONTES CLAROS LDA | U | 214 | 737 | 1501,44 |
| | AUTO PARQUE SA. | AU | 2 | 2 | 0,13 |
| | AUTO R.SERIZ MONTEIRO LDA. | AU | 2 | 2 | 14,11 |
| | AUTO REP. BAETA,LDA | AU | 2 | 4 | 7,28 |
| | AVENTURATRANS LDA | AU | 4 | 11 | 18,24 |
| | CARVALME AUTO,LDA | AU | 4 | 9 | 9,25 |
| | DOMINGUES TOME | AU | 20 | 27 | 18,07 |
| | FERNANDO ROCHA,LDA.REP.AUTOMOV | AU | 2 | 3 | 0,66 |
| | GARAGEM CONDESTAVEL, LDA | AU | 3 | 6 | 2,83 |
| | GARAGEM DO CHILE LDA | AU | 3 | 3 | 1,39 |
| | GARAGEM INTENDENTE DE POMBO | U | 27 | 79 | 221,49 |
| | GARAGEM SETIL, LDA | AU | 2 | 2 | 3,36 |
| | GLASSLIS LDA | AU | 3 | 4 | 4,42 |
| | HERDEIROS JOAQUIM LOPES, LDA | AU | 5 | 8 | 3,73 |
| | HUILACAR, LDA. | U | 47 | 109 | 113,13 |
| | JOSE M.P.C MONTEIRO | AU | 8 | 10 | 41,7 |
| | LX AUTO | AU | 1 | 1 | 0,05 |
| | MCS- PECAS E ACESSORIOS LISBOA | AU | 9 | 11 | 24,69 |
| | O DOUTOR DOS PNEUS | AU | 9 | 23 | 10,87 |
| | PLANETA AUTO COMERCIO E REP | AU | 20 | 41 | 54,36 |
| | REP MODERNA DE CAMPOLIDE | AU | 1 | 2 | 0,44 |
| | REVISTO REPARACOES AUTO, LDA | AU | 10 | 11 | 10,61 |
| | SANDRA PERALTA | AU | 1 | 1 | 1 |
| | SANTOS CHAMBEL,LDA.OF A UTO- | AU | 1 | 1 | 0,14 |
| | STROBOSOM,LDA | AU | 12 | 35 | 83,96 |
| | SUCURSAL OFICINA RF | U | 200 | 813 | 2026,17 |
| | TOME E NUNES LDA | AU | 3 | 3 | 12,58 |
| | VMS, UNIPESSOAL, LDA | AU | 5 | 6 | 2,62 |
| | WDBAUTO,LDA | AU | 9 | 11 | 12,84 |
| | YELLOW TALENT UNIPESSOAL,LDA | AU | 1 | 1 | 0,06 |
| **TOTAL** | | | **833** | **2790** | **6154,26** |

Table 22: Volume, weight and total number of placed orders by customers attributed to vehicle 2.

| Vehicle | Client | Classification | Sum of orders placed | Sum of Nº of volumes | Sum of weight (kg) |
|---|---|---|---|---|---|
| V3 | A.J.B. AMORIM | AU | 3 | 3 | 0,67 |
| | AUTO CENTRAL DE CAXIAS | AU | 1 | 1 | 3 |
| | AUTO CONTINENTE 2 - COMERCIO | U | 237 | 1900 | 5344,61 |
| | AUTO ELECTRO MEC DAMAIENSE | AU | 5 | 7 | 3,37 |
| | AUTO LUSO ALEMA | AU | 20 | 25 | 18,12 |
| | AUTO REP. MARQUES E IRMAO | AU | 3 | 3 | 0,56 |
| | AUTO REP.EUGENIO E MARQUES LDA | AU | 2 | 2 | 0,8 |
| | AUTO REPARADORA CASAL DO RATO | U | 5 | 8 | 4,35 |
| | AUTO W4V6 OFICINA REP AUTO UNI | AU | 4 | 15 | 24,25 |
| | BOAVENTURA E FILHOS,LDA | AU | 11 | 13 | 5,4 |
| | CARVIVAS - COM. E REP AUTOMOVE | AU | 12 | 33 | 60,47 |
| | CITROVERCA - COM. E REPARACAO | U | 176 | 580 | 825,77 |
| | ENTRE RODAS-AUTOMOVEIS,LDA | AU | 2 | 2 | 4,24 |
| | J. RAMIRO MARTINS | AU | 1 | 1 | 0,28 |
| | JOSE M.MARTINS FILIPELDA | U | 12 | 21 | 49,82 |
| | JOSE MANUEL FERREIRA ABRANTES- | AU | 2 | 2 | 1,05 |
| | JOSE MANUEL MARTINS, LDA | U | 207 | 714 | 1211,81 |
| | JOSE MARIA ANA PEDRO | AU | 5 | 14 | 13,33 |
| | LINDAUTO LDA | AU | 11 | 18 | 12,52 |
| | MANLOC LDA | AU | 1 | 3 | 1,69 |
| | MARCO TEIXEIRA MANUTENCAO E R | AU | 1 | 1 | 0,29 |
| | MARQUES SILVA LDA | U | 72 | 152 | 103,93 |
| | MIRA E LOBO, LDA | AU | 1 | 1 | 2,64 |
| | NARRATIVA SALUTAR,LDA | AU | 1 | 3 | 2,17 |
| | NASCIMENTO DINIS PECAS,LDA | AU | 15 | 17 | 40,87 |
| | PECA CERTA, UNIPESSOAL, LDA | AU | 1 | 1 | 5 |
| | PFF AUTO LDA ENTREGAS | AU | 5 | 5 | 2,75 |
| | PNEUCAR - SOC. COMERCIAL PNEUS | AU | 1 | 1 | 10 |
| | RXRS AUTO, LDA | AU | 1 | 6 | 73,64 |
| | SIMOES FLORENCIO LDA | AU | 23 | 67 | 81,67 |
| | SOBRAL E FONSECA, SA | AU | 13 | 23 | 13,59 |
| | STAND RICARDO HUMBERTO VILAR C | AU | 4 | 5 | 1,07 |
| | SUCURSAL OFICINA ALFRAGIDE | U | 241 | 4212 | 14546,2 |
| | VERTEXCAPRICE UNIPESSOAL LDA | U | 15 | 51 | 89,97 |
| TOTAL | | | 1114 | 7910 | 22559,9 |

Table 23: Volume, weight and total number of placed orders by customers attributed to vehicle 3.

| Vehicle | Client | Classification | Sum of orders placed | Sum of Nº of volumes | Sum of weight (kg) |
|---|---|---|---|---|---|
| V4 | AMERICO SILVEIRA E FILHOS,LDA | AU | 6 | 13 | 31,15 |
| | AUTO ARTUR JORGE FILHOS, LDA | AU | 12 | 18 | 9,45 |
| | AUTO PEDROSO DE JOAO SANTOS | AU | 2 | 4 | 1,15 |
| | AUTO REP.SALAZAR NUNES | AU | 2 | 2 | 0,57 |
| | AUTO REPARADORA DE VALE GRANDE | AU | 1 | 1 | 0,11 |
| | CAMEJO RAMALHO E SILVA LDA | U | 224 | 1175 | 2782,94 |
| | CARDOSO LUISA,LDA | AU | 6 | 11 | 1,69 |
| | CONSULT4YOU, LDA | AU | 1 | 2 | 15 |
| | EDUARDO LUCAS PNEUS UNIPESSOAL | AU | 2 | 2 | 0,84 |
| | F MARQUES E FILHOS LDA | U | 277 | 2003 | 3776,44 |
| | FRANCISCO ANTONIO RAMIRES | AU | 1 | 6 | 30 |
| | HERNANI DUARTE ACURCIO | AU | 3 | 3 | 0,54 |
| | M C D GARCIA LDA. | U | 86 | 132 | 49,9 |
| | PAINT GO, LDA | AU | 5 | 5 | 4,02 |
| | RAMALHO RAMALHO | U | 152 | 544 | 916,16 |
| | RETROCAL-ASSIST.TECNICA AO PNE | AU | 3 | 3 | 1,98 |
| | RUGEMPECAS, LDA S.DOMINGOS RANA | U | 37 | 54 | 27,4 |
| | RUGEMPECAS, LDA TERRUGEM | U | 61 | 79 | 26,12 |
| | SOLUGAR LDA | AU | 4 | 6 | 1,72 |
| | SUCURSAL OFICINA OEIRAS | U | 189 | 975 | 2207,29 |
| | VOLANSINTRA | AU | 4 | 5 | 4,85 |
| TOTAL | | | 1078 | 5043 | 9889,32 |

Table 24: Volume, weight and total number of placed orders by customers attributed to vehicle 4.

| Vehicles | Client | Classification | Sum of orders placed | Sum of Nº of volumes | Sum of weight |
|---|---|---|---|---|---|
| V5 | ADAO M A SOC. UNIPESSOAL LDA | AU | 21 | 36 | 45,86 |
| | AMBIMOTORS, LDA | AU | 3 | 4 | 1,93 |
| | AMBROCAR LDA | AU | 43 | 82 | 100,9 |
| | ANTONIO CARLOS ROSA LOURO | AU | 1 | 1 | 0,04 |
| | ANTONIO MANUEL PRATA CANDIDO | AU | 1 | 1 | 0,13 |
| | APONTAR BATERIAS AUTO UNIP LD | AU | 17 | 24 | 59,71 |
| | ASPHALTPOTENTIAL UNIPESSOAL, L | AU | 1 | 1 | 0,15 |
| | AUTO ARROTEIENSE REP AUTO LDA | AU | 3 | 7 | 16,45 |
| | AUTO FLORA-MANUEL ANTONIO PAU | U | 23 | 40 | 48,24 |
| | AUTO GUINOTE UNIPESSOAL | AU | 1 | 14 | 70 |
| | AUTO JOAO JORGE LDA | AU | 1 | 1 | 0,06 |
| | AUTO JOAO VAIA REP AUTO LDA | AU | 1 | 2 | 0,81 |
| | AUTO MONUMENTAL DE ALMADA AMORA | U | 139 | 1227 | 2525,19 |
| | AUTO MONUMENTAL DE ALMADA MOITA | U | 195 | 767 | 1370,09 |
| | AUTO PATRONILHO | AU | 4 | 8 | 8,58 |
| | AUTO QUALIDADE LDA | U | 95 | 187 | 221,41 |
| | AUTO REP. VALDEMAR FRANCO LDA | AU | 5 | 13 | 75,17 |
| | AUTO REPARADORA VALE MILHACOS | AU | 4 | 5 | 7,12 |
| | AUTO TORRE DA MARINHA LDA | AU | 13 | 17 | 13,02 |
| | BRUNO GADELHA | AU | 1 | 1 | 0,07 |
| | CONCEICAO E F. AUTOMOVEIS LDA | AU | 2 | 3 | 1,04 |
| | DANIEL CACIONES SOCIEDADE UNI | AU | 3 | 4 | 40,2 |
| | FIRMINO FERREIRA AUTO LDA | AU | 1 | 1 | 0,23 |
| | FRANCISCO PAULO BARRANCOS | AU | 1 | 2 | 0,09 |
| | FRESH MOTIVE REP AUTO UNIP LDA | AU | 1 | 2 | 1,17 |
| | HUBTYRELDA | AU | 3 | 4 | 4,02 |
| | HUGO MIGUEL MARQUES CIPRIANO | AU | 1 | 1 | 0,42 |
| | ILIDIO MANUEL | AU | 2 | 7 | 105,93 |
| | JESSICAR | AU | 3 | 3 | 0,37 |
| | JOAO ANTONIO A. FREIXINHO | AU | 12 | 21 | 24,83 |
| | JOAQUIM MARTINS BALULA | AU | 1 | 3 | 15,15 |
| | JOMADO COM REP AUTOMOVEIS LDA | AU | 8 | 11 | 1,64 |
| | JOSE JORGE CESARIO PALMA | AU | 4 | 9 | 7,36 |
| | JOSE PEDRO INFANTE AUTO,UNIPES | AU | 7 | 10 | 3,62 |
| | JOSE TACAO BALANCHO | AU | 2 | 2 | 15,16 |
| | L R - AUTO REPARACOES,L DA | AU | 2 | 3 | 0,26 |
| | LIMITABSOLUTO, UNIPESSOAL, LDA | AU | 4 | 4 | 0,79 |
| | LUIS ALBERTO M. DANIEL | AU | 7 | 60 | 85,14 |
| | LUIS FILIPE M. S. CUNHA | AU | 1 | 1 | 0,08 |
| | LUIS GABRIEL SANTOS | AU | 2 | 3 | 6,53 |
| | MANUEL JORGE DO SANTOS PEREIRA | AU | 2 | 3 | 2,59 |
| | MARCO FILIPE PACHECO CAETANO | AU | 3 | 3 | 3,22 |
| | MARIO RUI MIRANDA GALVAO | AU | 5 | 5 | 1,62 |
| | MESTRE E MOURA LDA | AU | 4 | 5 | 1,12 |
| | PAULO ALEXANDRE E MIGUEL GRACA LDA | U | 17 | 37 | 20,99 |
| | PNEUVIP-COM.DE PNEUS,LDA | AU | 3 | 3 | 17,77 |
| | RC MOTOR SPORT DE RICARDO JORG | AU | 2 | 6 | 1,36 |
| | REBOCOCHETE | AU | 1 | 1 | 0,96 |
| | RECOMAC LDA | AU | 1 | 2 | 10 |
| | RICARDO JOSE FERNANDES DOS SAN | AU | 1 | 1 | 0,03 |
| | RODRIGO E FILHOS LDA | AU | 1 | 1 | 5 |
| | RUDISOL, LDA | AU | 1 | 3 | 5,3 |
| | SOUTHCARS AUTOMOVEIS SA | AU | 9 | 9 | 5,52 |
| | SUCURSAL OFICINA SETUBAL | U | 110 | 765 | 1699,17 |
| | VALTERCAR LDA | AU | 9 | 12 | 8,91 |
| | VIRAGEM DECISIVA LDA | AU | 1 | 1 | 0,83 |
| | VITOR E LEONEL CARVALHO,L DA | AU | 6 | 9 | 6,82 |
| | VITOR GLORIAS, LDA | AU | 1 | 1 | 5,38 |
| | VITOR MANUEL GARRIDO MARTINS | AU | 8 | 21 | 40,17 |
| | VITOR MANUEL POLA CHARCAS | AU | 3 | 3 | 0,16 |
| TOTAL | | | 827 | 3483 | 6715,88 |

Table 25: Volume, weight and total number of placed orders by customers attributed to vehicle 5.

| Vehicle | Client | Classification | Sum of orders placed | Sum of Nº of volumes | Sum of weight (kg) |
|---|---|---|---|---|---|
| V6 | ALVARO VERISSIMO LDA. | AU | 1 | 1 | 0,87 |
| | ALVES DA LUZ, LDA | U | 147 | 549 | 820,21 |
| | AMH-AUTO REPAIR,UNIPESSOAL | AU | 3 | 4 | 2,95 |
| | ANDRADECAR LDA | AU | 4 | 13 | 4,85 |
| | ANDRE F.F. RAPOSO UNIPESSOAL L | AU | 2 | 2 | 0,18 |
| | ANENACLA-COM.PECAS AUTOMOVEIS, | AU | 13 | 21 | 114,32 |
| | ANTONIO DA SILVA E FILHOS LDA | AU | 4 | 6 | 8,03 |
| | ANTONIO MANUEL LOPES MOITA | AU | 4 | 4 | 1,62 |
| | ARTUR SILVA PINTURA AUTO, LDA | AU | 2 | 3 | 0,31 |
| | ATRACTIVERSAO ALUGUER DE MAQU | AU | 4 | 10 | 12,14 |
| | AUCOVIL, LDA | AU | 8 | 11 | 4,54 |
| | AUTO ALEGRIA - COMERCIO E REP | AU | 4 | 11 | 88,6 |
| | AUTO DIAGNOSTICO PEJ LDA | AU | 1 | 1 | 0,11 |
| | AUTO MECANICA TORROES LDA | AU | 8 | 10 | 3,1 |
| | AUTO REP DE VALE DE ESTACAS | AU | 8 | 12 | 4,38 |
| | AUTO REP.SANTOS E GENEBRA,LDA | AU | 1 | 1 | 1 |
| | BRUNO GOMES ANTUNES-MANUT.REP. | AU | 11 | 20 | 23,63 |
| | CARCENTURY-COMERCIODE AUTOMOV | AU | 1 | 1 | 0,59 |
| | CARVALHO E GUSTAVO | AU | 4 | 5 | 15,76 |
| | COLACO AUTO REPARACOES LDA | AU | 3 | 7 | 9,17 |
| | EXITO MAGNOLIA UNIPESSOAL,LDA | AU | 4 | 4 | 0,86 |
| | FABIO NUNES IRMAOS ,LDA | AU | 11 | 13 | 3,35 |
| | I S CAR | AU | 1 | 1 | 5 |
| | IHOR & LOPES - LIMPEZA E REPAR | AU | 1 | 1 | 5 |
| | J.M.POVOA LDA | AU | 10 | 16 | 11,73 |
| | JORGE FILHOS, LDA | AU | 1 | 1 | 0,41 |
| | JOSE CARLOS AUTO REP.UNIPESSO | AU | 2 | 2 | 1,68 |
| | JOSE VICENTE COSTA RODRIGUES | AU | 3 | 5 | 0,72 |
| | LEAL E CATITA OFICINA REP AUT | AU | 1 | 1 | 0,15 |
| | MANUEL PEGO E FILHOS | AU | 10 | 14 | 33,37 |
| | MANUEL ROSA BASTOS | AU | 1 | 2 | 0,14 |
| | MARCHANTECAR UNIPESSOAL LDA | AU | 8 | 13 | 79,52 |
| | MECANICA AGRICOLA LDA BENAVENTE | U | 158 | 637 | 1149,29 |
| | MECANICA AGRICOLA LDA VARZEA | U | 169 | 646 | 1254,95 |
| | NELSON CONSTANCIO UNIPESSOAL,L | AU | 2 | 2 | 0,89 |
| | NUNO SIMAO PEDRO | AU | 1 | 1 | 0,73 |
| | PAULO ALMEIDA LDA | AU | 2 | 2 | 0,29 |
| | PEDRO ANDRE SOUSA | AU | 7 | 8 | 6,92 |
| | PINHEIRO E GRACA, LDA | AU | 1 | 1 | 5 |
| | RAFAEL COROADO - OFICINA MECANIC | AU | 1 | 1 | 2 |
| | RAIMUNDO NUNES - OFICINA AUTO | AU | 6 | 20 | 33,61 |
| | RAMALHAL CAR-COMERCIO DE AUTO | AU | 5 | 9 | 3,97 |
| | RECOPARTS,LDA | AU | 4 | 10 | 27,55 |
| | ROCHA E CUNHA, LDA | AU | 1 | 1 | 0,07 |
| | RUI APOLINARIO UNIPESSOAL , LD | AU | 10 | 22 | 29,05 |
| | RUI MARQUES | AU | 4 | 4 | 0,33 |
| | SIMAO PEREIRA REP.AUTO.UN. | AU | 2 | 4 | 23,91 |
| | SOBRALCAR LDA ENTREGAS | AU | 4 | 14 | 40,88 |
| | SORICRAL, LDA | AU | 7 | 17 | 15,64 |
| | VASCO MIGUEL TEIXEIRA | AU | 3 | 4 | 1,71 |
| | VASILPNEUS,LDA | U | 28 | 37 | 16,51 |
| | VITOR M. RODRIGUES CARVALHO | AU | 1 | 1 | 0,06 |
| | VITOR MANUEL FILIPE MENDES | AU | 4 | 5 | 0,98 |
| TOTAL | | | 706 | 2211 | 3872,63 |

Table 26: Volume, weight and total number of placed orders by customers attributed to vehicle 6.

| | DAY | ROTATION |
|---|---|---|
| AVERAGE DELIVERIES | 20,70 | 6,90 |
| AVERAGE Nº VOLUMES | 138,63 | 46,21 |
| AVERAGE WEIGHT | 251,19 | 83,73 |

Table 27: Average deliveries, nº of volumes and weight of customers attributed to vehicle 1.

| | DAY | ROTATION |
|---|---|---|
| AVERAGE DELIVERIES | 13,88 | 4,63 |
| AVERAGE Nº VOLUMES | 46,50 | 15,50 |
| AVERAGE WEIGHT | 102,57 | 34,19 |

Table 28: Average deliveries, nº of volumes and weight of customers attributed to vehicle 2.

| | DAY | ROTATION |
|---|---|---|
| AVERAGE DELIVERIES | 18,57 | 6,19 |
| AVERAGE Nº VOLUMES | 131,83 | 43,94 |
| AVERAGE WEIGHT | 376,00 | 125,33 |

Table 29: Average deliveries, nº of volumes and weight of customers attributed to vehicle 3.

| | DAY | ROTATION |
|---|---|---|
| AVERAGE DELIVERIES | 17,97 | 5,99 |
| AVERAGE Nº VOLUMES | 84,05 | 28,02 |
| AVERAGE WEIGHT | 164,82 | 54,94 |

Table 30: Average deliveries, nº of volumes and weight of customers attributed to vehicle 4.

| | DAY | ROTATION |
|---|---|---|
| AVERAGE DELIVERIES | 13,78 | 4,59 |
| AVERAGE Nº VOLUMES | 58,05 | 19,35 |
| AVERAGE WEIGHT | 111,93 | 37,31 |

Table 31: Average deliveries, nº of volumes and weight of customers attributed to vehicle 5.

| | DAY | ROTATION |
|---|---|---|
| AVERAGE DELIVERIES | 11,77 | 3,92 |
| AVERAGE Nº VOLUMES | 36,85 | 12,28 |
| AVERAGE WEIGHT | 64,54 | 21,51 |

Table 32: Average deliveries, nº of volumes and weight of customers attributed to vehicle 6.

| Client | Vehicle | Street name | Zip code | Location | Latitude | Longitude |
|---|---|---|---|---|---|---|
| A.H.ALMEIDA | V1 | R D NUNO ALVARES PEREIRA N 4 | 2685 | SACAVEM | 38,798275 | -9,10198 |
| ACP-SERVICOS RAPIDOS PRIOR VELHO | V1 | R. GENERAL HUMBERTO DELGADO, 3 | 2685 | PRIOR VELHO | 38,788025 | -9,118417 |
| ANA GIL PEREIRA-REP.E COM.AUTO | V1 | R. DAS ARPALAS,LETRA C | 2680 | CAMARATE | 38,800037 | -9,145496 |
| AUTO ARTUR JORGE FILHOS, LDA | V4 | . RUA DOS CASAIS N 7 | 2725 | MEM MARTINS | 38,789165 | -9,344882 |
| AUTO BENFICA | V2 | AV CONSELH. BARJONA DE FREITAS | 1500 | LISBOA | 38,745675 | -9,185221 |
| AUTO CONTINENTE 2 - COMERCIO | V3 | R DAS FONTAINHAS 57 | 2700 | AMADORA | 38,751063 | -9,219422 |
| AUTO JMS | V1 | R.SECULO XX, N 9 | 2660 | SAO JULIAO DO TOJAL | 38,860463 | -9,119229 |
| AUTO LUSO ALEMA | V3 | AV. 25 DE ABRIL, LOTE 9 BURACA | 2610 | AMADORA | 38,745958 | -9,209193 |
| AUTO MONTES CLAROS LDA | V2 | AV MARCONI 6 C LISBOA | 1000 | LISBOA | 38,741818 | -9,138529 |
| AUTO REPARADORA MARIO E CARMO | V1 | ESTR NACIONAL 10 KM 127 | 2615 | ALVERCA DO RIBATEJO | 38,908012 | -9,029003 |
| AUTO SOUSAS, LDA. | V1 | R MIGUEL BOMBARDA N 88 | 2685 | SACAVEM | 38,801643 | -9,110329 |
| BOAVENTURA E FILHOS,LDA | V3 | ESTRADA PORTELA N 74 | 2790 | CARNAXIDE | 38,721824 | -9,221832 |
| CAMEJO RAMALHO E SILVA LDA | V4 | R DA INDUSTRIA N7 | 2740 | PORTO SALVO | 38,723025 | -9,301353 |
| CARVIVAS - COM. E REP AUTOMOVE | V3 | R. MIGUEL TORGA, PAV. ANEXO LT | 2745 | QUELUZ | 38,755923 | -9,282908 |
| CITROVERCA - COM. E REPARACAO | V3 | EST NAC 10 KM 126 5 ARM B | 2615 | ALVERCA DO RIBATEJO | 38,907972 | -9,031692 |
| DOMINGUES TOME | V2 | AV GENERAL ROCADAS N 13 LIS | 1170 | LISBOA | 38,7246 | -9,128781 |
| F MARQUES E FILHOS LDA | V4 | R DAS CAMELIAS N 1 | 2725 | MEM MARTINS | 38,790593 | -9,347796 |
| FORMULA F, LDA | V1 | QUINTA S. JOAO DAS AREIAS R.D. LT 138 | 2685 | SACAVEM | 38,79896 | -9,122408 |
| GARAGEM INTENDENTE DE POMBO | V2 | TRAVESSA MALDONADO N 1 INTENDE | 1100 | LISBOA | 38,721157 | -9,134017 |
| GRANLOURES-COMERCIO PECAS AUTO | V1 | R. MARECHAL CARMONA 3 A QUINTA | 2670 | LOURES | 38,840833 | -9,164493 |
| HUILACAR, LDA. | V2 | AV. ALM. G. COUTINHO 68-C R | 1700 | LISBOA | 38,74973 | -9,131055 |
| J.P.A.AUTO REPARADORA,LDA | V1 | QT S. JOAO DAS AREIAS LT -13 | 2680 | CAMARATE | 38,797826 | -9,119539 |
| JOSE M.MARTINS FILIPELDA | V3 | R PADRE AMERICO MONTEIRO DE AG | 1675 | PONTINHA | 38,78024 | -9,18736 |
| JOSE MANUEL MARTINS, LDA | V3 | EST NACIONAL 10 KM 127 LT B | 2615 | ALVERCA DO RIBATEJO | 38,908181 | -9,031998 |
| LINDAUTO LDA | V3 | R RODRIGUES SAMPAIO N 11 | 2795 | LINDA A VELHA | 38,708579 | -9,241812 |
| LOPES RIBEIRO PINTURAS LDA | V1 | COMPL IND DA GRANJA -ARM -A-9 | 2625 | VIALONGA | 38,862809 | -9,105036 |
| M C D GARCIA LDA. | V4 | AV 1 DEZEMBRO N 20 | 2715 | PERO PINHEIRO | 38,852783 | -9,324453 |
| M. COUTINHO - PECAS E REP. AUT | V1 | AV.BOMBEIROS VOLUNTARIOS DE CAMARATE | 2680 | CAMARATE | 38,794309 | -9,138414 |
| M.C.PECAS | V1 | R ANTONIO FERREIRA CARMO FRACC | 2615 | ALVERCA DO RIBATEJO | 38,890230 | -9,041675 |
| MARQUES SILVA LDA | V3 | RUA GAGO COUTINHO N 58 59 | 1675 | PONTINHA | 38,777557 | -9,21429 |
| MCS- PECAS E ACESSORIOS CAMARATE | V1 | RUA CIDADE DE LISBOA 32 LJB | 2680 | CAMARATE | 38,790736 | -9,141086 |
| MICROMOTOR LDA. PRIOR VELHO | V1 | R.PROF.HENRIQUE BASTOS,12 PR | 2685 | PRIOR VELHO | 38,787337 | -9,121861 |
| NASCIMENTO DINIS PECAS,LDA | V3 | AV EDMUNDO LIMA BASTO N 18 A | 2790 | CARNAXIDE | 38,720688 | -9,230528 |
| ODICAR - COMERC AUTO. E PECAS | V1 | R GENERAL ALVES ROCADAS 2 | 2620 | POVOA DE SANTO ADRIAO | 38,7945 | -9,165838 |
| PALOCAR,REPARACOES AUTO | V1 | R DA FE N 6 B ZON IND VALE FIG | 2695 | SAO JOAO DA TALHA | 38,822662 | -9,103498 |
| PECILOURES COM. DE PECAS | V1 | R. PADRE ANTONIO VIEIRA 25 LJ | 2670 | LOURES | 38,832283 | -9,17425 |
| PLANETA AUTO COMERCIO E REP | V2 | R JOSE ESTEVAO N 3 | 1150 | LISBOA | 38,728065 | -9,137709 |
| RAMALHO RAMALHO | V4 | AV AMALIA RODRIGUES 767 TIRES | 2785 | SAO DOMINGOS DE RANA | 38,716267 | -9,345997 |
| REVISTO REPARACOES AUTO, LDA | V2 | R FRANCISCO SANCHES N 14 EXT A | 1170 | LISBOA | 38,731029 | -9,13373 |
| RUGEMPECAS, LDA S.DOMINGOS RANA | V4 | ESTRADA NACIONAL 249-4 | 2785 | SAO DOMINGOS DE RANA | 38,719233 | -9,339665 |
| RUGEMPECAS, LDA TERRUGEM | V4 | AV 29 DE AGOSTO N 18 | 2705 | TERRUGEM | 38,840065 | -9,3730135 |
| RUI PAULO E ALMEIDA | V1 | RUA DA ESCOLA, N 31 A 31C | 2695 | SAO JOAO DA TALHA | 38,824761 | -9,103572 |
| SAQUINE SALEM,UNIPESSOAL, LDA | V1 | R ACURCIO DE FREITAS N 7 | 2680 | CAMARATE | 38,802827 | -9,125794 |
| SIMOES FLORENCIO LDA | V3 | EST. ALFRAGIDE OFIC. 12 E 13 | 2610 | AMADORA | 38,737818 | -9,211816 |
| SOBRAL E FONSECA, SA | V3 | R DAS MINAS LOTE E I16 IDANHA | 2605 | BELAS | 38,772986 | -9,271087 |
| STROBOSOM,LDA | V2 | ALAMEDA DAS LINHAS DE TORRES 157A | 1750 | LISBOA | 38,768605 | -9,159436 |
| SUCURSAL OFICINA ALFRAGIDE | V3 | RUA QTA DO PAIZINHO, 5 | 2794 | CARNAXIDE | 38,723337 | -9,215608 |
| SUCURSAL OFICINA OEIRAS | V4 | ESTRADA DE PACO DE ARCOS 56 | 2770 | PACO DE ARCOS | 38,708742 | -9,295271 |
| SUCURSAL OFICINA RF | V2 | RUA RODRIGO DA FONSECA, 80 A | 1250 | LISBOA | 38,724445 | -9,154198 |
| SUCURSAL OFICINA SACAVEM | V1 | RUA VASCO DA GAMA, 20 | 2685 | SACAVEM | 38,788197 | -9,113375 |
| VERTEXCAPRICE UNIPESSOAL LDA | V3 | R. PROJECTADA A ESTRADA PAIA N | 1675 | PONTINHA | 38,780413 | -9,19562 |
| ADAO M A SOC. UNIPESSOAL LDA | V5 | PAQ. IND VALE ALECRIM, RUA DO FERRO, 148 | 2950 | PALMELA | 38,611747 | -8,912218 |
| AMBROCAR LDA | V5 | EST NACIONAL 11-1 N 304 BAIX | 2835 | BAIXA DA BANHEIRA | 38,65686 | -9,037543 |
| APONTAR BATERIAS AUTO UNIP LD | V5 | SITIO DA CARRASQUEIRA,CCI N 1 | 2950 | QUINTA DO ANJO | 38,577067 | -9,009224 |
| AUTO FLORA-MANUEL ANTONIO PAU | V5 | ESTR MUNICIPAL1022 ARMAZEM 3 | 2860 | MOITA | 38,644672 | -8,97272 |
| AUTO MONUMENTAL DE ALMADA AMORA | V5 | R AZEDO GNECO N 57 QUINTA DE A | 2845 | AMORA | 38,63261 | -9,142943 |
| AUTO MONUMENTAL DE ALMADA MOITA | V5 | URBANIZACAO DO CARVALHINHO LT9 | 2860 | MOITA | 38,644672 | -8,97272 |
| AUTO QUALIDADE LDA | V5 | RUA ENCARNACAO COELHO N 11 | 2830 | BARREIRO | 38,635468 | -9,049432 |
| AUTO TORRE DA MARINHA LDA | V5 | R.EUGEGIO DOS SANTOS 6 ZN IN | 2840 | SEIXAL | 38,603237 | -9,085802 |
| JOAO ANTONIO A. FREIXINHO | V5 | R. DOS FAZENDEIROS QTA D TORRE | 2860 | ALHOS VEDROS | 38,643857 | -9,012226 |
| PAULO ALEXANDRE E MIGUEL GRACA LDA | V5 | R ELIAS GARCIA LT 1935 | 2975 | QUINTA DO CONDE | 38,55929 | -9,039882 |
| SUCURSAL OFICINA SETUBAL | V5 | EST DOS CIPRESTES, QT VARZ S | 2900 | SETUBAL | 38,549625 | -8,88528 |
| ALVES DA LUZ, LDA | V6 | R CANCELA DO LEAO S N | 2350 | TORRES NOVAS | 39,47033 | -8,532343 |
| ANENACLA-COM.PECAS AUTOMOVEIS, | V6 | R. CAMPO DA AVIACAO 18 | 2380 | ALCANENA | 39,470133 | -8,663381 |
| BRUNO GOMES ANTUNES-MANUT.REP. | V6 | AV DR.CARLOS LEAL,N 28 PAV.2 | 2600 | CASTANHEIRA DO RIBATEJO | 38,988828 | -8,969578 |
| FABIO NUNES IRMAOS ,LDA | V6 | LARGO DE SANTO ANDRE N 18 B | 2130 | BENAVENTE | 38,979797 | -8,810865 |
| J.M.POVOA LDA | V6 | ALTO DA BOAVISTA-,4 EST. DO | 2580 | ALENQUER | 39,060608 | -9,003834 |
| MANUEL PEGO E FILHOS | V6 | BECO DO ACUDE DE CIMA 24 | 2070 | CARTAXO | 39,15572 | -8,782927 |
| MECANICA AGRICOLA LDA BENAVENTE | V6 | ESTR NAC 118 KM 39 6 | 2130 | BENAVENTE | 38,963306 | -8,817409 |
| MECANICA AGRICOLA LDA VARZEA | V6 | R CONDE DA RIBEIRA GRANDE 11 L | 2005 | VARZEA STR | 39,255913 | -8,709349 |
| RUI APOLINARIO UNIPESSOAL , LD | V6 | R 5 DE OUTUBRO N 8 | 2125 | MARINHAIS | 39,05565 | -8,72956 |
| VASILPNEUS,LDA | V6 | ESTR NACIONAL 118 N 72 | 2125 | MARINHAIS | 39,0564 | -8,7287035 |
| WRP | WRP | | | | 38,907519 | -9,03014 |

Table 33: Coordinates of customers classified as A and B in the ABC Analysis.

| Client | Schedule for clients | Schedule to receive orders |
|---|---|---|
| A.H.ALMEIDA | 09:00-13:00/14:30-19:00 | 08:30-13:00/14:15-19:00 |
| ACP-SERVICOS RAPIDOS PRIOR VELHO | 08.30-12:30/14:00-17:30 | 24h |
| ADAO M A SOC. UNIPESSOAL LDA | 09:00-13:00/14:00-18:00 | 09:00-13:00/14:00-18:00 |
| ALVES DA LUZ, LDA | 08:30-19:00 | 08:30-19:00 |
| AMBROCAR LDA | 08:00-12:30/14:00-18:00 | 07:45-12:30/14:00-18:00 |
| ANA GIL PEREIRA-REP.E COM.AUTO | 08:00-18:00 | 08:00-18:00 |
| ANENACLA-COM.PECAS AUTOMOVEIS, | 08:00-18:00 | 08:00-18:00 |
| APONTAR BATERIAS AUTO UNIP LD | 08:30-18:00 | 08:30-18:00 |
| AUTO ARTUR JORGE FILHOS, LDA | 09:00-12:30/14:00-18:30 | 08:00-18:30 |
| AUTO BENFICA | 08:30-12:30/14:00-18:00 | 08:00-13:00/14:30-18:00 |
| AUTO CONTINENTE 2 - COMERCIO | 08:30-18:00 | 08:30-18:00 |
| AUTO FLORA-MANUEL ANTONIO PAU | 08:30-13:00/14:30-18:00 | 08:30-13:00/14:30-18:00 |
| AUTO JMS | 09:00-13:00/14:00-18:00 | 09:00-13:00/14:00-18:00 |
| AUTO LUSO ALEMA | 08:30-13:00/14:00-17:30 | 07:30-13:00/14:00-17:30 |
| AUTO MONTES CLAROS LDA | 08:30-12:30/14:00-17:30 | 07:00-17:30 |
| AUTO MONUMENTAL DE ALMADA AMORA | 08:30-12:30/14:00-18:00 | 07:00-18:00 |
| AUTO MONUMENTAL DE ALMADA MOITA | 08:30-12:30/14:00-18:00 | 08:30-12:30/14:00-18:00 |
| AUTO QUALIDADE LDA | 08:30-13:00/14:00-18:00 | 08:15-13:00/14:00-18:00 |
| AUTO REPARADORA MARIO E CARMO | 09:30-18:00 | 09:30-18:00 |
| AUTO SOUSAS, LDA. | 08:00-12:30/13:30-17:00 | 07:50-12:30/13:30-17:00 |
| AUTO TORRE DA MARINHA LDA | 09:00-13:00/14:30-18:30 | 08:30-13:00/14:10-18:30 |
| BOAVENTURA E FILHOS,LDA | 08:30-12:30/14:00-18:00 | 08:30-12:30/14:00-18:00 |
| BRUNO GOMES ANTUNES-MANUT.REP. | 09:00-18:00 | 09:00-18:00 |
| CAMEJO RAMALHO E SILVA LDA | 08:30-12:30/14:00-18:00 | 07:15-18:00 |
| CARVIVAS - COM. E REP AUTOMOVE | 08:00-12:00/13:00-18:00 | 08:00-12:00/13:00-18:00 |
| CITROVERCA - COM. E REPARACAO | 08:30-12:30/14:30-18:30 | 24h |
| DOMINGUES TOME | 07:00-12:30/13:30-21:00 | 07:00-12:30/13:30-21:00 |
| F MARQUES E FILHOS LDA | 08:00-19:00 | 08:00-19:00 |
| FABIO NUNES IRMAOS ,LDA | 08:30-18:00 | 08:30-18:00 |
| FORMULA F, LDA | 08:30-18:30 | 08:30-18:30 |
| GARAGEM INTENDENTE DE POMBO | 08:00-12:30/14:00-18:00 | 07:30-12:30/14:00-18:00 |
| GRANLOURES-COMERCIO PECAS AUTO | 09:00-12:30/14:00-19:00 | 09:00-12:30/14:00-19:00 |
| HUILACAR, LDA. | 09:00-13:00/14:30-18:00 | 09:00-13:00/14:30-18:00 |
| J.M.POVOA LDA | 09:00-13:30/14:30-20 | 09:00-13:30/14:30-20 |
| J.P.A.AUTO REPARADORA,LDA | 08:30-18:00 | 07:45-18:00 |
| JOAO ANTONIO A. FREIXINHO | 08:30-18:00 | 08:30-18:00 |
| JOSE M.MARTINS FILIPELDA | 09:00-18:00 | 09:00-18:00 |
| JOSE MANUEL MARTINS, LDA | 08:30-12:30/14:30-18:30 | 24h |
| LINDAUTO LDA | 08:00-12:30/14:00-18:00 | 08:00-12:30/14:00-18:00 |
| LOPES RIBEIRO PINTURAS LDA | 08:30-12:30/14:00-18:00 | 08:00-13:00/13:30-18:00 |
| M C D GARCIA LDA. | 09:00-13:00/14:00-19:00 | 08:30-19:00 |
| M. COUTINHO - PECAS E REP. AUT | 09:00-12:30/14:00-18:30 | 07:30-12:30/14:00-18:30 |
| M.C.PECAS | 08:30-20:00 | 08:15-13:00/14:00-20:00 |
| MANUEL PEGO E FILHOS | 09:00-18:00 | 09:00-18:00 |
| MARQUES SILVA LDA | 08:00-19:00 | 08:00-19:00 |
| MCS- PECAS E ACESSORIOS CAMARATE | 09:00-19:00 | 09:00-19:00 |
| MECANICA AGRICOLA LDA BENAVENTE | 08:30-12:30/13:30-17:30 | 24h |
| MECANICA AGRICOLA LDA VARZEA | 08:30-19:00 | 07:00-19:00 |
| MICROMOTOR LDA. PRIOR VELHO | 08:00-18:00 | 08:00-18:00 |
| NASCIMENTO DINIS PECAS,LDA | 09:00-18:00 | 09:00-18:00 |
| ODICAR - COMERC AUTO. E PECAS | 08:30-13:00/14:00-18:30 | 08:30-13:00/14:00-18:30 |
| PALOCAR,REPARACOES AUTO | 08:30-19:30 | 08:30-19:30 |
| PAULO ALEXANDRE E MIGUEL GRACA LDA | 09:00-13:00/14:00-18:00 | 08:50-13:00/14:00-18:00 |
| PECILOURES COM. DE PECAS | 09:00-13:00/14:00-19:00 | 08:15-13:00-14:00-19:00 |
| PLANETA AUTO COMERCIO E REP | 09:00-18:00 | 09:00-18:00 |
| RAMALHO RAMALHO | 08:30-12:30/14:00-18:00 | 07:45-12:30/14:00-18:00 |
| REVISTO REPARACOES AUTO, LDA | 08:30-12:30/14:00-18:00 | 08:00-18:00 |
| RUGEMPECAS, LDA S.DOMINGOS RANA | 09:00-13:00/14:30-19:30 | 08:45-19:30 |
| RUGEMPECAS, LDA TERRUGEM | 09:00-19:00 | 09:00-19:00 |
| RUI APOLINARIO UNIPESSOAL , LD | 09:00-18:00 | 09:00-18:00 |
| RUI PAULO E ALMEIDA | 09:00-13:00/14:30-19:00 | 08:30-19:00 |
| SAQUINE SALEM,UNIPESSOAL, LDA | 09:00-18:00 | 09:00-18:00 |
| SIMOES FLORENCIO LDA | 08:30-12:30/13:30-17:30 | 08:30-17:30 |
| SOBRAL E FONSECA, SA | 08:30-12:30/14:00-18:00 | 08:15-12:30/14:00-18:00 |
| STROBOSOM,LDA | 09:00-12:30/14:00-18:30 | 09:00-12:30/14:00-18:30 |
| SUCURSAL OFICINA ALFRAGIDE | 08:00-20:00 | 24h |
| SUCURSAL OFICINA OEIRAS | 09:00-20:00 | 24h |
| SUCURSAL OFICINA RF | 08:00-18:00 | 08:00-18:00 |
| SUCURSAL OFICINA SACAVEM | 08:00-18:00 | 24h |
| SUCURSAL OFICINA SETUBAL | 08:00-18:00 | 08:00-18:00 |
| VASILPNEUS,LDA | 08:00-20:00 | 24h |
| VERTEXCAPRICE UNIPESSOAL LDA | 09:00-19:00 | 09:00-19:00 |

Table 34: Customers' schedules to receive orders and to receive clients.

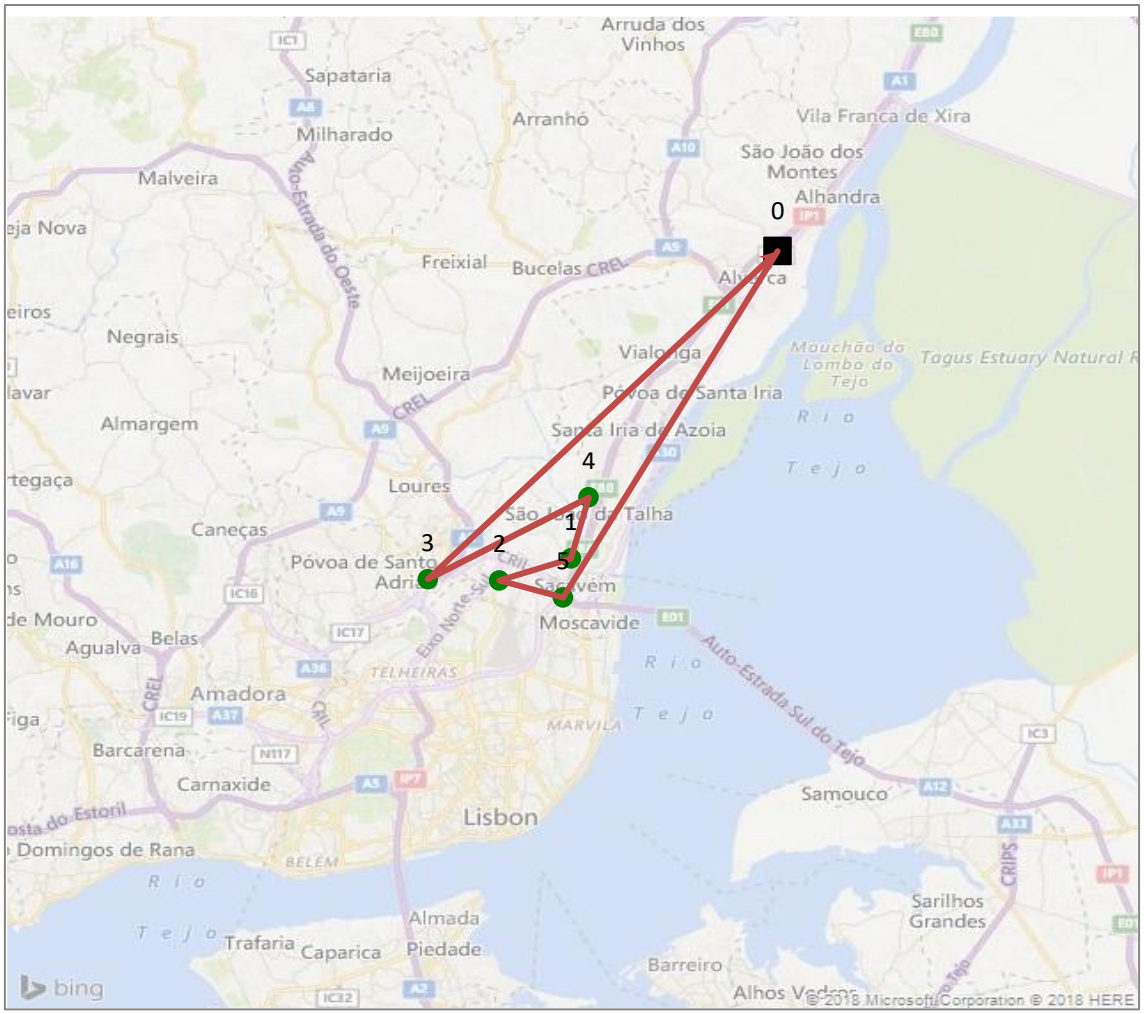


Illustration 1: Optimized route obtained for rotation 1, assuming all U customers which are attributed to vehicle 1 place orders.

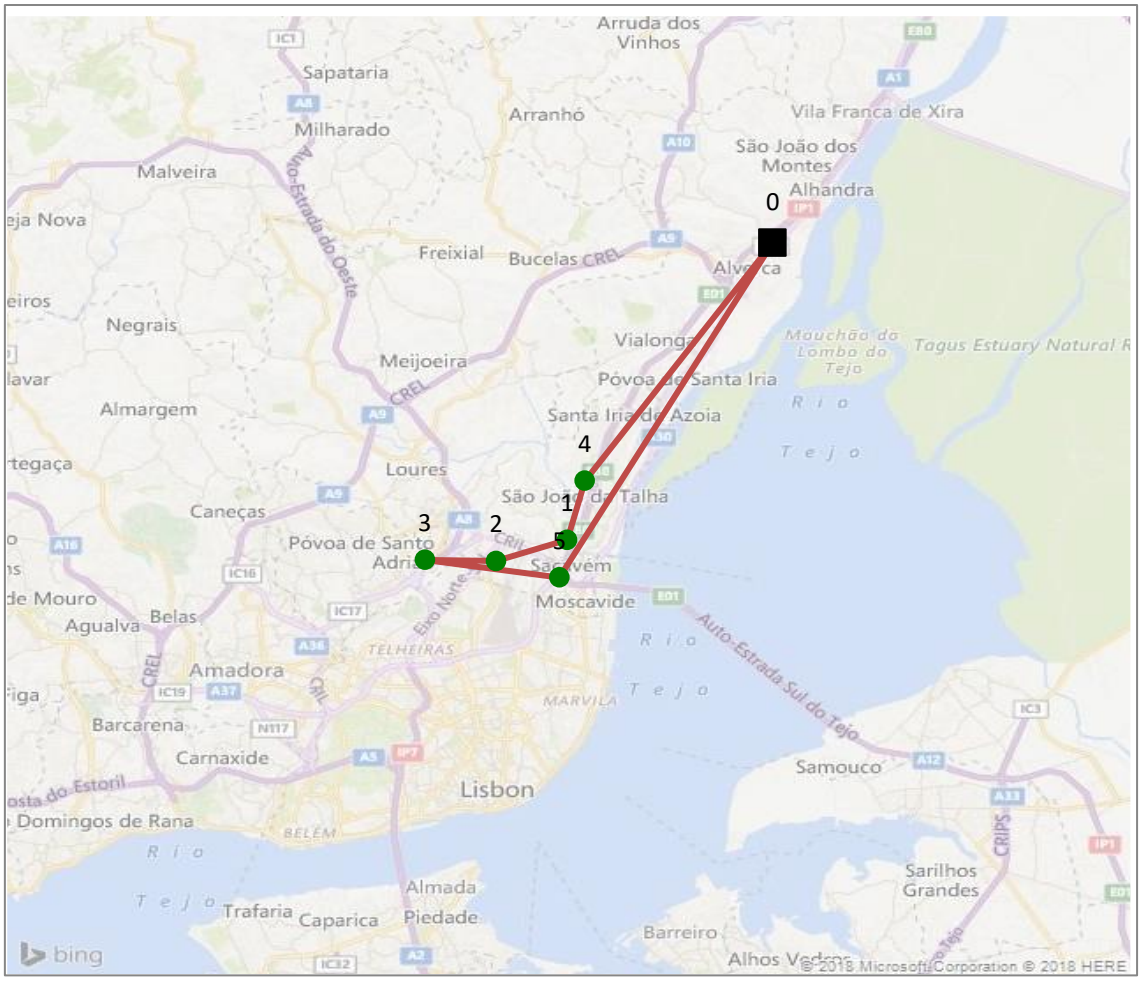


Illustration 2: Optimized route obtained for rotation 2, assuming all U customers which are attributed to vehicle 1 place orders.

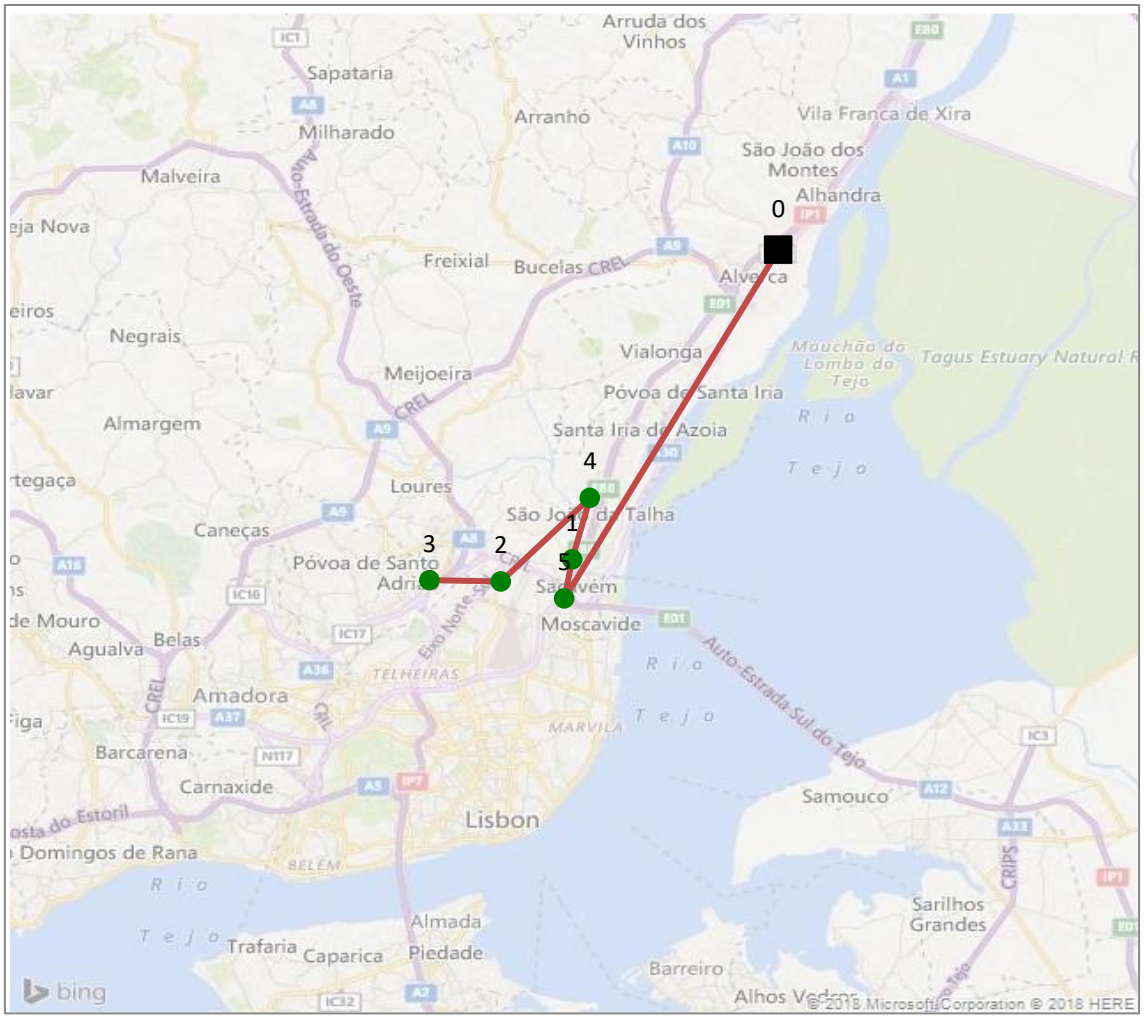


Illustration 3: Optimized route obtained for rotation 3, assuming all U customers which are attributed to vehicle 1 place orders.

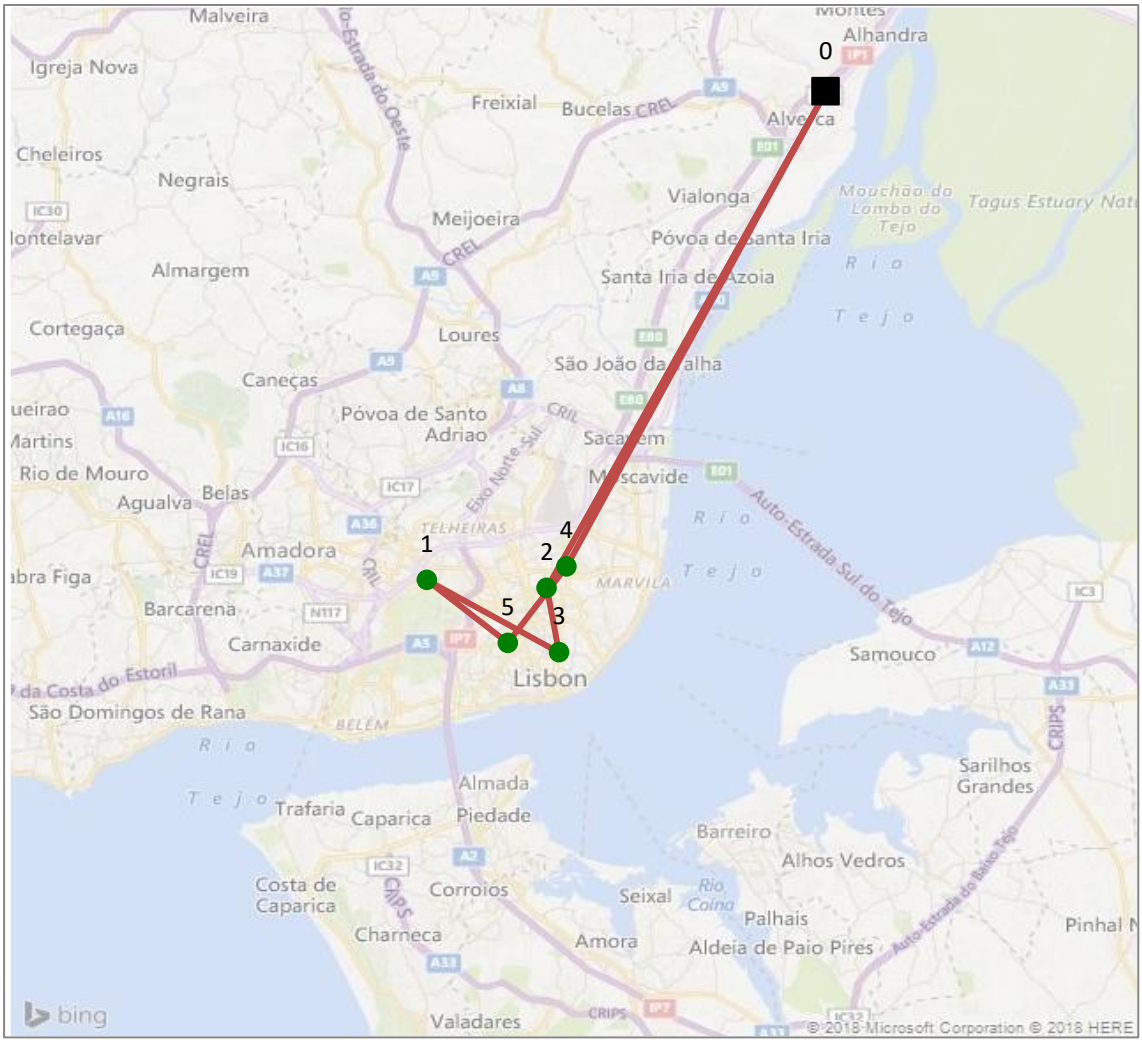


Illustration 4: Optimized route obtained for rotation 1, assuming all U customers which are attributed to vehicle 2 place orders.

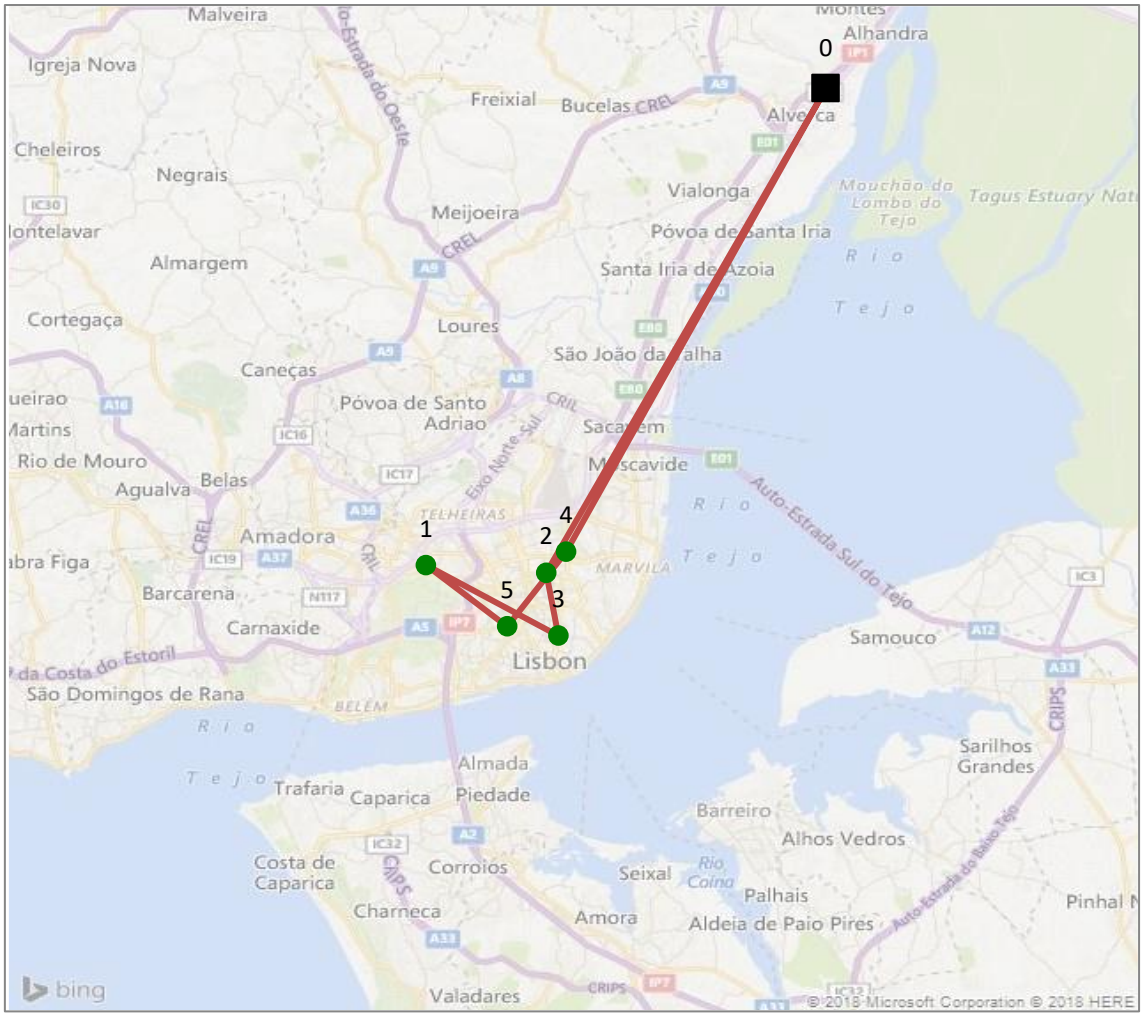


Illustration 5: Optimized route obtained for rotation 2, assuming all U customers which are attributed to vehicle 2 place orders.

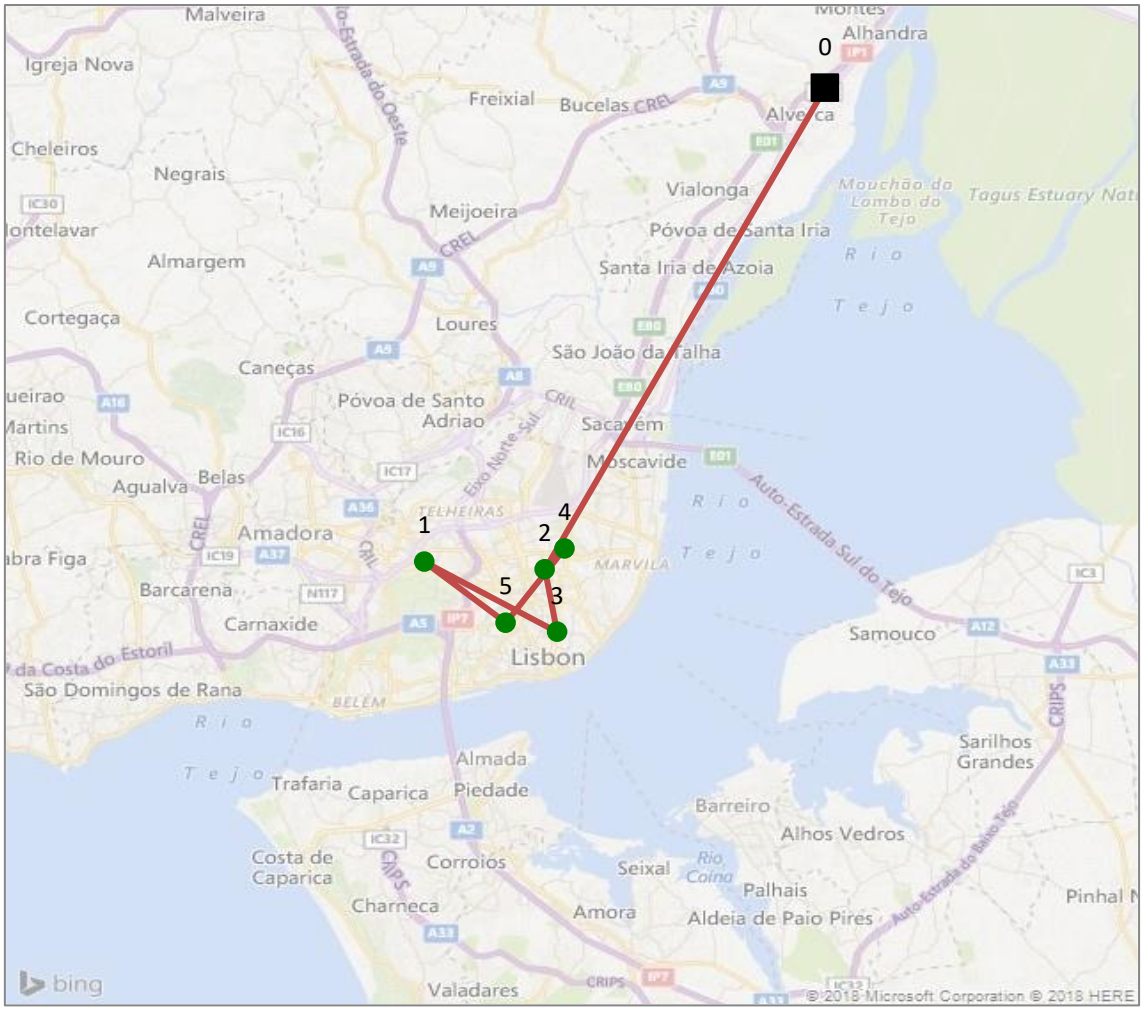


Illustration 6: Optimized route obtained for rotation 3, assuming all U customers which are attributed to vehicle 2 place orders.

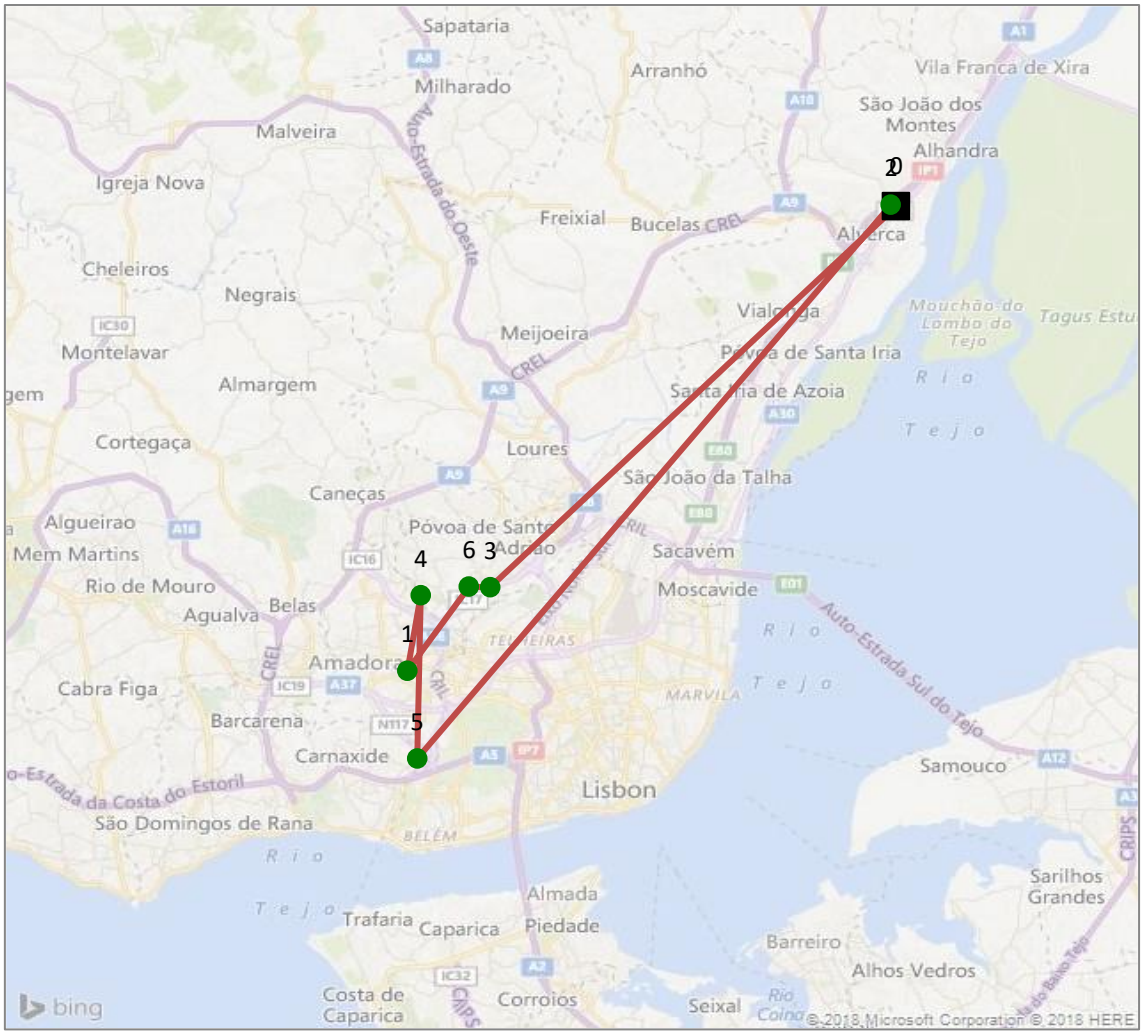


Illustration 7: Optimized route obtained for rotation 1, assuming all U customers which are attributed to vehicle 3 place orders.

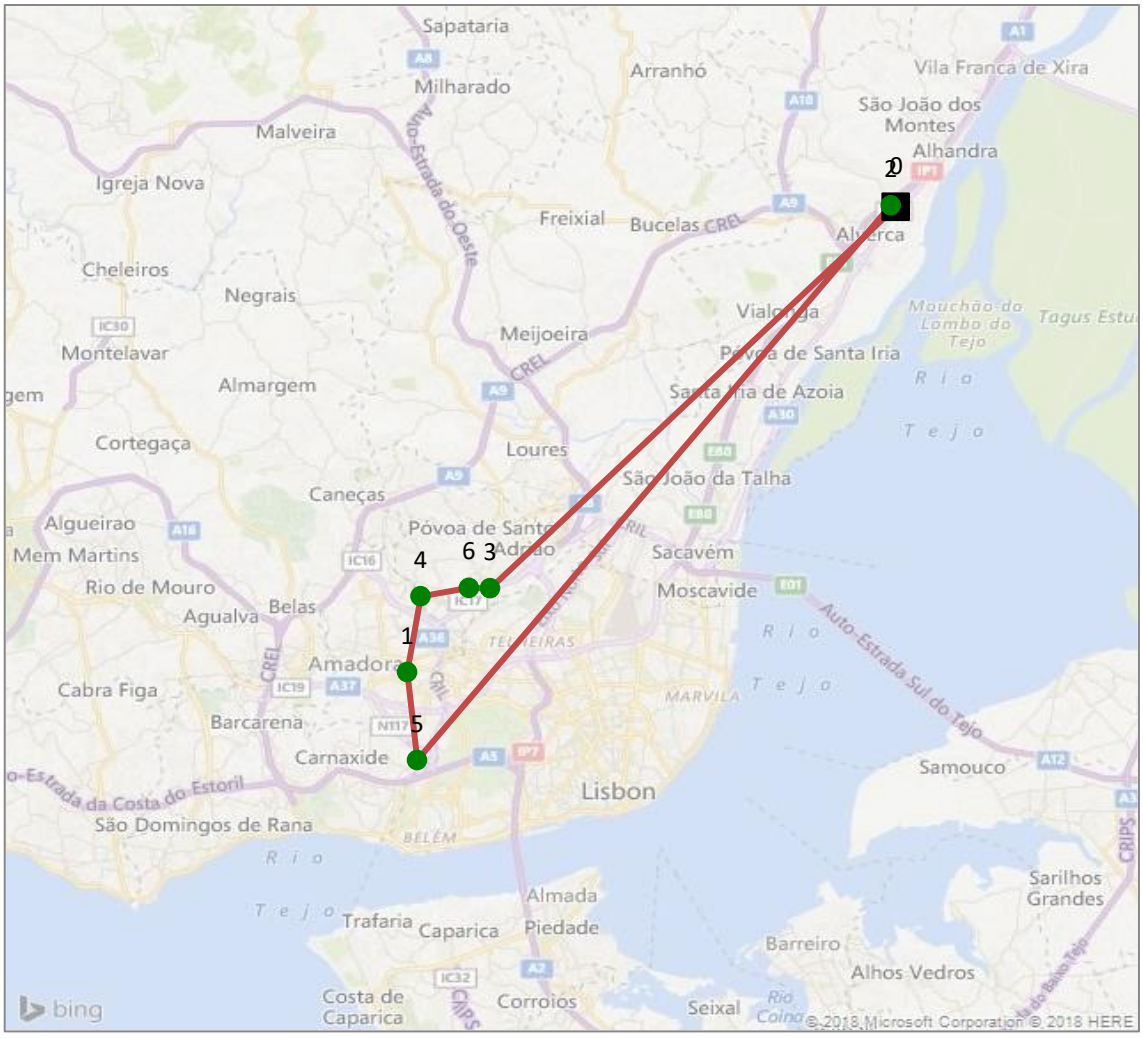


Illustration 8: Optimized route obtained for rotation 2, assuming all U customers which are attributed to vehicle 3 place orders.

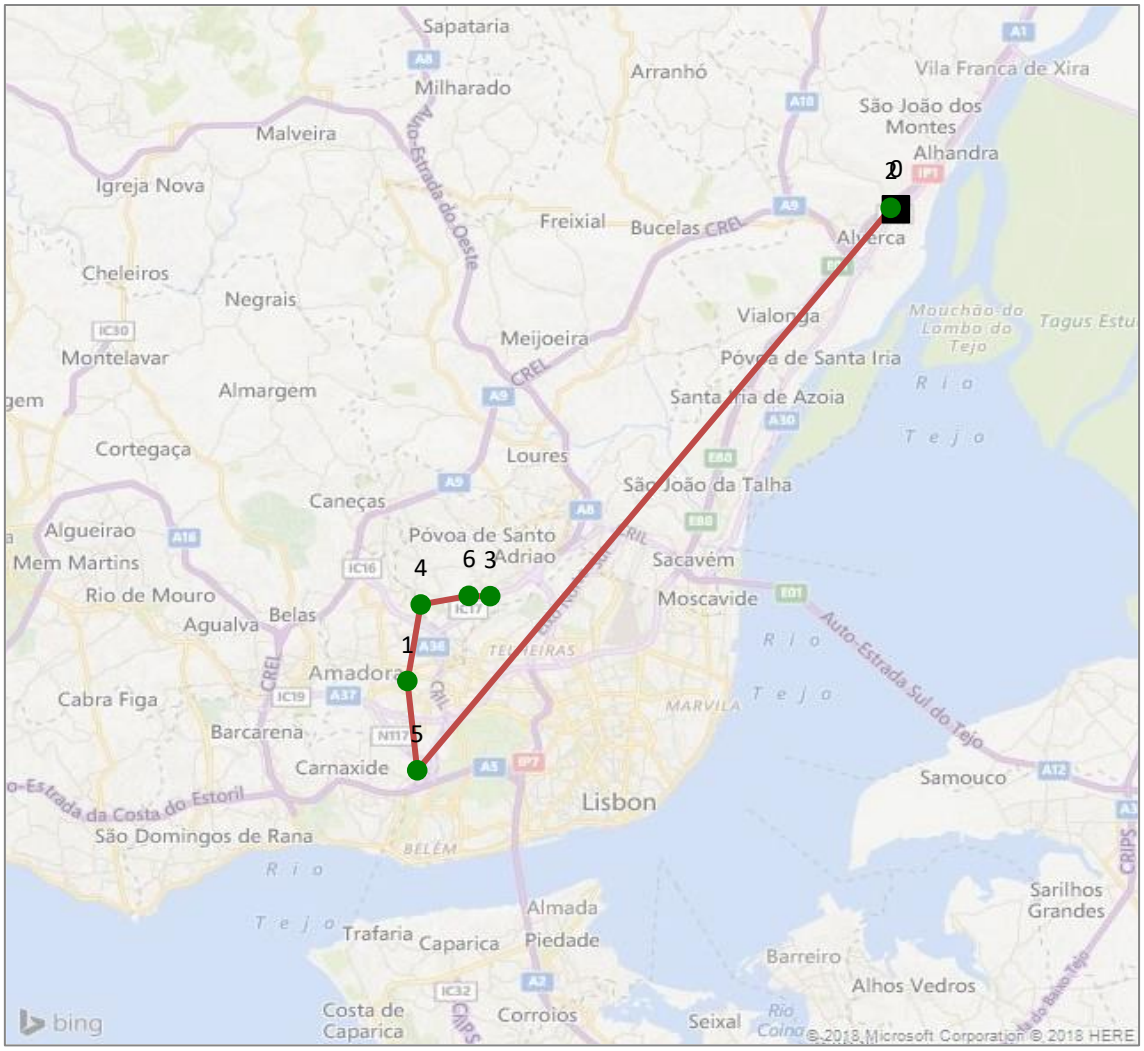


Illustration 9: Optimized route obtained for rotation 3, assuming all U customers which are attributed to vehicle 3 place orders.

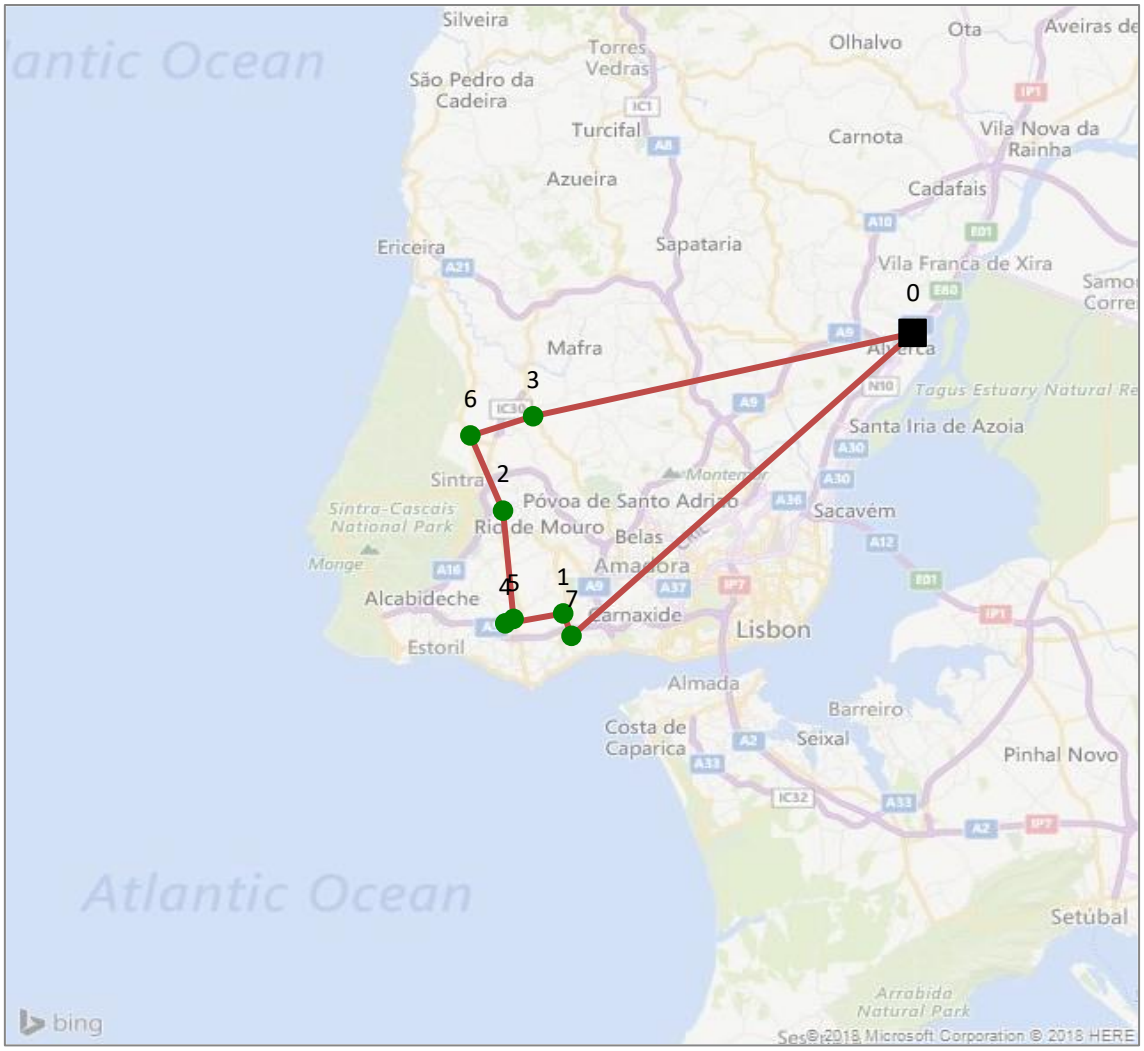


Illustration 10: Optimized route obtained for rotation 1, assuming all U customers which are attributed to vehicle 4 place orders.

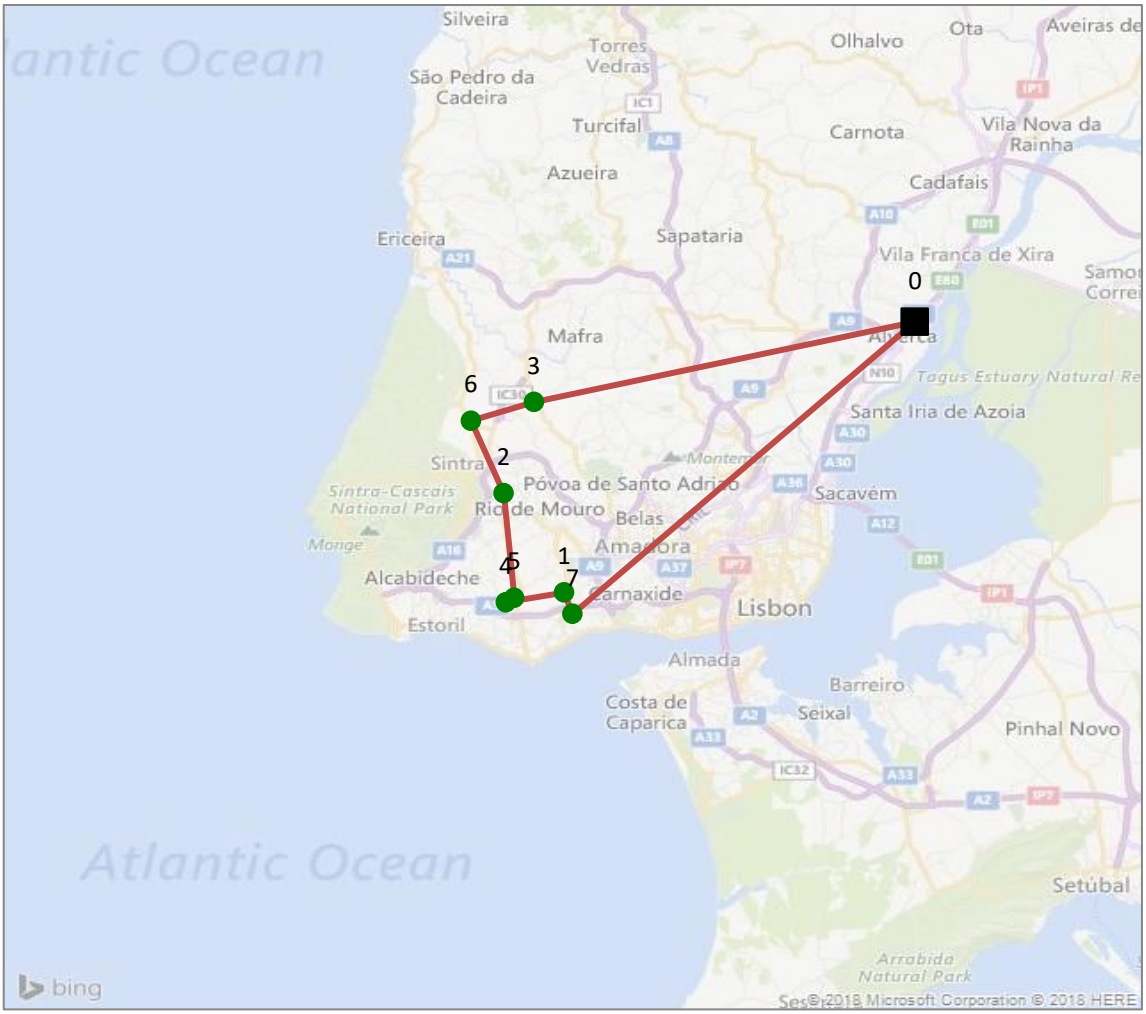


Illustration 11: Optimized route obtained for rotation 2, assuming all U customers which are attributed to vehicle 4 place orders.

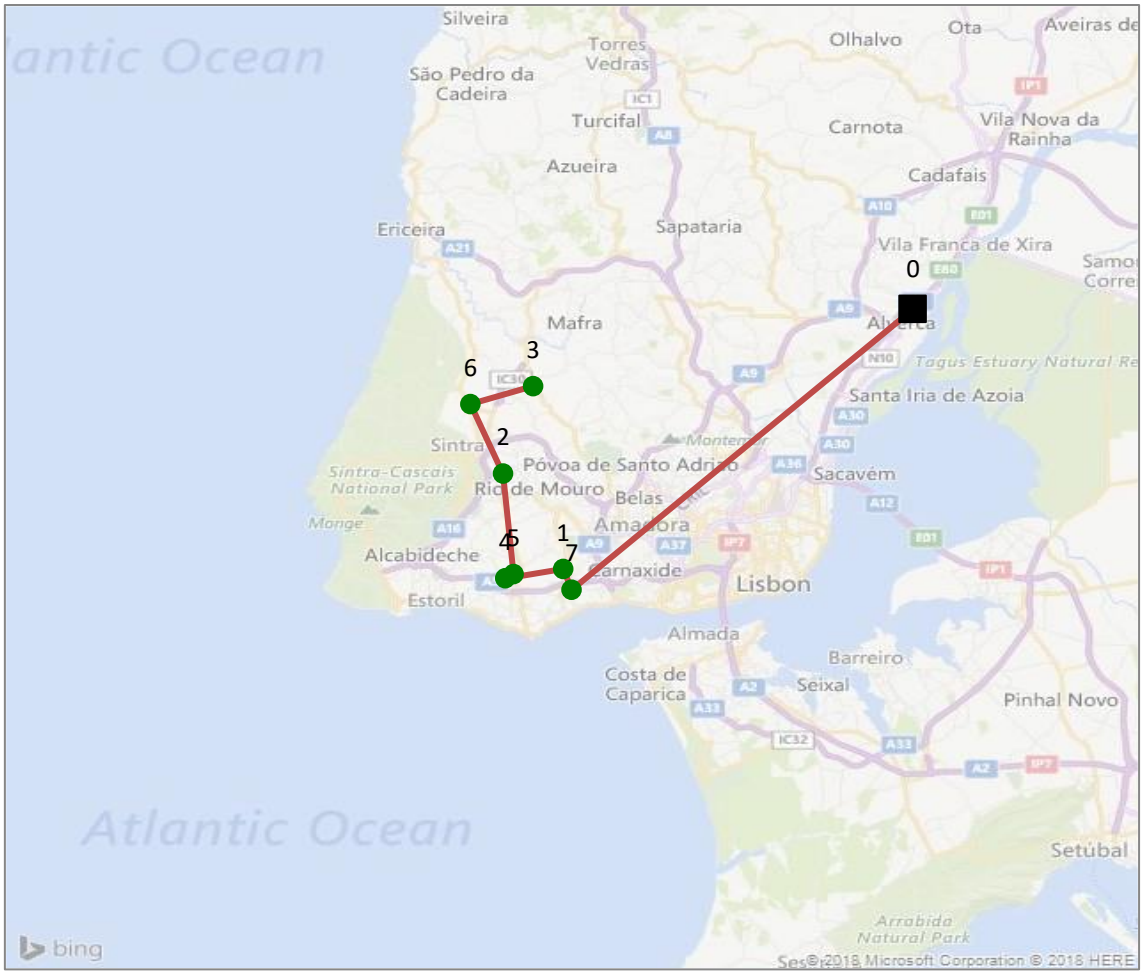


Illustration 12: Optimized route obtained for rotation 3, assuming all U customers which are attributed to vehicle 4 place orders.

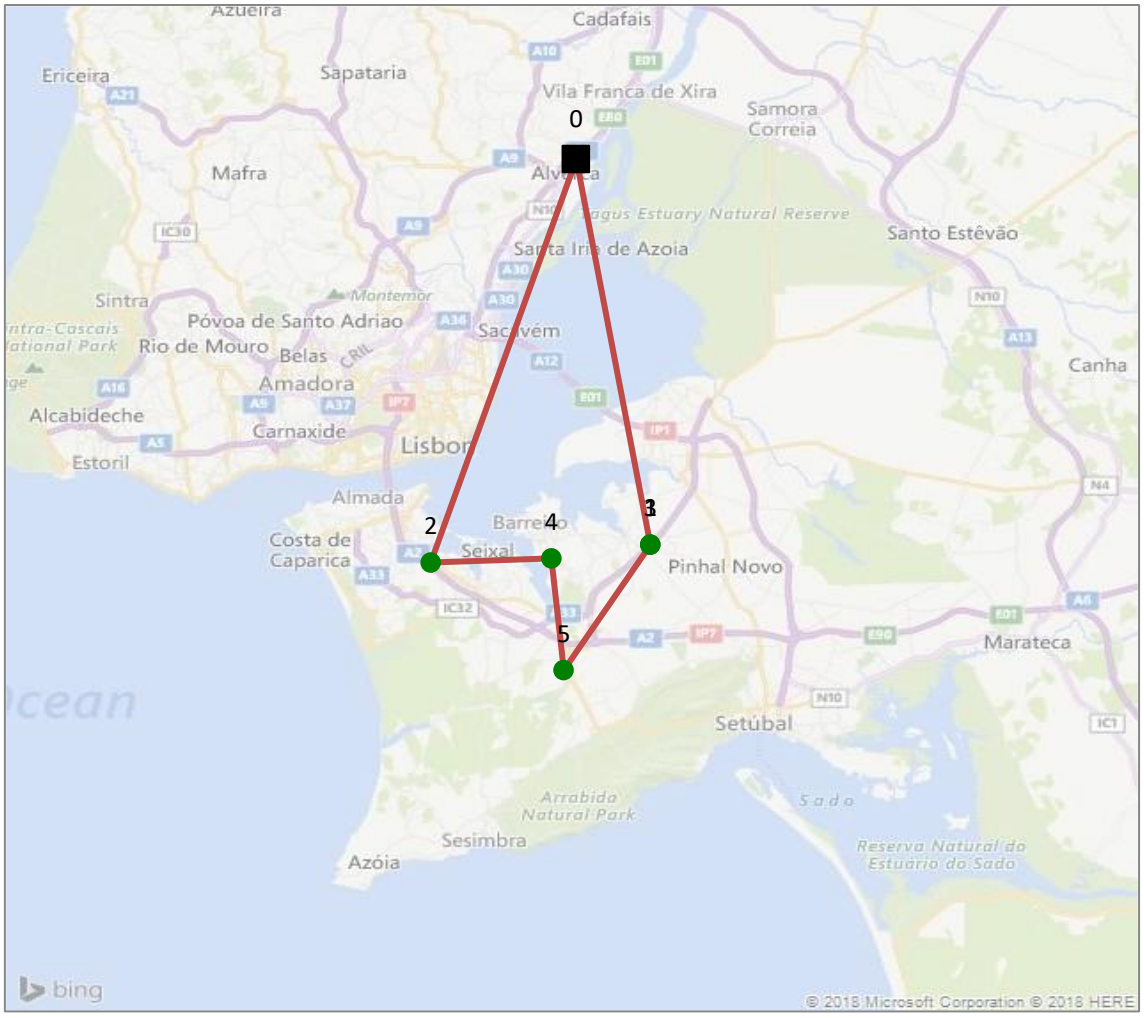


Illustration 13: Optimized route obtained for rotation 1, assuming 5 U customers which are attributed to vehicle 5 place orders.

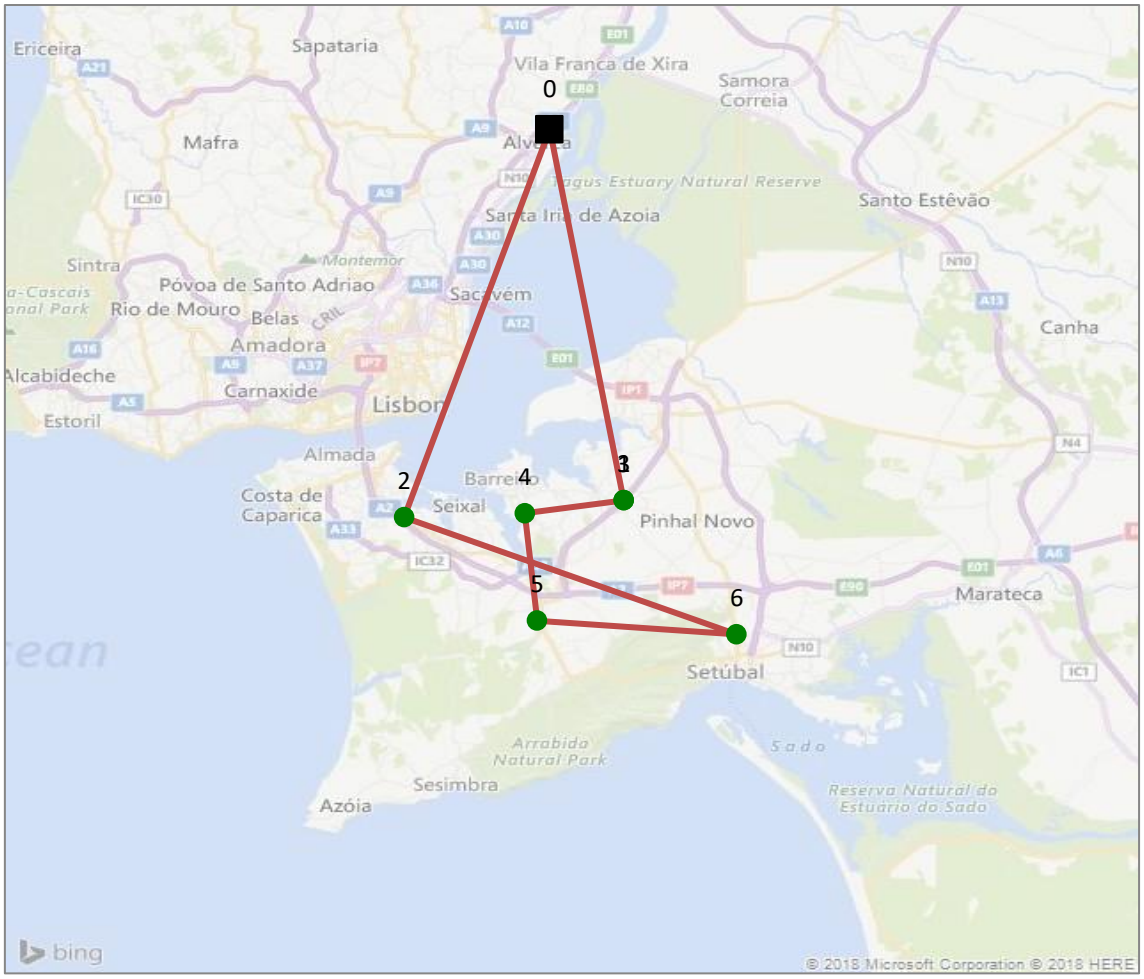


Illustration 14: Optimized route obtained for rotation 2, assuming all U customers which are attributed to vehicle 5 place orders.

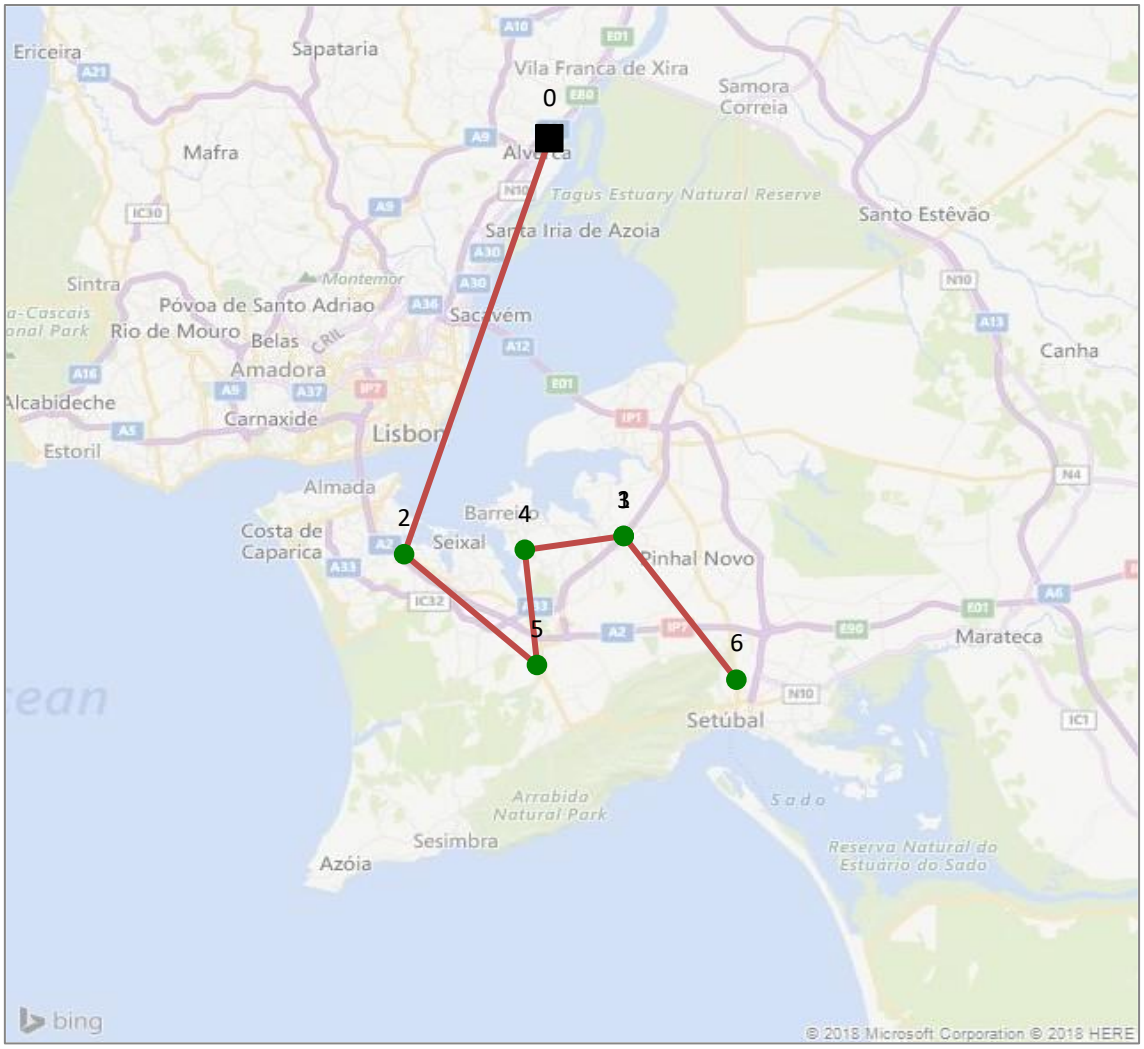


Illustration 15: Optimized route obtained for rotation 3, assuming all U customers which are attributed to vehicle 5 place orders.

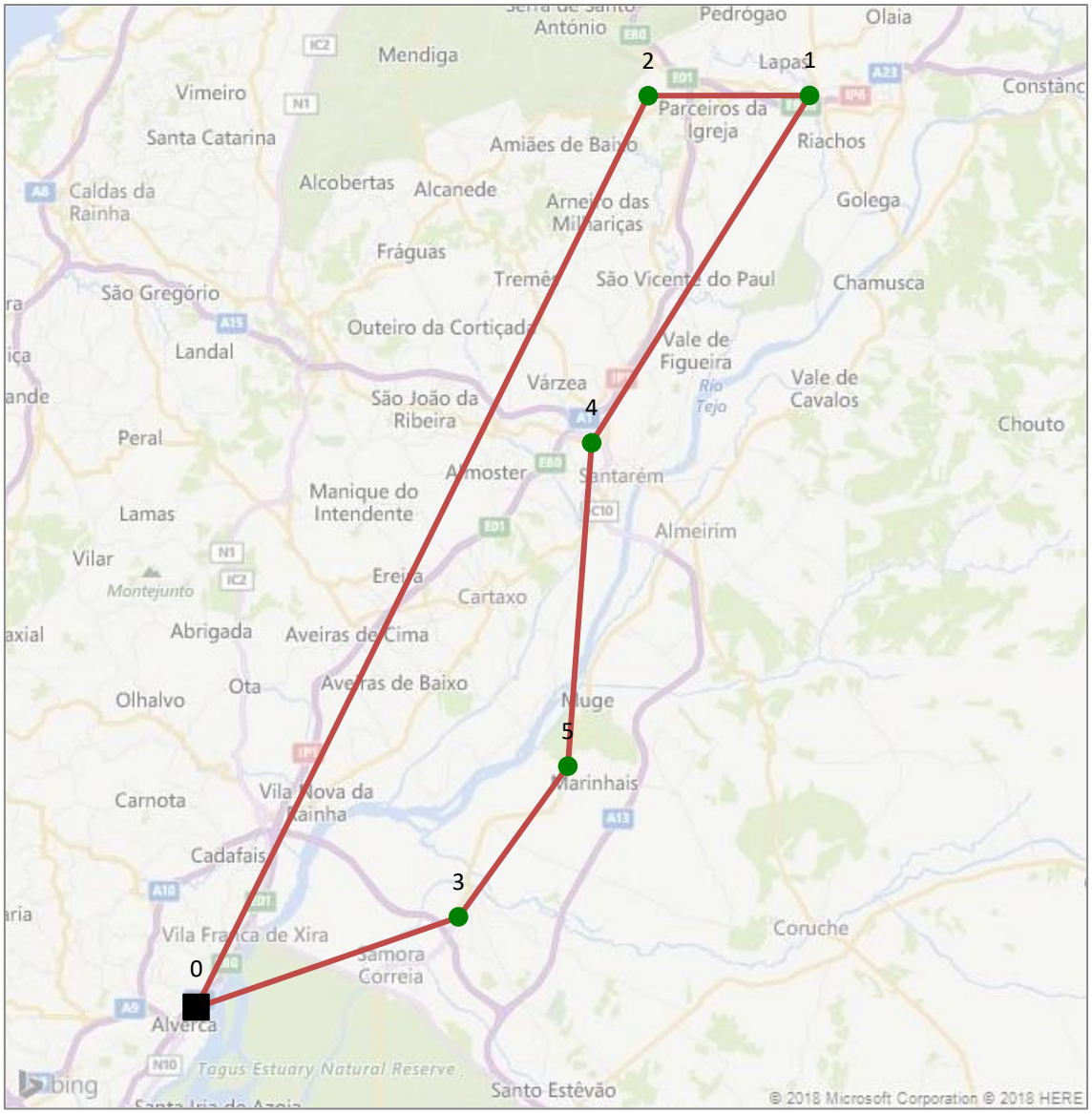


Illustration 16: Optimized route obtained for rotation 1, assuming all U customers which are attributed to vehicle 6 place orders.

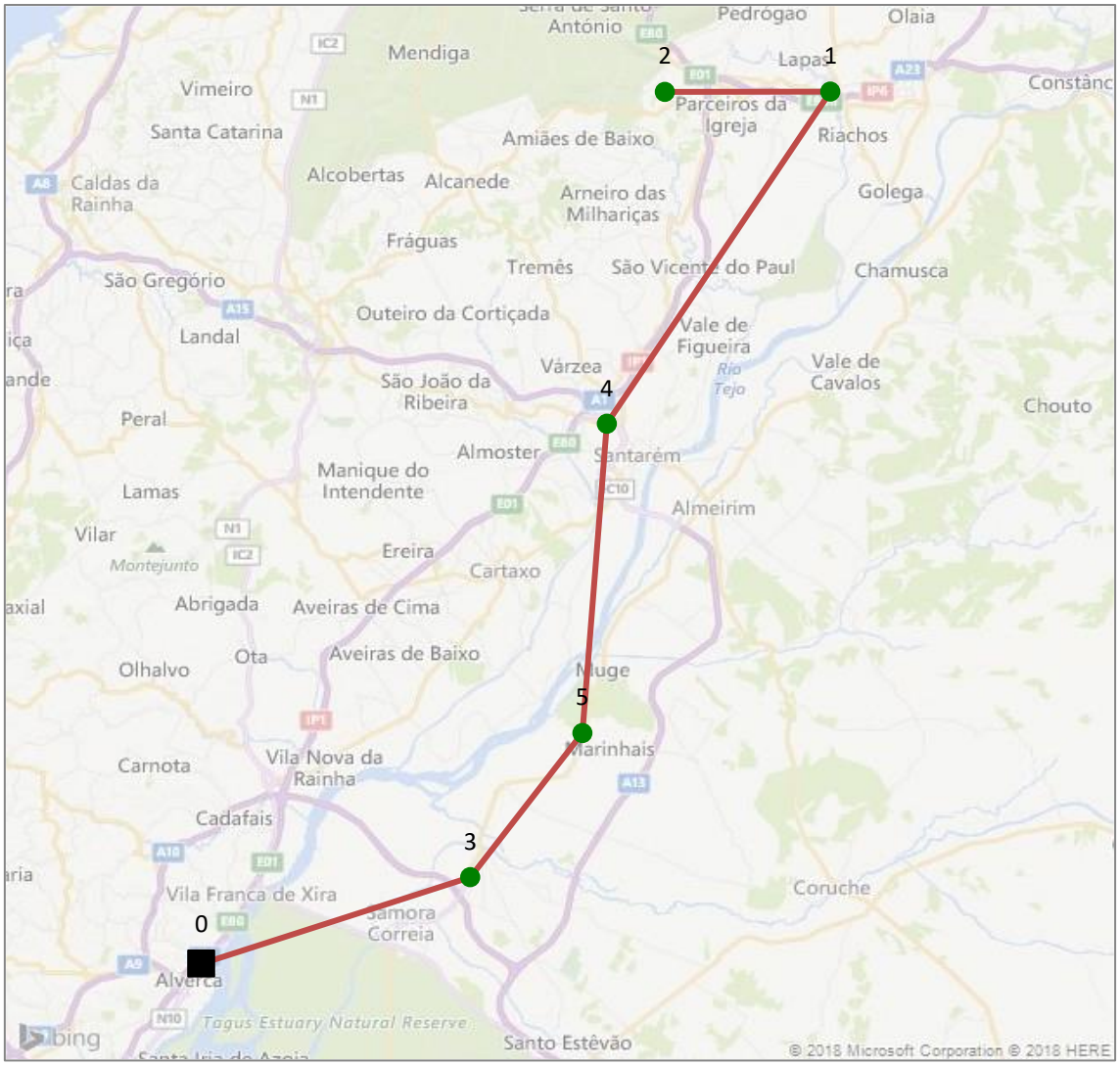


Illustration 17: Optimized route obtained for rotation 2, assuming all U customers which are attributed to vehicle 6 place orders.