MESG

Mestrado em Engenharia de Serviços e Gestão

Improvement in the process of shipping non-perishable goods

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Master Thesis

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"A mind that opens to a new idea never returns to its original size."

Albert Einstein

Abstract

When deciding how to ship goods from warehouses to stores, companies have some challenges to overcome concerning the planning of the best routes and managing the fleet of trucks. Nowadays, it still relies on intuition and lifetime experience of the fleet manager, as they have to take on consideration many variables such as loading and unloading goods; distances between warehouses and stores, driver's workload and at same time to guarantee a high service level.

This thesis was developed in a practical context, based in a real problem which intends to determine the best method set of routes for shipping different types of non-perishable goods (Just In Time and Stock), from warehouse to the stores. It also cares about providing the daily delivery and to fulfilling the time-window of the stores.

This is a Vehicle Routing Problem (VRP) with Time Windows and a Heterogeneous Fleet with a single depot. In order to minimize costs and guarantee that time-windows of stores are accomplished, we developed a mathematical model and present some heuristics approaches to solve it. We proposed a VRP Spreadsheet Solver that conducted a series of experiments to find a feasible solution. With different combinations of type of fleet, type of goods and time-windows we conclude that the best solution is shipping the two types of goods (Just In Time and Stock) instead of one type at a time.

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Table of Contents

List of Tables

List of Figures

List of acronyms, abbreviations and definitions

Acronyms and Abbreviations

2L-HFVRP	Two dimensional Loading Heterogeneous Fleet Vehicle Routing Problem
CARP	Capacitated Arc Routing Problem
CVRP	Capacitated Vehicle Routing Problem
DSS	Decision Support System
GA	Genetic Algorithms
HMA	Hybrid Metaheuristic Approach
HVRP	Heterogeneous fleet Vehicle Routing Problem
ILS	Iterated Local Search
JIT (logistic term)	Just in Time
JMR	Jerónimo Martins Retalho
LNS	Large Neighborhood Search
LNS	Large Neighbourhood Search
MTSP	Multiple Travelling Salesmen Problem
QWL	Quality of Working Life
RO	Robust Optimization
TMS	Transport Management System
VBA	Visual Basic for Applications
VRLP	Vehicle Routing and Loading Problem
VRP	Vehicle Routing Problem
VRPPD	Vehicle Routing Problems with Pickup and Delivery
VRPTW	Vehicle Routing Problem with Time Window

Definitions

Terms	Definition
Backhauling	Refers to the practice of not sending the cargo trucks back empty rather having them take some cargo from some suppliers in their journey back to the main warehouse.
Distribution Centers	Set of warehouses that allows physically separation of the several categories of goods that exist in the stores.
JIT	Just in time system of producing goods is based on preventing waste by producing only the amount of goods needed at a particular time and not paying to produce and store more goods than those needed.
Non-Perishable goods	There are two types: food and non-food goods but all of them have a large expiration date.
Pallets	A platform, on which goods can be executed, moved and stored.
Risks boxes	Plastic boxes containing small and expensive materials that are sealed to control that no one open before gets to store.
Rollcontainers	Metallic object used to transport goods.
Stock	The goods storage in the warehouse until needed for distribution.
Store	A place that daily order the goods need, received and store them to sell to customers.
Warehouse	A large building where goods may be stored before they are distributed.

1 Introduction

1.1 Context

The routing problems are a well studied subject since the 70s, useful to many different areas such transportation, distribution and logistics, especially in retail companies. Retail companies need to ensure the best routes of their truck fleets to minimize distances and so, minimizing costs. In some situations, the experience of the fleet manager is still the way to best plan the routes and to guarantee the daily distribution to stores.

For that kind of problems is common to use Vehicle Route Problems (VRP), that is a generic name used to several types of problems, but basically is about planning a set of routes for fleet vehicles (homogeneous or heterogeneous) based at depot (one or many) and shipping goods to customers (or stores). So, VRP can help define a set of routes performed by a fleet of trucks and guarantee that each route starts and ends at warehouse at minimum costs.

VRP can be divided into some constraints types as:

- **Capacitated Vehicle Routing Problem** (CVRP), where each vehicle has a limited capacity;
- **Vehicle Route Problem with Time Window** (VRPTW), is a problem that involves a time-window that each store has and must be insured;
- **Multi-depot VRP** there are several depots to satisfy customers;
- **Vehicle Routing Problems with Pickup and Delivery** (VRPPD), each store has associated two quantities: demands to be delivered and demands to be picked up.
- **Backhauls VRP**, when a demand will be collected, normally, each route starts and ends at warehouse, each store is visited by exactly a single route, but the total demand of backhauls or orders to store can’t exceed separately the vehicle capacity.

These types of problems, with high complexity and data dimensions are classified as a NP-Hard problem which means they require a large computational effort and solutions are hard to find. Therefore approaches such as heuristic algorithms or metaheuristics have proven to be more adequate for finding solutions in an achievable time.

1.2 Problem Description

1.2.1 Description of the project context

The problem studied in this thesis is "Improvement in the process of shipping non-perishable goods" of a retail company and aims to provide new ideas and solutions to minimize their shipping costs. It is a case study in real context of a Portuguese retail company; which intends to find out solutions for the shipment of non-perishable goods (food and non-food). This study was developed while the company is launching a new warehouse, so the model presented in this thesis could help to optimize the shipping process of the new warehouse.

The shipping process is connected with warehouses, stores and transport's team. Hence is necessary to distinguish the two types of current warehouses (JIT and Stock), how they operate individually and jointly, to understand the criteria used to define the routes from the currently warehouses to the stores.

The preparation of this thesis is related to the following objectives:

- Understand deeply some processes in Logistics and Operations;
- Develop problem-solving skills;
- Understand the different layout of Stock and Just in Time´s (JIT) warehouse and their efficient management;
- Distinguish the main differences between JIT and Stock´s warehouses;
- Identify the critical processes related to the shipping of non-perishable goods;
- Identify the inputs and outputs needed to resolution of this problem;
- Study different heuristic approaches.

1.2.2 The project and the specific problem addressed

As we set out to study: "Under what conditions should the company ship from the new warehouse to the stores?" is important to ensure a model for the company to conceive and decide on the most viable solution. The problem is based on the route improvement suggestion and optimization of processes in warehouses. So, for that we should study the current processes, routes and time-windows of warehouses and stores and understand whether they are the most appropriate or not.

This research is intended to achieve the following research objectives:

• Minimize company costs with the shipping process;

• Analyze the advantages of shipping non-perishables (JIT and Stock) together, and create relational synergies with transport' team;

• Explore the relationship between warehouses, stores and transport on the shipping process.

This investigation research is relevant to be conducted since it will have a direct impact on business operations in the company, that provided the physical and human resources which made the research possible and achievable.

1.3 Research questions and Methodology

It is critical to define at this stage, the research questions:

Research Question 1: Should JIT volumes be shipped with the Stock volumes?

Research Question 2: Should the company use one or two fleet carriers?

These research questions aim to develop scenarios to optimize the shipping route of non-perishable goods. It is important to minimize the transportations costs while maintaining a high level of service (distributed all demands to the stores). As we will see, it is important for the company to know how to ship their goods. It is more advantageous to unify cargo (JIT and Stock) or ship separately? Since the company has a contract with two carriers trucks, it should realize what brings more benefits: using the two carriers or only one with a larger fleet, because the fixed costs of the carriers are different as we will see in following chapters.

The methodology used in this research was divided into three phases, as shown in **figure 1**, the first one is background research in which the scope and research questions are defined. The second phase is about literature review about this subject, especially about Vehicle Routing Problems and heuristic approaches topics. The last one is about, the mathematical formulation of the problem, a heuristic approach description, a Spreadsheet VRP to solve it and the results found.

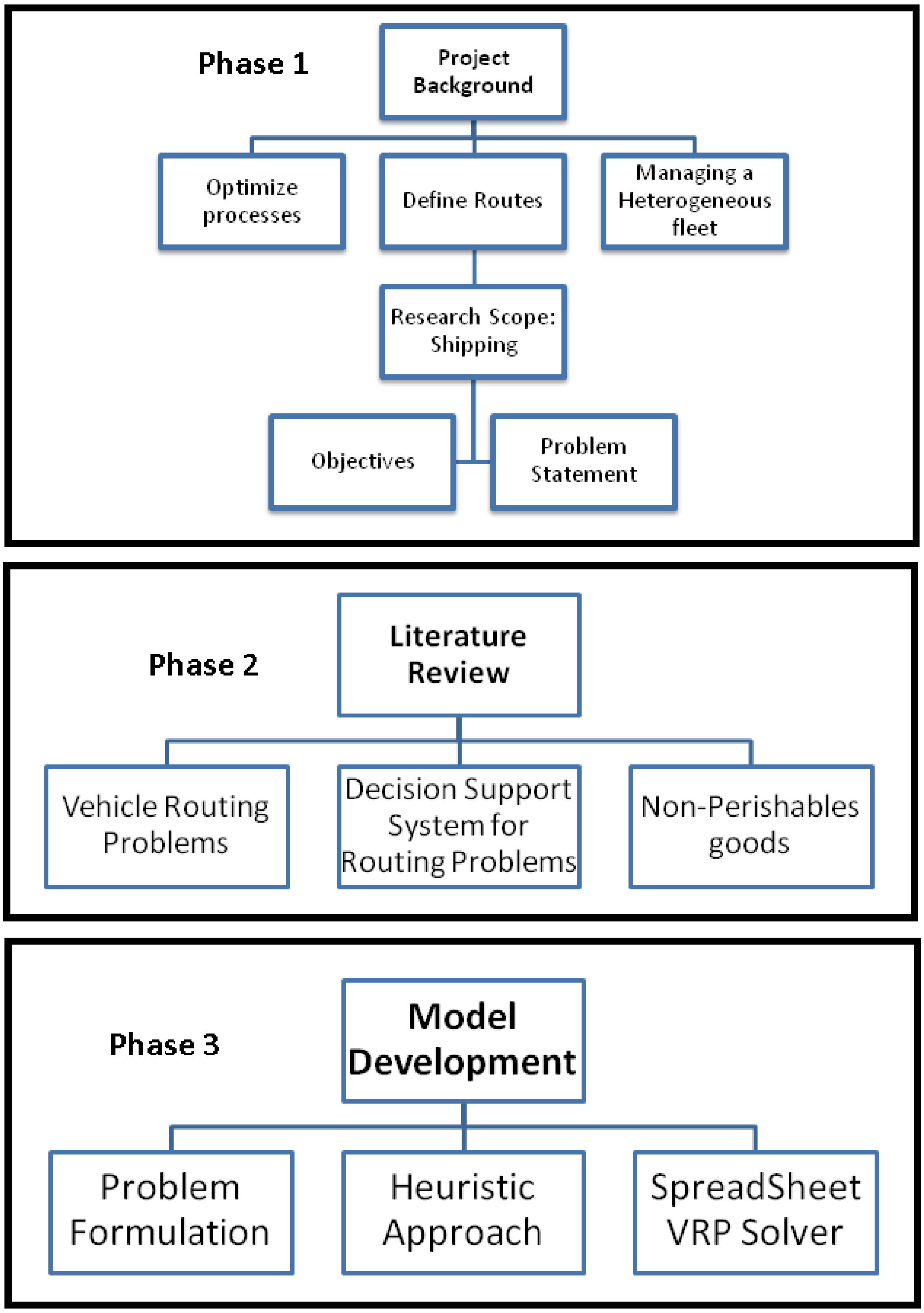


Figure 1 – Research Methodology.

A VRP is an interesting tool for the retail sector because companies can make use of mathematical models to minimize costs by adjusting routes. This study is related to the new needs of shipping and warehouses processes in Jerónimo Martins Retalho (JMR) Company. The development of this project is related to the issue of shipping non-perishable goods while ensuring their deliveries in the exact time-windows of the stores and reducing kilometers traveled by trucks. Each task of this study was planned beforehand in order to promote the efficiency and success of the project. The complete Gantt Diagram can be seen in **Appendix A**.

1.4 Document outline

This chapter provides an overview of this document research and makes an introduction to the subject. The remainder of this document includes five further chapters and appendix. The second chapter is related to the state of the art. The third chapter provides an overview of the problem, characterization of the company, its current facilities and description of new warehouse. The fourth chapter presents a mathematical model that mentions the system constraints, assumptions and dependencies, heuristic approaches and a Spreadsheet VRP Solver. The fifth chapter of this document is related to the conclusion of this entire thesis project, the main objectives achieved, study limitations and future recommendations. The end of the document includes the appendix that contain all information collected during this project and because of space limitation couldn’t be integrated in the previous sections.

2 Theoretical Background

The literature review provides a frame of reference to interpret the results; leads to the establishment of hypotheses and guides on how to conduct the study. It is a continuous process, initially more difficult by lack of knowledge of the subject and gradually becomes clearer what we should investigate as theoretical approaches, methodology and data collection techniques are concerned.

This section highlights the state of the art on Vehicle Routing Problems. The purpose of the literature review is to find gaps on the chosen topic. In this way, it contributes to increase the scientific knowledge of the under area study. During this project, we made a research about the subject: Operations Research using Quantitative Methodology as Vehicle Routing Problem in Retail Businesses. A literature review will help to identify the appropriate methodology through comparing different models, *as one of the main reasons for conducting the literature review is to enable researchers to find out what is already known*. (Levy & Ellis, 2006). The literature review helps to strengthen the results obtained during the thesis, and at the same time helps others to acquire knowledge on these topics.

Levy & Ellis (2006) state, *doing so will enable the researcher to provide a solid argument for the need of study as well as their spot where literature fits into their own proposed study*. A crucial step for writing a thesis is to carefully make a quality literature review and know the state of the art about that topic and get as much information as possible. At this point, the main objectives are to explore articles and books that have studied the topic and check the existence of a gap, and then set the research method. We review some former and recent articles using the databases: Scopus, Ebsco and Google Scholar for this research.

Throughout all this process, it is necessary to follow a particular pattern because there are too many articles on this topic. After searching several papers and articles, it should be noted that not all articles show the same quality and rigor, so, taking this into account, we must choose the most relevant. The need arises to catalog and categorize the information of these articles, which can be used to build new knowledge. After reading the articles it is crucial to understand and define the concepts: Non-perishables goods, Operational Research, Vehicle Routing Problems and Heuristics approaches.

As this study is focus on non-perishable goods, it is important to establish difference between perishables and non-perishable goods.

2.1 Non-perishables and perishable goods

H.-K. Chen, Hsueh, & Chang (2009), describe perishable goods, *such as food goods, vegetables, flowers, living animals and ready-mix concrete, often deteriorate during the production and delivery processes. More and more suppliers adopt just-in-time production and delivery strategy to fulfill their orders from retailers because they can reduce the loss of their own profit due to deterioration of perishable goods*. While perishables have to take account their shorter shelf life period (counting from the day it is produced and the day it is no longer acceptable to consume), non-perishables have a longer shelf life. Amorim, Günther, & Almada-Lobo (2012), study for a production and distribution problem of perishable goods, and realize that, *the logistic setting of our operational problem is multi-product, multi-plant, multi-DC and multi-period* and is a fixed shelf-life it most have an integrated model, *the integrated production and distribution planning of perishable goods with fixed shelf-life (PDP-FSL) may be formulated as a multi-objective mixed-integermodel*.

Govindan, Jafarian, Khodaverdi, & Devika (2014), propose other approach to ship perishable food, *a multi-objective optimization model by integrating sustainability in decision-making, on distribution in a perishable food supply chain network* and it *introduces a two-echelon location–routing problem with time-windows*. Although the goods have different expiration dates, the JIT layout of non-perishable goods requires also a reception, execution and delivery just 24 hours in the warehouse, such as the perishables. To our knowledge, there is a gap in studies about shipping of non-perishables goods in a retail businesses.

This study is based on the real case of a retail company, so it is important to define and explain the main activities of a retail business.

2.2 Retail Business

According to Sorescu, Frambach, Singh, Rangaswamy, & Bridges (2011), *a retail business model articulates how a retailer creates value for its customers and appropriates value from the markets. Innovations in business models are increasingly critical for building sustainable advantage in a marketplace defined by unrelenting change, escalating customer expectations, and intense competition*. It is important to a company invest time and money to better understand the way that warehouses and stores operated, their layouts, shelf allocations, and with that make changes in order to increase profits.

The next topics to be addressed are related to a very wide and discussed in scientific area – Operational Research.

2.3 Operational Research

2.3.1 Robust Optimization (RO)

Opher Baron, Joseph Milner (2010), study *a robust optimization to the problem of locating facilities, consider a variant of the capacitated fixed-charge multi-period facility location problem where the production capacity of each facility must be determined before observing demand during the horizon*.

In a robust approach, minimax-regret and minimax-cost are applied. Baron realizes that the robust model with the box uncertainty performs poorly with respect to balancing robustness with profit. In contrast, the model with the inscribed ellipsoid provides small but significant improvements in the average profit. And most important, that a single ellipsoid is able to provide good solutions over a wide range of parameter choices.

Based on these models and their uncertainty, the manager must be able to take an option, according to Gabrel, Murat, & Thiele (2012), *must determine what it means for him to have a robust solution: is it a solution whose feasibility must be guaranteed for any realization of the uncertain parameters? Or whose objective value must be guaranteed? Or whose distance to optimality must be guaranteed? The main paradigm relies on worst-case analysis: a solution is evaluated using the realization of the uncertainty that is most unfavorable*. This author specific the applications of Robust Optimization in several areas, which he considers using RO in a combinatorial optimization or scheduling problems.

2.3.2 Vehicle Routing Problem (VRP) – Definition

VRP was introduced by Dantzig & Ramser (1959), as an approach of Traveling Salesman Problem (TSP). VRP represents distances, travel cost and times, normally V_0 is the origin called depot (warehouse) and *V* represent the customer (or stores) that want to be served. So VRP tries to define a set of routes for *k* vehicles that start at depot and visit customers exactly once, that minimize the routing costs.

After Dantzig and Ramser, several studies report some modifications, VRP is classified as NP-hard problem because its variants, so there is: CVRP that treat vehicles with finites capacity; VRPTW, customer should be visited in a time frame; PDP and HVRP, a heterogeneous fleet with vehicles with different capacity. It depends if it is a single or a multiple depot; homogeneous or heterogenous fleet; existence of time-windows, and so on. As Macedo, Alves, Valério de Carvalho, Clautiaux, & Hanafi (2011), VRP consists of finding the best set of routes according to a given objective function, such that all operational constraints of vehicles are respected, this objective function can be the minimization of all traveling costs, the maximization of the number of served customers, or some combination of these or other factors.

2.3.3 Multi Routes and Time Windows Problem

Macedo et al. (2011) proposes a new algorithm that is based on a pseudo-polynomial network flow model, represent discrete time instants and whose solution is composed of a set of paths, each representing a workday. In this paper there is a single depot and homogeneous vehicles and the objective function translates the fact that it is always desirable to visit as many customers as possible.

Osvald & Stirn (2007), study *MVRPTWTD* where the times between two locations depends on both the distance and on the time of the day. This was applied in perishable food on the Slovenian vegetables market. *In the VRPTW we know location, the demand and the delivery window.* Here if the time window was violated there is a penalty cost but it is not allowed a hard time windows for the depot. The new network model presented for *MVRPTW* solved with CPLEX, the algorithm was tested and compared with branch-and-price algorithm and used the same set of instances and the same values of parameters. Osvald & Stirn (2007), on their study, firstly used a sequential constructive heuristic that solves a classical VRPTW, second introduced a tabu search, which is a local method that uses memory structures.

2.3.4 Heterogeneous Fleet Vehicle Problem

According to Grı Koç, Bekts, Jabali, & Laporte (2015) , HVRP generally consider limited or an unlimited fleet of capacited vehicles, where each has a fixed cost, in order to serve a set of customers with known demands. There are different types of vehicles, one depot and a set of customers, as a NP-hard problem Wang, Li, & Hu (2015), use to solve a modified Clark-Wright route construction heuristic and two, a ruin-recreate heuristic and a threshold tabu search. Wang et al. (2015), introduce Solomon´s instances and adjust to fit in a real case study, a supermarket chain in China. In the literature review there are many approaches to VRP, but the real cases are for perishables, omitting cases of shipping non-perishable goods, so it is a gap that could enhance profit to retail companies that work with non-perishable goods. In this case involving heterogeneous fleets, a single deposit, various stores, time windows there are some gaps regarding the application of these variances. It is necessary to develop more studies that merge these variances to optimize the operation - Shipping - and minimize the costs of transport routes.

Anand Subramanian a,b, Puca Huachi Vaz Penna d, Eduardo Uchoa c, & Luiz Sat, n.d., consider the existence of different vehicle types, with distinct capacities and costs and want to determine the best fleet composition, the set of routes that minimize the total costs. They studied five variants involving limited and unlimited fleet with fixed and or variable costs were considered, to solve this type of problem they proposed a hybrid algorithm composed by an Iterated Local Search based heuristic to limited and to unlimited (Fleet Size and Mix) fleet.

In cases like this, it is not easy to find an optimal solution because of the complexity of the problem and it is a multi-objective optimization problem. Ehrgott, Ide, & Schöbel (2014), explain that in real-world applications optimal solutions are often of limited value, because disturbances of or changes to input data may diminish the quality of an optimal solution or even render it infeasible. So, this study tries to gain insight into the new area of robust multi-objective optimization, merging robust (single objective) and deterministic (multi-objective optimization). They provide three methods to minmax robustness to be extended to multi-objective optimization problems.

Mancini (2015), introduce a VRP with heterogeneous fleet and with a multi depot problem. Here a limit on the maximum route duration is imposed, and not every customer will be served by all the vehicles or from all the depots. It proposes an Adaptive Large Neighborhood Search (LNS) metaheuristic approach followed by digital results, pertaining to realistic instances, which show the effectiveness of the method. Like most of the papers, the goal is to carry out delivery operations at the minimum costs, while respecting constraints due to driver scheduling and customer/vehicle compatibilities. This approach brings innovations in the capability of exhaustively exploring a large neighborhood in a very short computational time, so this LNS framework is more effective than the traditional LNS.

Leung, Zhang, Zhang, Hua, & Lim (2013), introduce another variant of the classical VRP is the two-dimensional loading heterogeneous fleet vehicle routing problem (2L-HFVRP), which fleets have different capacity, fixed and variable operating costs, length and width in dimension and two-dimensional loading constraints. As several others studies the objective is to minimize transportation cost of set of routes in order to satisfy customers demand. They use a simulated annealing with heuristic local search to solve the problem and the search was then extended with a collection of packing heuristics to solve the loading constraints.

Once more, Leung et al. (2013) addressed a NP-hard for 2L-HFVRP and solve with heuristic local search but realize that it could also be capable to solve 2L-CVRP with a good set of results. In this study was missed the time-window factor.

Y. Chen, Hao, & Glover (2016), contribute to the Capacitated arc routing problem (CARP) with a Hybrid Metaheuristic Approach (HMA), which incorporates an effective local refinement procedure, coupling a randomized tabu thresholding procedure. HMA showed the ability to identify either the best known results or improved the best known results for almost all currently available CARP benchmark instances.

Many heuristic approaches were submitted over the years, such as a "packing first, routing second" heuristic approach that reported 46 VRLP instances. Bortfeldt & Homberger (2012), analyze, if routing and packing should be tackled, in the Vehicle Routing and Loading Problem (VRLP), which combine vehicle routing, time-windows and three dimensional loading.

Low, Chang, Li, & Huang (2014), focus on a production scheduling with delivery problem, although they studied the delivery of the goods to retailers instead of to the customers (or stores), there is based on determine the sequence of a vehicle (heterogeneous fleet) respecting the time windows. It was applied a non linear mathematical model to minimize the total cost (transport, vehicle arrangement cost, penalty costs). To solve the problem, they used two adaptive genetic algorithms (AGAs), and the computational results were evaluated through randomly generated test problems in various environments.

H.-K. Chen et al. (2009), propose a nonlinear mathematical model to a scheduling vehicle routing problem with time-windows but for perishable food. In contrast to others studies this has the objective to maximize the expected total profit of the supplier. Here they elaborate a solution algorithm composed of the constrained Nelder-Mead method and a heuristic for the vehicle routing with time window to solve the complex problem, the results show that this algorithm is effective and efficient. They conclude that *production scheduling and vehicle routing for perishable goods are integrated into a unified framework which is also applicable to the fields like food, vegetables, flowers, living animals and so on*.

In conclusion, there isn´t an unique methodology to solve a VRP with time-windows, heterogeneous fleet and one depot as variants for shipping non-perishable goods. Regarding to this thesis it will be important to unify methodologies to find the best solution to this problem.

In the next section, we will summarize the main contributions and results of papers that most supported the writing of this thesis.

2.4 Presentation of findings

Authors	Citations	Methods	Results/Contributions
Anand (Anand Subramanian a,b et al., n.d.)	*The objective is to determine the best fleet composition as well as the set of routes that minimize the total costs.*	HFVRP using Iterated Local Search (ILS) based heuristic and a Set Partitioning (SP) formulation.	They determined the best fleet composition that minimize the sum of fixed and travel costs. *The hybrid algorithm was tested in 67 benchmark instances with up to 360 customers and it was found capable to obtain 8 new improved solutions, to equal the result of 54 instances and failed to obtain the best known solution of only 5 instances*.
(Bortfeldt & Homberger, 2012)	*The main idea of the heuristic is to separate packing boxes in loading spaces and constructing routes from each other in order to structurally reduce the packing effort and to thus obtain an efficient heuristic method*.	Vehicle Routing with Time Windows and three-dimensional Loading (VRLP) using a two-stage heuristic *packing first, routing second*.	They achieved high quality results for 46 VRLP instances by Moura and Oliveira.
Song, Byung Duk; Ko, Young Dae	*Managing the delivery of food products because of the customer satisfaction issues coming from the*	A nonlinear mathematical model and a heuristic algorithm to generate efficient vehicle routings with the objective of	Comparing the use of refrigerated and general-type of vehicles for multi-commodity perishable food products delivery, *the average number of served*

	freshness of delivered food products.	maximizing the level of customer satisfaction.	*customers per each route by refrigerated-type vehicle tended to be greater than that of general-type vehicle duo to the constraint of the minimum customer satisfaction*.
Wang, Zheng; Li, Ying; Hu, Xiangpei	*A HVRPTW-ILC can be defined as an undirected network with single depot a set of n customers. Two types of vehicles refrigerated and non-refrigerated and three types of goods stored in the depot*.	A heterogeneous multi-type fleet vehicle routing problem with time windows and an incompatible loading constraint using a mathematical model, a ruin-recreate heuristic algorithm and a threshold tabu search method.	Wang investigated in a real supermarket chain, Lehaha Supermarket, in Dalian city of China to prove feasibility and effectiveness. Their contribution is huge because HVRPTW-ILC is not very much studied in the literature.
Osvald Ana; Stirn, Lidija	*To minimize the overall distribution cost, the objective function must not only model the number of vehicles, the total distance-traveled and the total travel-time, but additionally the loss of quality of the load.*	A Vehicle Routing Problem with Time Windows and time-dependent travel-times using a heuristic approach based on tabu search and verified using modified Solomon's problems.	Osvald applied in Slovenian food market giving improvements of up to 47% reduction in perished goods. They studied the quantification of quality loss in perishable goods. When time-dependent travel-times were taken into account the savings increases on average to 40%.
Chen, Huey-Kuo; Hsueh, Che-Fu	*The objective of this model is to maximize the expected total profit of the supplier*.	A nonlinear mathematical model to consider production scheduling and vehicle routing problem with time windows for perishable food products	Using Visual C++ 6.0 based on Solomon's problem set. This algorithm solve PS-VRPTW-P efficiently and returns a reliable solution for production scheduling and vehicle routing problems for

		(PS-VRPTW-P) using the Nelder-Mead methos for solving nonlinear optimization and applied to non-convex problems.	perishable goods under stochastic demands.
Macedo, Rita; Alves, Cláudio	*The problem consists of finding the best set of routes, according to a given objective function, such that all operational constraints of the vehicles are respected, and the set of customers is covered.*	For a VRPTW problem they used an iterative algorithm that relies on a pseudo-polynomial network flow model with a homogeneous vehicle.	This method is able to solve more instances than the exact method described in literature.
Amorim, P; Gunther, H. O.	*In the first objective, total costs are minimized, namely: production costs, transportation costs and spoilage costs. (...) This objective function aggregates the measurable economic importance throughout the considered supply chain*.	A multi-objective framework was used for two types of perishable goods: with fixed shelf-life and with loose shelf-life.	As an exploratory research in this field, they realize that in the fixed shelf-life case for a 70% mean remaining shelf-life of delivered products reach savings around 42%.

3 Problem Characterization

As shown in **figure 2**, to better understand the problem we should understand the currently reality and then make a description in order to know the important data to collect for the model formulation. After select the method we could validate the model and then implement the solution found.

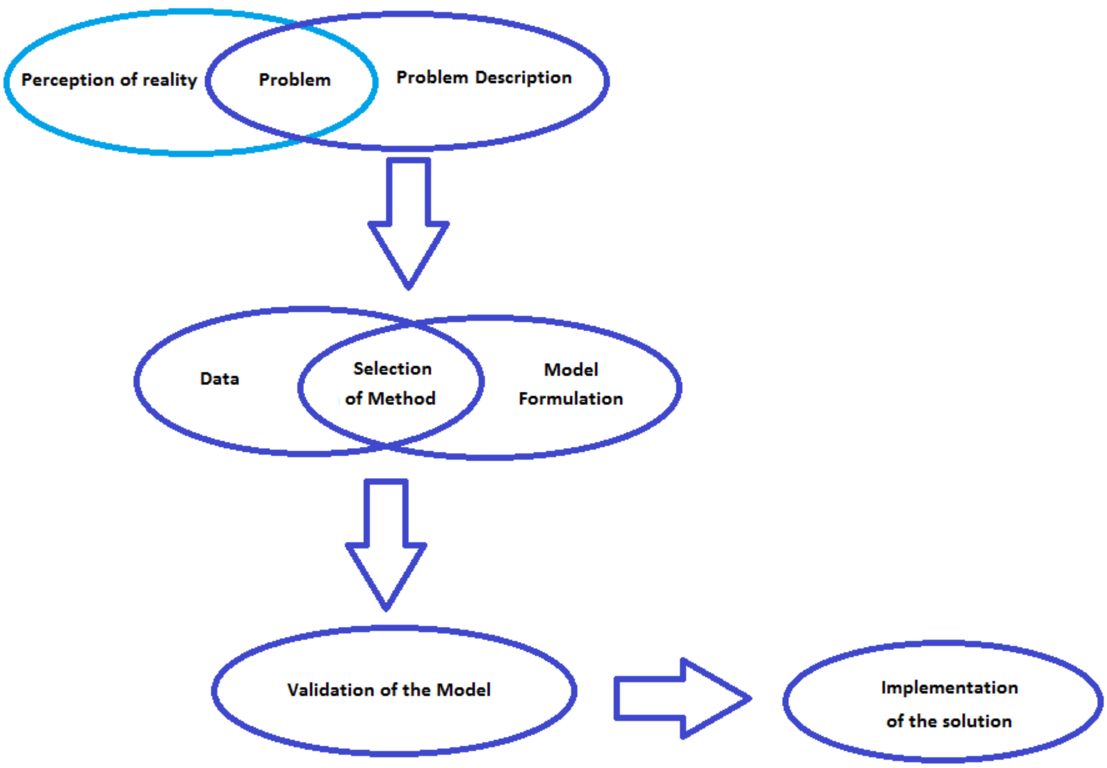


Figure 2 – Several steps to find a solution to the problem.

Therefore this chapter describes the company; explains the current situation of warehouses; how they operate separately and jointly and how they will proceed at the new warehouse.

3.1 Company´s Description

Jerónimo Martins is a Portuguese company with 200 years of history. In 1980 they established a strategy for the supermarket segment and recovered the original activity: food distribution. The main activity is Food Distribution through supermarket chains (Pingo Doce) and cash & carry (Recheio) in Portugal, food stores in Poland (Biedronka) and Colombia

(Ara). Although the company has various business areas, we will focus our attention on Jerónimo Martins Retalho (JMR).

JMR is primarily engaged in the distribution of non-perishable and perishable goods to their supermarket chains: Pingo Doce and Recheio. The company has a market position in Portugal for its low prices' policy, strengthening the value proposition and the quality of its goods. They are also involved in various activities: ordering, purchase, transport and storage.

During this thesis we will look to JMR Warehouses in north of Portugal that focuses its activity in the cities Guardeiras (Stock), Freixieiro (Stock) and Laúndos (JIT) where they have the three warehouses for non-perishables goods. In **Appendix B**, is represented the process map of non-perishable goods, describing the management, core and support processes.

3.2 Routes

Routes can be described as a graph where the warehouse and the stores are the vertices and the roads are the arcs. Each arc has an associated value that represents the distance traveled (between the warehouse and the stores) and the time of travel.

The routes have restrictions: total orders of the stores must be equal to or less than the capacity of the fleet and take into account the time-window of stores. For the company the costs of transports are very high, so is helpful to minimize distances and the time spent on the shipping (the warehouses to the stores). To calculate the cost of the routes is necessary to take into account the price of kilometers, fixed costs of each fleet and the distance traveled (help to know latitude and longitude from warehouses and stores), as shown in the **Appendix C**, **D** and **E**.

3.3 AS-IS (Current situation)

Currently there are three warehouses for non-perishable goods and they are distant from each other. Guardeiras warehouse distance 5 km from the Freixieiro warehouse and 26 km from the Laúndos warehouse. As the goods are distributed in the three warehouses is necessary to develop different routes and joint routes. Joint routes implies that the trucks go to one of the warehouses (Laúndos or Freixieiro) collect certain amount of pallets and turn to Guardeiras warehouse to add more quantities of pallets, and only then follow to stores. This additional effort implies that the truck makes a change on the route (increasing the number of kilometers), wastes time on loading and unloading at two different warehouses before getting to the stores' destination. Nowadays, non-perishable warehouses are dependent on perishable warehouses (goods as fruit, fish, fresh food and frozen food), because the truck fleet of transport is used by all warehouses.

JMR has a strong internal dynamics between the warehouses: Stock and JIT, transport, carriers and stores, to achieve the goals successfully. JMR also knows that its good performance depends strongly between the relationship with its stakeholders, in **Appendix F**, is shown a workflow diagram with these interactions.

3.4 Organization of warehouses facilities

At this moment it is important to clearly define the dynamics of JIT and Stock warehouses and transport, since it depends on the success of operations. The warehouses divide their tasks by reception, executing and shipping teams.

Each warehouse has gates (are used to receive or ship goods), which are currently divided into four lines, which means greater space. However, certain stores occupy the four lines (the whole gate) depending on pallet volumes. Each lines holds up to 11 pallets or 22 half pallets. It is important to explain that each pallet stores an average of approximately 55 units (height up to 1.80 meters) and half pallets approximately stores approximately 25 units, and after finished are wrapped in plastic film (either manually or with the robot itself).

Currently, the volumes produced at warehouses are shown in the **table 1** below.

	Stock Warehouses		**JIT warehouse**	
Average	Guardeiras	Freixieiro	Laúndos	**Total**
Boxes/year	20 722 119	1 413 225	35 215 714	57 351 058
Boxes/day	66 000	4 530	97 900	168 430
Pallets/year	370 648	135 003	640 285,71	1 145 936,7
Pallets/day	1 210	433	1 780	3 423

Table 1 – Average of volumes produced in each warehouse.

The reception team receives the goods either by suppliers, backhauling or transshipment, ordered by stores, register them in the system (give input and put labels with product information and barcode) so then can be carried or stored, as we can see in **Appendix G**.

The execution team, in all of the warehouses, has the task of assembling the pallets for the stores, according to information provided by the system of requests from the stores.

The shipping team is in charge of moving the pallets produced by the execution team to the gates, to be shipped to stores.

The Transport team provides a map to the shipping team, with the daily planning of delivery of pallets per store and route (which stores are delivered together in the same truck).

While the JIT warehouse features as approved condition and ships within 24 hours all the items, the warehouse Stock besides receive and send, store items (stock). Next we will explain deeply each warehouse operations.

3.4.1 JIT Warehouse

The JIT warehouse, in the current context of the company, dispatches from Mondays to Fridays since 2 p.m to 12 a.m and since 2 p.m. from 11 p.m on Saturdays, in three shifts: 6 a.m to 3 p.m; 2 p.m to 11 p.m and 10 p.m to 7 a.m. Suppliers come to warehouse to unload the goods of the day, which are checked and compared to the ordered, by the reception team. In **Appendix H**, it is shown the workflow diagram of the suppliers into the JIT warehouse. After reception, goods are put in the system, to await for further handling.

This warehouse has a specific layout divided by spaces for each store, there the pallets are performed on the ground by the picking operators according to previous instructions and when finished wrapped in plastic film. After this, the pallets begin to be displaced (by the shipping team) to the pre-load zone or immediately to gates.

If by any reason (delay of the dispatch, overflow of goods, end of the working day,…) some of the pallets of the JIT warehouse are not shipped, they are added to the Stock warehouse load and sent to the respective stores. In **Appendix I** is shown the process map of shipping in JIT warehouse.

3.4.2 Stock Warehouses

Stock warehouses (in Guardeiras and Freixieiro) have the task of storing goods, mainly their own brands (Pingo Doce and Amanhecer), on shelves sorted by date. They work 24 hours from Monday to Sunday until 1 p.m, divided into three shifts. The Warehouse in Freixieiro just stores a few items because of its small size; it is a backup for Guardeiras warehouse. The Stock warehouse in Guardeiras, receives pallets from JIT and Freixieiro warehouses in the afternoon and add them to their load as previously referred. In **Appendix J** is shown the Stock warehouse's operations before shipping.

3.4.3 Stores description

At this moment, the shipping is made to 168 stores (Pingo Doce and Recheio). During this study we will present data from just 162 stores, because the others stores are too recent and no historical data were available. There are three types of delivery in stores:

- Those that are supplied during the day, normally 84 stores (JMR called wave 1 to identify which stores are dispatched first) and sometimes 17 stores (when there are free gates and the pallets are already executed, stores can be stocked ahead of schedule, called anticipation);

- Those that can be supplied over night (normally 109 stores, if the 17 stores are supplied in advance no longer count);

- The key stores (drivers have access to the key and leave the goods in the store without no one to receive them).

Each store has a predefined time-window (half-hour for each) for delivery, so employees can organize themselves to receive and store the goods in the store. For example, Pingo Doce Grijó's time window is 20:30/20:59. In **Appendix K**, there is represented the time-windows of the different stores. The setting of the time-window is related to the characteristics of stores: the reception docks, the number of employees, if it has an antechamber (that works like a second store warehouse) or if the store is in a residential area. But not always this time-windows is accomplished, often there are delays in deliveries. In this cases, the goods can be out of stock in stores and overflow the warehouses blocking new deliveries and delaying shipping processes.

We must refer that not every store can receive all types of trucks, there are a few of them that have some constraints, on **Appendix L** we can verify each type of truck can be receive by the stores.

3.4.4 Transport Team

The warehouses receive the demand of each store and for that this delivery is always planned 24 hours in advance. Therefore, each warehouse sends to the transport team a daily forecast of the number of pallets per store for the next day, JMR transport team coordinate truck fleet and plans the route (to stores) of the trucks a day in advance, having to make slight adjustments during the day in the operation. The transport team plans depending on the inherent constraints (type of trucks, time-windows of stores; existing fleet) and according to the registration number of each truck, which route will be taken the next day.

JMR works with two carriers ZAS and TJA, in **table 2**, is described capacity of different types of trucks.

	Carriers		
Type of truck fleet	**ZAS**	**TJA**	**Total**
Trailers (33 pallets)	23	9	**32**
24 pallets	18	-	**18**
22 pallets	33	18	**51**
12 pallets	11	-	**11**
Total	**85**	**27**	**112**

Table 2 – Capacity of the fleet of trucks.

ZAS has a fleet of 85 trucks and 188 drivers 24 hours available and is an exclusive company of JMR. TJA has 27 trucks and 60 drivers available 24 hours (not exclusive JM). Each driver works for 9 hours and in average makes 2 routes (from warehouse to stores and back to warehouse, twice a day). The truck fleet is in warehouses and operates 24 hours, travels to the set routes to taking the goods to stores intended. At the end of this journey trucks return to the warehouses. If the driver has finished his shift (9 hours) is replaced by his colleague, if not he will make the remaining hours.

Each truck has installed a routing system control that provides an alarm (advice) if the driver arrives late to the store or if the truck diverge from the planned route (using the motorway instead of national roads; change the order of stores, etc.). It also has sensors that locate the truck if it is in the store or warehouse. Each load takes 30-45 minutes on average and if the truck is a trailer (33 pallets) takes up to 1 hour. In case of unloading the trucks, both in the warehouse and in store, takes 30 minutes and if is a trailer up to 45 minutes.

Normally, routes are planned to supply the biggest stores (Recheio), to furthest stores (IP4 and IP5) and then to the nearest stores. The transport team also decides how to make store transfers to other stores for excess stock, or to the warehouse stock and, when drivers have to collect in stores rollcontainers, pallets, risk boxes and return to the warehouse.

The daily counting of kilometers is made in the next day for adjust if any route was changed. The distribution per store is assigned to a number registration, so if there are changes have to be made in the warehouse (in loco), not by the system.

The profitability of transport happens when the percentage of occupancy of the truck is 100%, but the actual average is far away from that, as represented in **Appendix M**.

Transport team is starting to use the tool Transport Management System (TMS), but is still in testing mode, when TMS implementation is completed it will be an important tool for planning routes using real quantities. The TMS with the introduced variants (warehouse-store and store-store distances; consider the load time in the warehouse, the unload time in the store and the time to return to the warehouse) will help to define the set of routes should each truck go to each store.

3.5 TO BE situation - New Warehouse

In order to unify its warehouses of non-perishable goods, the company is building from scratch one new warehouse which will join all types of non perishable goods (JIT and Stock). It is easily concluded that the advantages are huge because of the fact that, the warehouses being currently far away from each others, implies greater costs and loss of time. It will also allow greater flexibility in the operation (fewer people, fewer processes, less charges), creates synergies in teams and also with resources.

The new warehouse with 70 000 m^2, will integrate the three existing warehouses of non-perishable goods. It will have 24 gates dedicated to the JIT layout and 73 gates for the Stock layout. The increased space will decrease the transhipment and improve the capability of organization, storage and pick up of the goods in the layout, therefore saving time. The gates will be at both sides, in one side to receive the goods, and the other side to send the goods to the stores. Non-perishables will be divided into food and non-food goods in each layout. These new settings will save time in the executing of pallets and consequently on their shipping. It would be important too, manage the entropy with drivers inside the warehouse, like avoid passing the discharge lines and be kept to their destinated gates.

With the aim of providing a even more efficient response to shipping non-perishable, this model will help improve the overall efficiency of all these processes. **Figure 3**, represents the new warehouse, the different layout of it and its organizations.

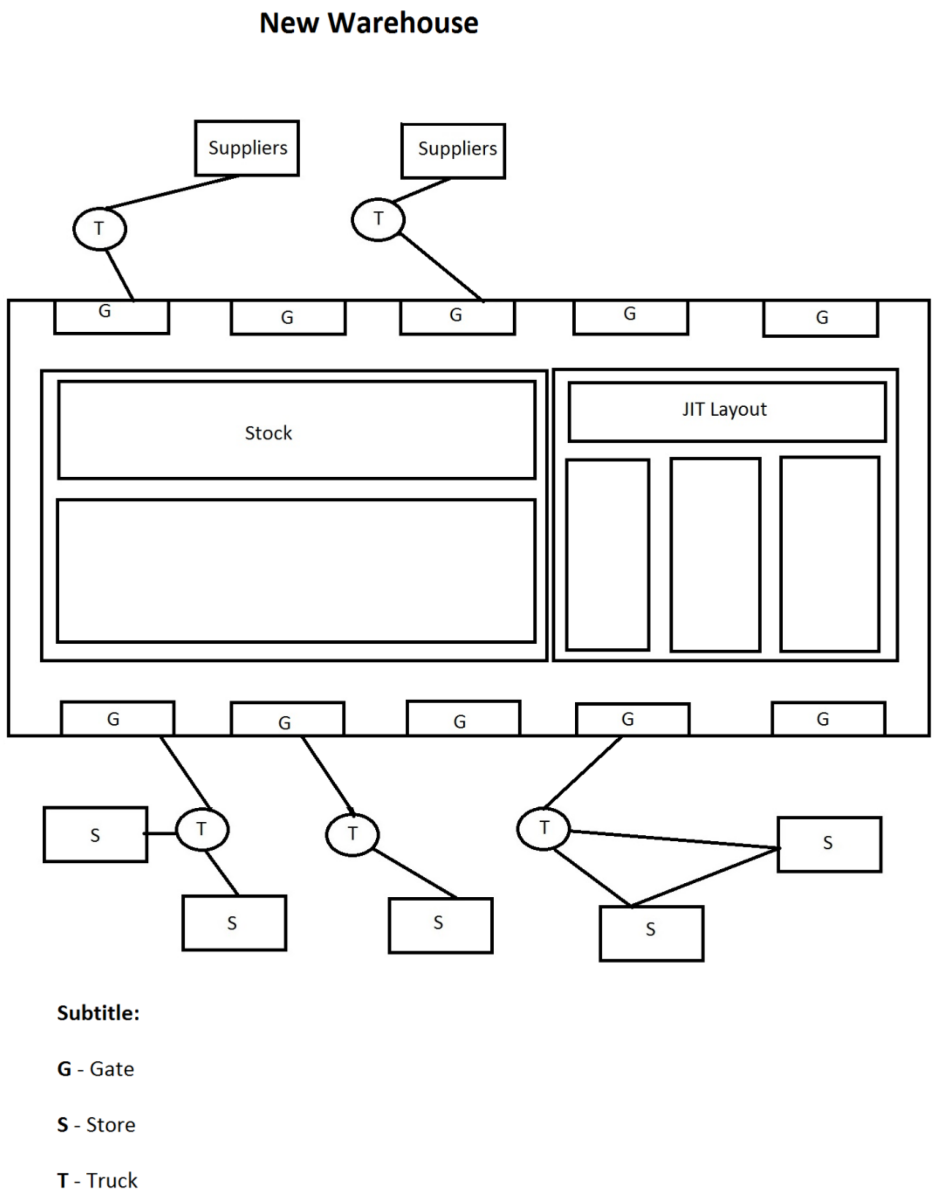


Figure 3 – New Warehouse Shipping Process.

A new warehouse will bring new challenges and requires synergy between all stakeholders, as shown in **Appendix N**.

4 Model Development

4.1 Quantitative Methodology

4.1.1 Comparative analysis of existing approaches

Management Science, operations research and decision science are connected to quantitative analysis. We should understand and define the problem, decide the set of alternative solutions, determine the criteria that should be used to evaluate the alternatives. After evaluating them we choose the best alternative and implement it.

Quantitative approach is associated to data analysis of the problem and developing mathematical model to describe the objective function, constraints and the connections between all variables. So, for complex problems that involve high financial investment, this type of implementation can help to save costs and time to the company. It was important to understand the problem and then adequately structured mathematically to find solutions.

For model development we could use representations of real situations or object: iconic models (a real model of the objects), analog models (similar but do not have the same physical appearance as the object being modelled) and the last one, the use of symbols and mathematical relationships or expression to represent the problem.

The use of models helps to understand the situation and if it helps to avoid bad decisions or losing money. The third model was considered the most apropriated in this particularly problem, so it was used to define an objective function to minimize the costs and define a set of constraints. For decision making the critical aspect it is formulate and expressed correctly the objective function, constraints and their relationships.

Aiming to transform information into knowledge contributing to fulfill simple or complex tasks, using DSS helps a greater organization of data and its treatment which allows the decision maker to have a more coherent decision. Nowadays the rising costs of fuel is harmful to businesses that depend on transport. The use of DSS allows the company to choose the best route taking into account a set of criteria and restrictions. Thus, it will be expected that decision makers are able to do a better fleet management and give a better informed response to this multidimensional problem. This system does not totally eliminate the role of the manager as there are elements of the problem not possible to be model (daily unpredictability), however the use of this type of system that favours decision-making is faster and supported by data.

The method used in the project is a quantitative approach called Vehicle Routing Problem after the formulation and description of the problem remains choosing the models and algorithms suitable for solving this problem.

In this work, the constructive heuristic, is intended to know which route should be chosen to minimize the cost of transportation and ensure delivery. So, three heuristic approaches called Pseudo-code of Priority-based, Ruin and Recreate Heuristics and Large Neighbourhood Search algorithm are used.

4.1.2 Method used in the project

The method is an oriented plan of work which aims to certain objectives and that leads to the research process. The quantitative method involves collecting and analysing numerical data in order to explain, predict and control phenomena. It is linked to experimental research and tries to find the relationship between variables, making descriptions and test theories. In this case, the method is based on the literature review.

The classical transportation model is characterized by a set of trucks each with known capacities; a set of demand locations each with known requirements and the unit costs of transportation between warehouse to stores. This difficult combinatorial problem conceptually lies at the intersection of these two well-studied problems: The Multiple Travelling Salesmen Problem (MTSP) and The Bin Packing Problem (BPP). MTSP: that ensure k vehicles, with minimum cost routes, visit at least one store and each store is visited exactly once. BPP: The question of whether there exists a feasible solution for a given instance of the VRP is an instance of the BPP, in which all edge costs are taken to be zero (so that all feasible solutions have the same cost). Hence, we can think of the first transformation as relaxing the underlying packing (BPP) structure and the second transformation as relaxing the underlying routing (TSP) structure.

In this research is used VRP that concerns to the shipping process of non-perishables goods, using a single depot, a set of routes performed by a fleet of trucks. The routes start and end in the depot after being in stores to satisfy their demands. A constructive heuristic approach could start by allocating the maximum amount possible of orders in the trucks by the highest value of profit and the process continuous until there is no more capacity in all trucks or using metaheuristics (tabu search or genetic algorithms) we could reach a quality.

Real life problem presents a high degree of complexity, special concerning multi-dimensional variants (vehicle capacity, time-windows, …) so we must use approaches to find feasible solutions. Is important to find robust and efficient tools in order to determine a valid solution.

4.2 Problem Formulation

In this study there is a problem of shipping non-perishable goods (*p*) from the warehouse (V_0) to stores. The new warehouse will be divided in two types of layout: JIT and Stock.

A graph is a type of diagram constructed to make possible the visualizations of the relationships (arcs) between the entities involved (nodes). The stores are distant from each other and from the warehouse, a direct graph G = (V, A), where V = {0,1,..,n} is the set of n+1 nodes that represents stores and A the set of arcs. Node 0 corresponds to warehouse and the others nodes set V´=V\{0} represents *n* stores. Each store $i \in V'$ requires a supply of q_i volumes from warehouse. There is a heterogeneous truck fleet (*K*), with M = {1, 2, 3 e 4} with certain capacity (K_T - it could have 12, 22, 24 and 30 pallets) to take the goods to stores.

We must supply all the stores with minimum costs, so is important to save kilometers and put maximum charge into the trucks. Each vehicle type has associated a fixed cost, equal to f_k. So each arc $(i, j) \in A$ and each vehicle type $k \in M$ has a positive routing cost c^k_{ij}. A route is represented by (R, k), where R = (i_1, … i_R), a simple circuit in *G* containing the warehouse and each *k* used with the route. *R* will refer both to the visiting sequence and to the set of stores of the route. A route (*R*, *k*) is feasible if the total demand of the stores visited by the route does not exceed the vehicle capacity. The cost of a route corresponds to the sum of the costs of the arcs forming the route, plus the fixed cost of the truck associated.

In a VRP problem there are feasible solutions that guarantee minimum total cost, each costumer is visited by exactly one route and the number of routes performed by truck $k \in M$ is not greater than m_k.

Currently, planning is based on the distances to the stores (geographic location), type of truck that could go to that store, time-window of the stores and the volumes that are accurate transport. The initial priority is given to the biggest stores (Recheios) and also to stores that have greater distances to make and there are formed clusters (if the truck's capacity is enough to supply more than one store). Stores have a time-window so unload the pallets have to be made at these times.

We could organize the data set in input data: number of stores; order request from stores; truck capacity; distance between warehouse and stores; delivery transportation cost; truck fixed costs; delivery time for each store; number of trucks and output data: prediction and analysis result of estimated costs and store satisfaction and arrangement of product delivery for each truck.

4.2.1 Sets

$V - Set\ of\ store\ nodes$

$K - Set\ of\ all\ trucks$

$K_T - Set\ of\ general-type\ of\ truck$

$P - Set\ of\ non-perishable\ goods$

$SS_{ij}^{K} - store\ satisfaction\ between\ node\ i\ and\ node\ j$

4.2.2 Parameters

$s_i^k - \mathrm{Re}quired\ Service\ Time\ of\ store\ i\ at\ truck\ k$

$p_i -\ Volume\ of\ pallets\ ordered\ by\ store\ at\ node\ i$

$t^K - \mathrm{Pr}eparation\ time\ of\ truck\ K\ in\ warehouse$

$v_i - service\ \cos ts$

$c_{ij}^k - routing\ \cos t$

$f_k - fixed\ \cos ts\ of\ each\ truck$

$m_k - capacity\ of\ each\ truck$

$t_{\max}^k -\ Maximum\ delivery\ time\ of\ truck\ K\ at\ each\ operation$

4.2.3 Decision Variables:

If there are *n* related quantifiable decision to be made, they are represented as decision variables whose respective values are to be determined.

$y_i^K -$ *Binary decision variable indicating that store at node i is served by truck K*

$x_{ij} -$ *Binary decision variable indicating wether the customer at node j is visited directly after customer of node i is served*

$x_{i0j} -$ *Binary decision variable indicating that truck that o return to the warehouse* (0) *from store before going to store j*

$\alpha_{ki} -$ *number of pallets each truck transport to each store*

$y_j^k -$ *decision variable* $\{0,1\}$

4.2.4 Mathematical Model

As Hillier (1990) says, mathematical models have many advantages over a verbal description of the problem. One obvious advantage is that a mathematical model describes a problem much more concisely.

At the beginning we thought it was important to analyze what would be the impact of the store to receive or not receive the required goods, and as such, our objective function would be to maximize the satisfaction of the store. The satisfaction of the store is measured by ensuring that the goods are daily shipped to every store. If not, the store is penalized by the lack of goods.

This model should maximize the store satisfaction, with the objective function:

Maximize:

$$Z_{JIT+Stock} = \sum_k \sum_i SS_i^k y_i^k$$

Such that:

(1) $p_i \geq \sum_{k=1}^{118} \alpha_{ki} \quad y_i^k , \quad i = 1,...,162$

these sum represent the possibility to have more than one truck to serve store *i* over the total time of loading the stores.

(2) $\sum_{i \in V^+} x_{i0j} \leq 1, \;\; j \in V$

(3) $\sum_{i \in V^+} x_{j0i} \leq 1, \;\; j \in V$

(4) $\sum_{i \in V} x_{0i} = \sum_{i \in V} x_{i0}$,

guarantees that number of direct connection between warehouse and all stores and reciprocally are equal.

(5) $x_{i0} + x_{0j} \geq 2.x_{i0j}$

(6) $\sum_{k=1}^{k} y_i^k \leq 1, \;\; i \in V$

(7) $\sum_{k=1}^{k} y_i^k y_j^k \geq x_{ij}, \;\; i, j \in V$

(8) $\sum_{i \in V} x_{0i} y_i^k = \sum_{i \in V} x_{i0} y_i^k, \;\; \forall k$,

Number of times that each truck leaves warehouse equals number of times it returns.

(9) $\underset{i \in V}{Max}\left[t_i^k + s_i + t_{i0} x_{i0}\right] \leq t_{\max}^k, \;\; j \in V, \forall k$, the store that has the maximum sum of start time of the service, service time and travelling time between store and warehouse is always smaller that a given time for delivery. Notice that start time of delivery, t_i^k , already includes the time to travel to node *i*, independent of the path it took to reach *i*.

(10) $t_i^k + s_i + t_{ij} - M(1 - x_{ij}) \leq t_j^k, \;\; i, j \in V, \forall k$

for each truck, in case we don't go through the path that links *i* and *j* directly, but still go to both *i* and *j* stores, we want to subtract some time M to the sum of the service time, the travelling time between *i* and *j* and the start service time in store *i*, but only if we go through the direct link between *i* and *j*. Otherwise, we do not subtract any time. In the end we have to guarantee that this time is still smaller than the overall time in takes to reach store *j*.

(11) $t_i^k \leq M.y_i^k, \;\; i \in V_k, \forall k$

Time until truck *k* reaches store *i* has to be less or equal than some time *M* if truck *k* actually goes to store *i* (hence the multiplication by y_i^k)

(12) $$ss_i^k \geq SS_{p,\min} . y_i^k, \quad i \in V, k \in K, p \in P$$

Store satisfaction for each delivery (each truck) in each store has to be bigger or equal to a minimum predetermined stores satisfaction, given that truck *k* actually goes to store *i*.

(13) $$c_i^k \geq 0, \quad i \in V_k, \forall k$$

(14) $$t_i^k \geq 0, \quad i \in V^+, \forall k$$

(15) $$y_i^k \in \{0,1\}, \quad i \in V^+, \forall k$$

(16) $$x_{ij} \in \{0,1\}, \quad i, j \in V^+$$

(17) $$x_{i0j} \in \{0,1\}, \quad i, j \in V$$

(13), **(14)**, **(15)**, **(16)** e **(17)** defines only the set that variables belong. The capacities and times are positive numbers and the rest are binary decision variables.

(18) $$SS_i^k = \underset{j \in V}{Max} \; f_p\left(t_i^k - \left(t_j^k - t_{0j}\right) x_{0j} . y_j^k + s_i\right) - 0_p^k . n0_i, i \in V, k \in K, p \in P$$

Store satisfaction value definition: it is the maximum of the function f_p (for some specific product *p*) minus the product of the unit satisfaction reduction 0_p^k times $n0_i$.

Function f_p is a function of time it takes the truck *k* coming to the store *i* more service time in that store, less the difference between the times to get to the store *j* and the time between the warehouse and the store *j* $\left(t_j^k - t_{0j}\right)$. And then multiply by the decision variables that tell it was really done the way between the warehouse and the store *j* and *k* the truck actually went to the store *j*.

The maximum store *j* that makes $f_p(A - B + C)$ has the highest possible value. Of course f_p is a decreasing function because the satisfaction depends on the time, it is natural as time increases, satisfaction decreases.

As maximizing store satisfaction is not enough to answer the research question "Should the company use one or two fleet carriers?" we proceeded to the mathematical formulation to minimize costs.

Minimize:

$$Z_{JIT+Stock} = \sum_{i,j \in V, k \in K} x_{ij}^{k}.(c_{ij} + v_j) + \sum_{k \in K} \left(f_k \sum_{i \in V'} x_{0i}^{k} \right)$$

The objective function represents the total cost of the routes to be minimize, including the routing and service cost and the fixed vehicle cost.

Such that:

(1) $\sum_{i \in V} x_{0i}^{k} = \sum_{i \in V} x_{i0}^{k} \leq 1, \quad \forall K \in K_T$

Ensure that a route start and end at warehouse.

(2) $\sum_{i,j \in V, k \in K} x_{ij}^{k}. \leq 1, \quad \forall K \in K_T$

Ensure each store can be visited at least one time.

(3) $q_j x_{ij}^{k} \leq y_{ij} \leq (Q_k - q_i) x_{ij}^{k}$**,** $\forall i, j \in V, i \neq j, \forall k \in M$

Ensure that the vehicle capacity is never exceed.

Like Hillier (1990) explain, the problem formulation, leads to a better comprehension of cause effect relationships and understand the overall structure of the problem.

4.3 Method Approaches

4.3.1 Heuristic approaches

As the model is too complex, it arises to use some approaches and simplifications. After some research and according to Song & Ko (2016), it could be used a Priority-based heuristic (PBH) in order to maximization of the total sum of the store satisfaction, as shown in the **table 3** below.

STEP 1	Let cl_k be the current location of vehicle h and ct_k be the current time of vehicle k. Initially $cl_k = 0$ and $ct_k = 0$ for $\forall k \in (1,2,...,k)$. Select vehicle dispatching rule and arrange vehicles according to the rule. Set k=1.
STEP 2	Calculate p_i for every $i \in \{V \cap y_i^k = 0 \ \ for\ every\ \ k\}$. IF $k = \lvert K \rvert, k \leftarrow 1$.
STEP 3	Selected seed $i = \max\{p_i \ \}$ and define corresponding p_{ir}
STEP 4	Let TD_{ij} be the route generation function. Calculate route generation factor $TD_{ij} = a \times D_{ij} + q_j$ where $0 \le \alpha \le 1$.
STEP 5	Let t be the index of store node in p_{ir} .
STEP 6	$t = \min\{jTD_{clkj}\}$
STEP 7	$cl_k \leftarrow t, ct_k \leftarrow t_{clk,t} + s_t$ and $y_t^k = 1$. $TD_{it} = INT\_MAX$ for every $i \in V$.
STEP 8	**IF** any constraint (9), (13) is not violated, GO TO STEP 6. **ELSE IF** one of (13) violated, $k \leftarrow k+1$. GO TO STEP 2. **ELSE IF** a vehicle violates constraint (9), delete vehicle index k in K and GO TO STEP2. **ELSE IF** $\sum_{i \in V, k \in K} y_{ik} = \lvert v \rvert$ or $ct_k > t_{\max} t$ for $\forall k \in \{1,2,...,k\}$, GO TO STEP 9.
STEP 9	Calculate the total store satisfaction $\sum_{k=K} \sum_{i \in V} SS_i^k y_i^k$
STEP 10	Finish PBH.

Table 3 – Pseudo-code of Priority-based Heuristic (PBH).

TD_{ij} *– Route generation factor; certain vehicle which is located at node i, is dispatched at node j which has lowest value of* TD_{ij} *where* $j \in J$ *and* $TD_{ij} = \alpha_{Ki} \times D_{ij} + q_j$

D_{ij} *– Euclidean distance between node i and node j*

In this Song & Ko (2016) heuristic algorithm, *priority is calculated for every uncovered customer node*, p_i is the priority value of the customer node and R be the Euclidean distance.

For each iteration during PBH, the best priority node is selected as a seed, in this way, trucks visit a single route as many stores as possible, satisfying the capacity limit.

Follow the Wang et al. (2015), it is presented a Ruin and Recreate heuristic approach, based on the procedure of the modified Clark and Wright algorithm, *and its basic idea is to generate a set of new solutions by destroying parts of the current solution, follow by recreating procedure trying to arrange the removed nodes into one route*. This approach could be explained by a ruin strategy, a recreation procedure and a solution acceptance criterion, as shown in **table 4**.

STEP 1	Generate an initial solution *Init* by using the modified Clark-Wright algorithm and add the solution to *IncumbentSet.*
STEP 2	Set n=1, $Pool = \phi,\ S_{best} = Init,\ i = 1,\ TabuList = \phi,\ i_{non-improve} = 0$
STEP 3	While $i < RRMaxTimes$ or $i_{non-improve} < RRMaxNon\text{Im}\,proveTimes$, do steps 4 to 9.
STEP 4	For each solution *Sol* in *Incumbent-set*, do steps 5 to 13.
STEP 5	Set $SolPool = \phi$.
STEP 6	For each pair of routes r_1 and r_2 in *Sol* whose goods can be loaded to onevehicle, do steps 7 to 11.
STEP 7	**Ruin**: remove all the nodes from routes r_1 and r_2;
STEP 8	**Recreate**: reroute the removed nodes by a **recreation procedure** and a new solution can be generated.
STEP 9	According to **the acceptance criterion**, if new solution can be accepted, add solution to *SolPool* or replace the worst solution in *Solpool* with it.
STEP 10	If there are *n* solutions in *SolPool* that are better than *Sol*, go to step 12.
STEP 11	Endfor.
STEP 12	Add all the obtained solutions in *SolPool* to *Pool*.
STEP 13	Endfor.
STEP 14	Sort solutions in *Pool* according to the acceptance criterion, retain the first *n* solutions, and remove the others in *Pool*.

STEP 15	**<u>Update *n*</u>** according to the following rule: if $i_{non-improve} > RRNonImproveTimes$ and the best solution in *Pool* is better than S_{best}, set $n = MaxSolutionNum$ otherwise set $n = \max\{1, n-1\}$ if $i_{non-improve}$ mod $RRModifyNum$ is 0.
STEP 16	**<u>Update $i_{non-improve}$</u>** according to the following rule: if the best solution in *Pool* is better than S_{best}, set $i_{non-improve} = 0$ and replace S_{best} with the best solution in *Pool*, otherwise set $i_{non-improve} = i_{non-improve} + 1$.
STEP 17	**<u>Update *IncumbentSet* and *TabuList*</u>** which will be used in the RR approach, according to the following rule: if $i_{non-improve}$ mod $RestartBestIterator = 0$ set $IncumbentSet = \{S_{best}\}$ otherwise set $IncumbentSet = Pool$ and add all the solutions in *Pool* to *TabuList*.
STEP 18	Set $i = i + 1$.
STEP 19	Endwhile.
STEP 20	Return S_{best}.

Table 4 – Ruin and Recreation heuristic approach.

Wang et al. (2015), after the route ruin step start with the route recreation operator that will be applied to many nodes as possible, taking account the restrictions of time-windows and vehicle capacities. After this process, in order to understand if the solution is feasible we most *guarantee that the difference of the total costs between the new solution and any solutions in Pool should be more than a value Diversity/Threshold and the size of Pool should be smaller than the pre-defined solution number n, or otherwise the new solution should be better than the worst solution in Pool, which will be followed by a different operation of replacing the worst solution with the new solution*.

Others approach have been proposed such as Large Neighbourhood Search (LNS), Iterated Local Search (ILS) and Genetic Algorithms (GA), Dr. Güneş Erdoğan (2015) presented a variant of the LNS algorithm, as shown in the **table 5** below.

Solution Algorithm	
Step 1 (Initialization)	Initialize the incumbent solution, the best known solution, and the iteration counter *k*=1. Read the solution on the solution worksheet into the incumbent solution if a "warm start" is required. Set α_1=LNS minimum removal rate, α_2= LNS maximum removal rate, and β=LNS candidate list size.
Step 2 (Stopping condition)	If the time limit is exceeded, stop and report the best known solution.
Step 3 (Break)	Randomly select and remove $\alpha 1 + U[0, 1] * (\alpha 2-\alpha 1)$ percent of the locations from the incumbent solution.
Step 4 (Repair)	Randomly choose and insert a location among the best β candidate locations for insertion, until no more vertices can be inserted.
Step 5 (Polishing)	Select and apply the best among the operators of vertex relocation, vertex swap, 2-opt, and vehicle swap, until no further improvement is possible.
Step 6 (Best solution update)	If the incumbent solution is feasible and better than the best known solution, update the best known solution. Increment *k* and go to Step 2.

Table 5 – A LNS algorithm approach.

Another way for testing is using Solomon instances [1], but because we have real data set is possible to test using the data in a VRP Solver, as described in the following section.

4.4 Using VRP Excel Solver

[1] http://neo.lcc.uma.es/vrp/vrp-instances/description-for-files-of-solomons-instances/

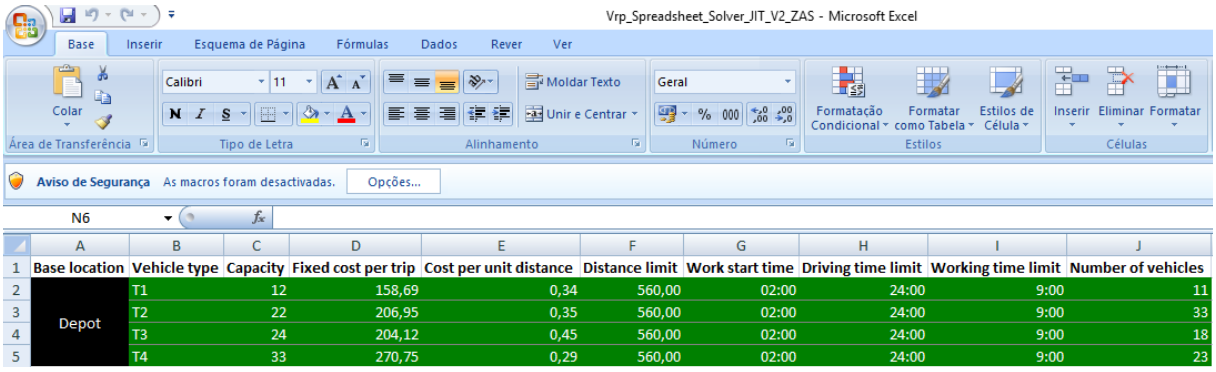
Given the need to present real results and that can be used as decision parameters for the company, we used a VRP Spreadsheet Solver (free software) to support this study. This software was developed by Dr Güneş Erdoğan (2015) from School of Management, University of Bath. This VRP Spreadsheet Solver use Visual Basic for Applications (VBA), a programming language that is embedded within Excel, as tool for representing, solving, and visualizing the results of VRPs. In this Spreadsheet we register locations data, latitude/longitude; distance between warehouse and stores and between stores, the time-window of stores and the volumes of JIT and Stock to be delivered (delivery amount), as shown in the **figure 4** below. The data are from a regular week of 15 to 21 of February 2016. We made some combinations to check for the best feasible solution, so in some cases we will put stores' time-windows.

Location ID	Name	Address	Latitude (y)	Longitude (x	Time window start	Time window end	Must be visited?	Service time	Pickup amount	Delivery amount	Profit
0	Depot	Rua Noss	41,2372000	-8,4967610	00:00	23:59	Starting location	0:00	0	0	0
1	Customer 1	Gav. Av.	41,1811300	-8,6826090	00:00	23:59	Must be visited	0:20	0	14,50	0
2	Customer 2	Rua do A	41,1786000	-8,6140000	00:00	23:59	Must be visited	0:20	0	16,07	0
3	Customer 3	R. Filipe	41,5313000	-8,6236000	00:00	23:59	Must be visited	0:20	0	12,36	0
4	Customer 4	R. 5 de O	41,2248000	-8,6126590	00:00	23:59	Must be visited	0:20	0	12,71	0
5	Customer 5	Avenida	40,9886000	-8,5391000	00:00	23:59	Must be visited	0:20	0	7,86	0
6	Customer 6	Campo 2	41,1499100	-8,5983830	00:00	23:59	Must be visited	0:20	0	17,50	0
7	Customer 7	R. Hernâ	41,1684100	-8,5988970	00:00	23:59	Must be visited	0:20	0	10,00	0
8	Customer 8	Av. Liber	41,5473600	-8,4220910	00:00	23:59	Must be visited	0:20	0	9,29	0
9	Customer 9	Avenida	41,1161900	-8,6475410	00:00	23:59	Must be visited	0:20	0	9,50	0
10	Customer 10	Prª. Repu	41,1537000	-8,6134000	00:00	23:59	Must be visited	0:20	0	14,71	0
11	Customer 11	R. D. San	41,4037700	-8,5207320	00:00	23:59	Must be visited	0:20	0	14,57	0
12	Customer 12	R. Serpa	41,1667400	-8,6202590	00:00	23:59	Must be visited	0:20	0	4,86	0
13	Customer 13	Pcª. Marc	41,3819000	-8,7621000	00:00	23:59	Must be visited	0:20	0	14,00	0
14	Customer 14	Largo Luí	40,8394300	-8,4799630	00:00	23:59	Must be visited	0:20	0	14,36	0
15	Customer 15	R. Sá Ban	41,1493900	-8,6074460	00:00	23:59	Must be visited	0:20	0	8,14	0
16	Customer 16	Avenida	40,3996300	-8,1333230	00:00	23:59	Must be visited	0:20	0	10,79	0
17	Customer 17	R. Coope	41,1817800	-8,6301500	00:00	23:59	Must be visited	0:20	0	14,50	0
18	Customer 18	Avenida	40,9285600	-8,2483150	00:00	23:59	Must be visited	0:20	0	9,57	0
19	Customer 19	Avenida	40,5505300	-7,2474930	00:00	23:59	Must be visited	0:20	0	15,57	0
20	Customer 20	R. de Ave	41,6963200	-8,8260730	00:00	23:59	Must be visited	0:20	0	10,00	0
21	Customer 21	R. Manue	41,3393200	-8,5607690	00:00	23:59	Must be visited	0:20	0	10,43	0

VRP Solver Console | 1.Locations | 2.Distances | 3.Vehicles | 4.Solution

Figure 4 – Framework of the Spreadsheet for locations.

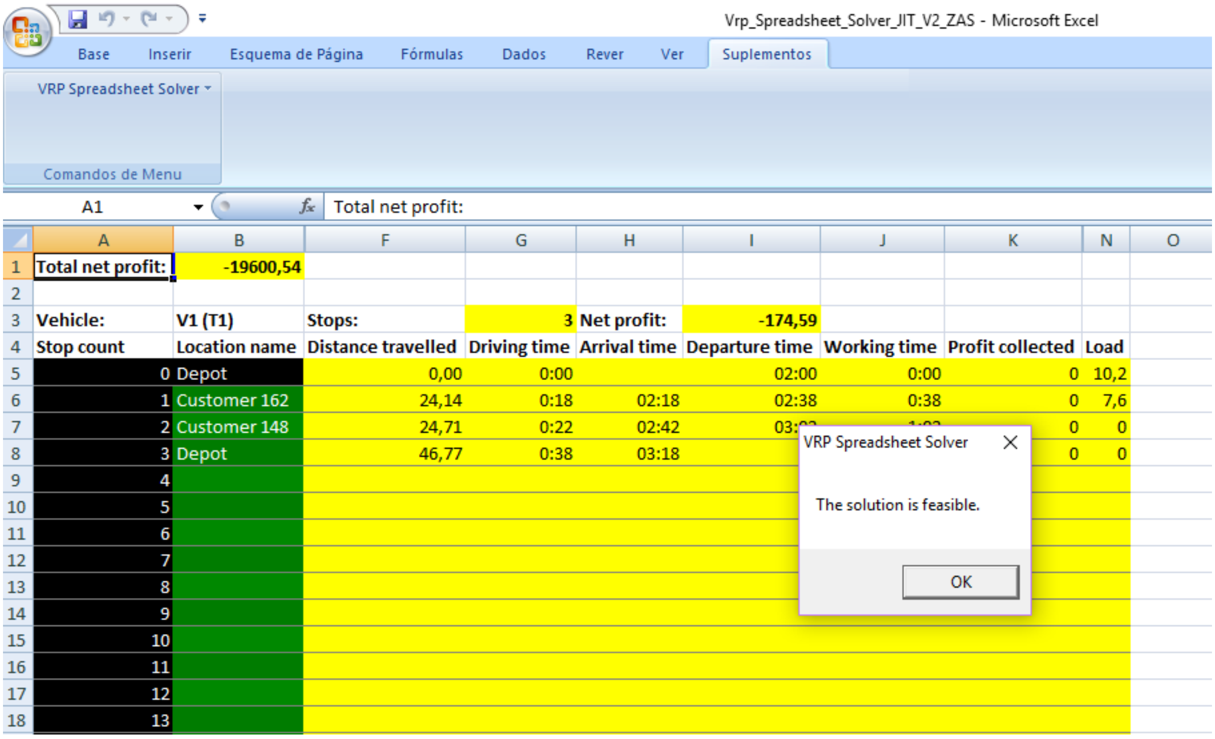
Other data that we must fill is about vehicles: type of vehicles, capacity, fixed costs, distant limit, work start time, driving time limit (24 hours), working time limit (9 hours) and the fleet size, as shown in **figure 5**. We put as average vehicle speed 70 km/h, but it could change a little depending on traffic. The company have two transports carriers, because they have different fixed costs and fleet size, it was study separately their actions. We check possibilities exclusive with ZAS fleet and with both fleets (ZAS and TJA).



Base location	Vehicle type	Capacity	Fixed cost per trip	Cost per unit distance	Distance limit	Work start time	Driving time limit	Working time limit	Number of vehicles
Depot	T1	12	158,69	0,34	560,00	02:00	24:00	9:00	11
	T2	22	206,95	0,35	560,00	02:00	24:00	9:00	33
	T3	24	204,12	0,45	560,00	02:00	24:00	9:00	18
	T4	33	270,75	0,29	560,00	02:00	24:00	9:00	23

Figure 5 – Framework of distances data.

This VRP Spreadsheet Solver is limited to 200 customers, but in our case it is enough (just use 162 customers that represent each store). We define as guarantee that all vehicles return to the warehouse in the end of which route and all store should be visited once. In this problem we didn´t care about the backhauls or pick up deliveries. The software generates solutions for the routes that should be taken and there is a option that we could check if the solution is feasible, as shown in **figure 6**.



Total net profit:	-19600,54							
Vehicle:	V1 (T1)	Stops:	3	Net profit:	-174,59			
Stop count	Location name	Distance travelled	Driving time	Arrival time	Departure time	Working time	Profit collected	Load
0	Depot	0,00	0:00		02:00	0:00	0	10,2
1	Customer 162	24,14	0:18	02:18	02:38	0:38	0	7,6
2	Customer 148	24,71	0:22	02:42	[illegible]	[illegible]	0	0
3	Depot	46,77	0:38	03:18			0	0
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								

Figure 6 – Framework of the total costs of JIT volumes, without time-windows and using just ZAS fleet.

With the VRP Spreadsheet we generated a map with the routes, as shown in **figure 7** that represents the set of routes to supply the stores. Because we have 162 stores instead of a few, is not very helpful but give us a global idea.

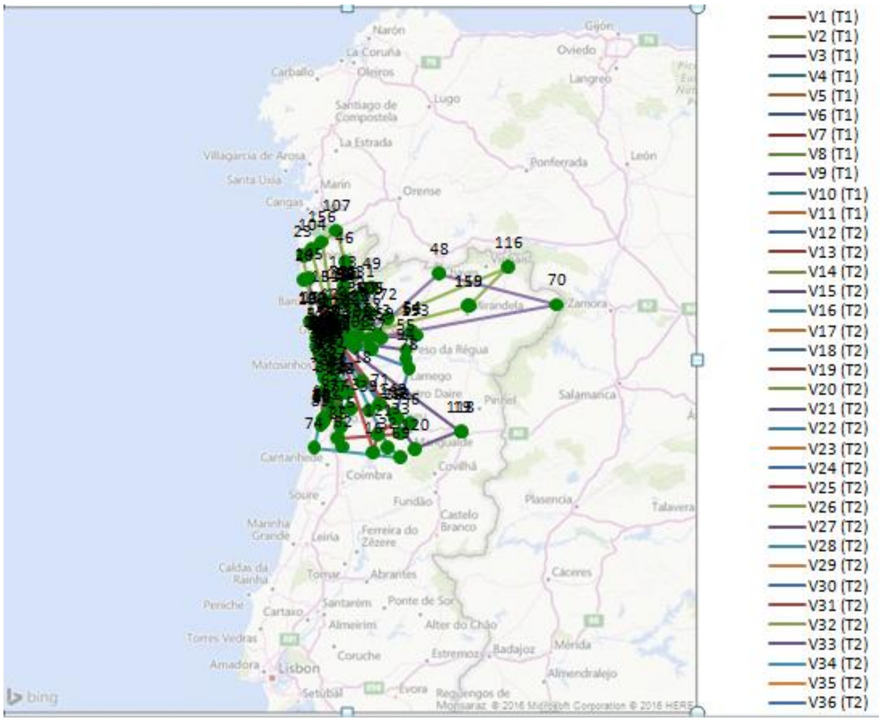


Figure 7 – Geographical descriptions for operation routes of fleet vehicles.

4.5 Results

After proceeding to all the combinations we obtained the results shown in **table 6** and **7**.

ZAS carriers	Stock	Stock +Time Window	JIT	JIT + Time Window	Stock + JIT	Stock + JIT + Time Window
Costs (€)	-17 064,71	-12 514,70	-19 600,54	-19 221,86	-23 743,25	-20 638,02

Table 6 – Results of total cost with transportation using just ZAS fleet.

ZAS + TJA carriers	Stock	Stock +Time Window	JIT	JIT + Time Window	Stock + JIT	Stock + JIT + Time Window
Costs (€)	-16 052,20	-17 064,71	-20 293,17	-20 075,13	-29 458,78	-27 943,40

Table 7 - Results of total cost with transportation ZAS and TJA fleets.

In synthesis, on **table 8**, is represented the results of all combinations made. We try to understand the impact of the time-windows and the possibility that in the new warehouse different types of non-perishable goods (JIT and Stock) be ship together.

Stock without Time-Windows (ZAS)
The parameters used change in respect to: the quantity of volumes (the average of Stock volumes); without time-window and using just ZAS fleet. The solution found was infeasibility, because some vehicles exceeds the working time limit; some initial load of the vehicle exceeds its capacity, so in practice that store will be visited more than once; the visit time of some stores were past its time window.
We obtained a total cost for that routes of: **17 064,71€.**

Stock with Time-Windows (ZAS)
The parameters used change in respect to: the quantity of volumes (the average of Stock volumes); with time-window of each store and using ZAS fleet. The solution found was infeasibility, because exceeds its capacity and working time limit.
We obtained a total cost for that routes of: **12 514,70€.**

JIT without Time-Windows (ZAS)
The parameters used change in respect to: the quantity of volumes (the average of JIT volumes); without time-window and using just ZAS fleet. The solution found was feasible.
We obtained a total cost for that routes of: **19 600,54€.**

JIT with Time-Windows (ZAS)
The parameters used change in respect to: the quantity of volumes (the average of JIT volumes); with time-window and using just ZAS fleet. The solution found was feasible
We obtained a total cost for that routes of: **19 221,86€.**

Stock + JIT without Time-Windows (ZAS)
The parameters used change in respect to: the quantity of volumes (the average of Stock and

JIT volumes); without time-window of each store and using ZAS fleet. The solution found was infeasibility, because exceeds its capacity and working time limit.
We obtained a total cost for that routes of: **23 743,25€.**

Stock + JIT with Time-Windows (ZAS)
The parameters used change in respect to: the quantity of volumes (the average of Stock and JIT volumes); with time-window of each store and using both carriers' fleet. The solution found was infeasibility, because the capacity of the given fleet is not enough to transport the mandatory delivery.
We obtained a total cost for that routes of: **20 638,02€.**

Stock without Time-Windows (ZAS+TJA)
The parameters used change in respect to: the quantity of volumes (the average of Stock volumes); without time-window of each store and using both carriers' fleet. The solution found was feasible.
We obtained a total cost for that routes of: **16 052,20€.**

Stock with Time-Windows (ZAS+TJA)
The parameters used change in respect to: the quantity of volumes (the average of Stock volumes); with time-window of each store and using both carriers' fleet. The solution found was feasible.
We obtained a total cost for that routes of: **17 064,71€.**

JIT without Time-Windows (ZAS+TJA)
The parameters used change in respect to: the quantity of volumes (the average of JIT volumes); without time-window of each store and using both carriers' fleet. The solution found was feasible.
We obtained a total cost for that routes of: **20 293,17€.**

JIT with Time-Windows (ZAS+TJA)
The parameters used change in respect to: the quantity of volumes (the average of JIT

volumes); without time-window of each store and using both carriers' fleet. The solution found was infeasibility, because some vehicles exceeds the working time limit; some initial load of the vehicle exceeds its capacity, so in practice that store will be visited more than once; the visit time of some stores were past its time window.
We obtained a total cost for that routes of: **20 075,13€.**
Stock + JIT without Time-Windows (ZAS+TJA)
The parameters used change in respect to: the quantity of volumes (the average of Stock and JIT volumes); without time-window of each store and using both carriers' fleet. The solution found was infeasibility, because exceeds its capacity.
We obtained a total cost for that routes of: **29 458,78€.**
Stock + JIT with Time-Windows (ZAS+TJA)
The parameters used change in respect to: the quantity of volumes (the average of Stock and JIT volumes); using time-window of each store and using both carriers' fleet. The solution found was infeasibility, because some vehicles exceeds the working time limit; some initial load of the vehicle exceeds its capacity, so in practice that store will be visited more than once; the visit time of some stores were past its time window.
We obtained a total cost for that routes of: **27 943,40€.**

Table 8 – Results of different combinations of variables.

5 Conclusion, limitations and future research

5.1 Conclusion

In the literature review there are many approaches to VRP, that involved heterogeneous fleets, a single deposit, several stores with time-windows, but still have some gaps regarding to the study of all these variables. It is necessary to develop more models to optimize the shipping operation and minimize the costs of transport routes.

This research aims to set the best route, under the conditions of a heterogeneous truck fleet and regarding stores fixed time-windows. To achieve this, a mathematical model were formulated, that try to maximize stores satisfaction and minimize company transportations costs. Some heuristic approaches were presented and a Spreadsheet VRP Solver used to present results with real data set. Different situations were conducted to evaluate the best alternative to minimize trucks' cost. The VRP spreadsheet guarantees that all stores are visited once by the best route possible.

Based on the results of this study, we conclude that shipping both type of non-perishables goods (JIT and Stock) is the best alternative.

We realize that using TJA and ZAS carrier is 1,4 more expensive, on average than just using ZAS carrier, but at other hand it is necessary to have more trucks in order to deliver goods to stores in the correct time-windows. Using time-windows both with only JIT, only Stock or Stock and JIT is always more cheaper to the company than without time-windows. In the results' tables we realize that some are infeasible because of time-windows restriction, so, company should remodel the time-windows of the stores, in that way some small delays would be outdated.

Analyzing the results we understand that is better to have a fleet just for non-perishable goods, so in that case it will not be necessary to wait for trucks that are still delivering perishables goods. We must remember that we are just studying non-perishable goods but they ship perishables and non perishables goods.

We this research we achieved the main objectives proposed for this thesis and with these alternatives company could decrease costs.

5.2 Study Limitations

The fact that the model admitted default values, because doesn't take into consideration small fluctuations that might occur in week's promotions, celebrations, seasonality, it leads to some approached results.

Averages were made in particular to assume that each pallet holds 55 product units which is not always the case, because it depends on the article type.

The current fleet of trucks is not exclusive to non-perishable goods, which means that only after the perishables (fruit, meat, fish, vegetables and frozen) have been dispatched is that the fleet begins with non-perishable goods. So is not always true having all trucks in the warehouse ready for non-perishable goods.

This study, because of that complexity, did not take into account:

- small specifications of the stores, as having or not loading dock;
- what type of truck is possible in the pier;
- local dimensions of unload;
- the backhauling;
- the pickup deliveries;
- transfers;
- returns/complaints;

5.3 Future Research

We can present a number of improvements for future research, as try to get new algorithms to be able to achieve more feasible solutions.

Given the volume of data, it is important to continue to deepen study this problem, like extend the study to backhauling and picking/deliver processes. According to (Bortfeldt & Homberger, 2012), *Packing and transport processes in a company can display a high degree of interdependence. In this case it is important from the viewpoint of the company that both operations are carried out together efficiently and in high quality. For example, there is little advantage in having a well-filled truck loading space if packed goods are for customers who are located far away from each other, so that it is uneconomical, or even impossible, to deliver the goods in a single route.*

One of the suggestions is that when the truck arrives at the warehouse instead of waiting for pre planned volumes it should start the route with the volumes ready at the gate at that time.

It would also be important to perform a sensitivity analysis and check the margin costs, such as a positivist and as a pessimistic perspective.

After the shipping process been analyzed, it is considered major to take a closer picture at Pingo Doce and Recheio stores. It will be important to have a standardization of their layout, not just for customer loyalty but also for helping the processes at the stores and to the transport team.

Another further study is to consider ways of reducing fuel (reducing unnecessary movements); decrease maintenance cost (saving on tires, reduce wear and tear of the machine, etc.) and thus decrease the carbon dioxide emission to the atmosphere. The company should think about studying the replace of fossil fuels (non-renewable energy), for reducing costs, and the possibility of investing in renewable energy. Although they already have trucks using EURO6, that reduce efficiently carbon dioxide emissions, they should have more hybrid trucks to reduce the cost of fuel and take care of the planet by reducing carbon dioxide emissions.

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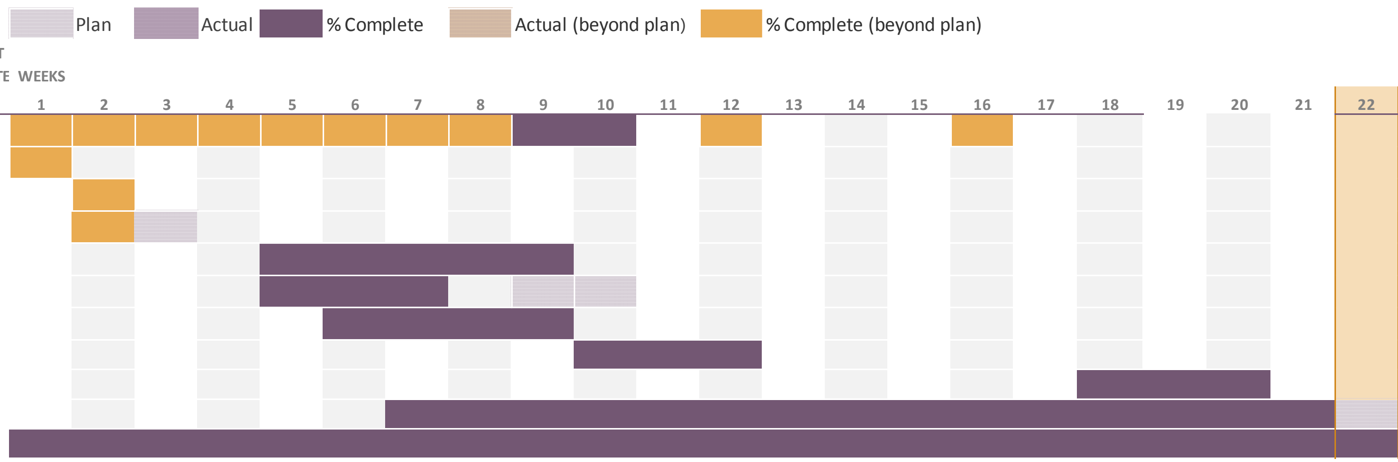
APPENDIX A: Gantt Diagram.

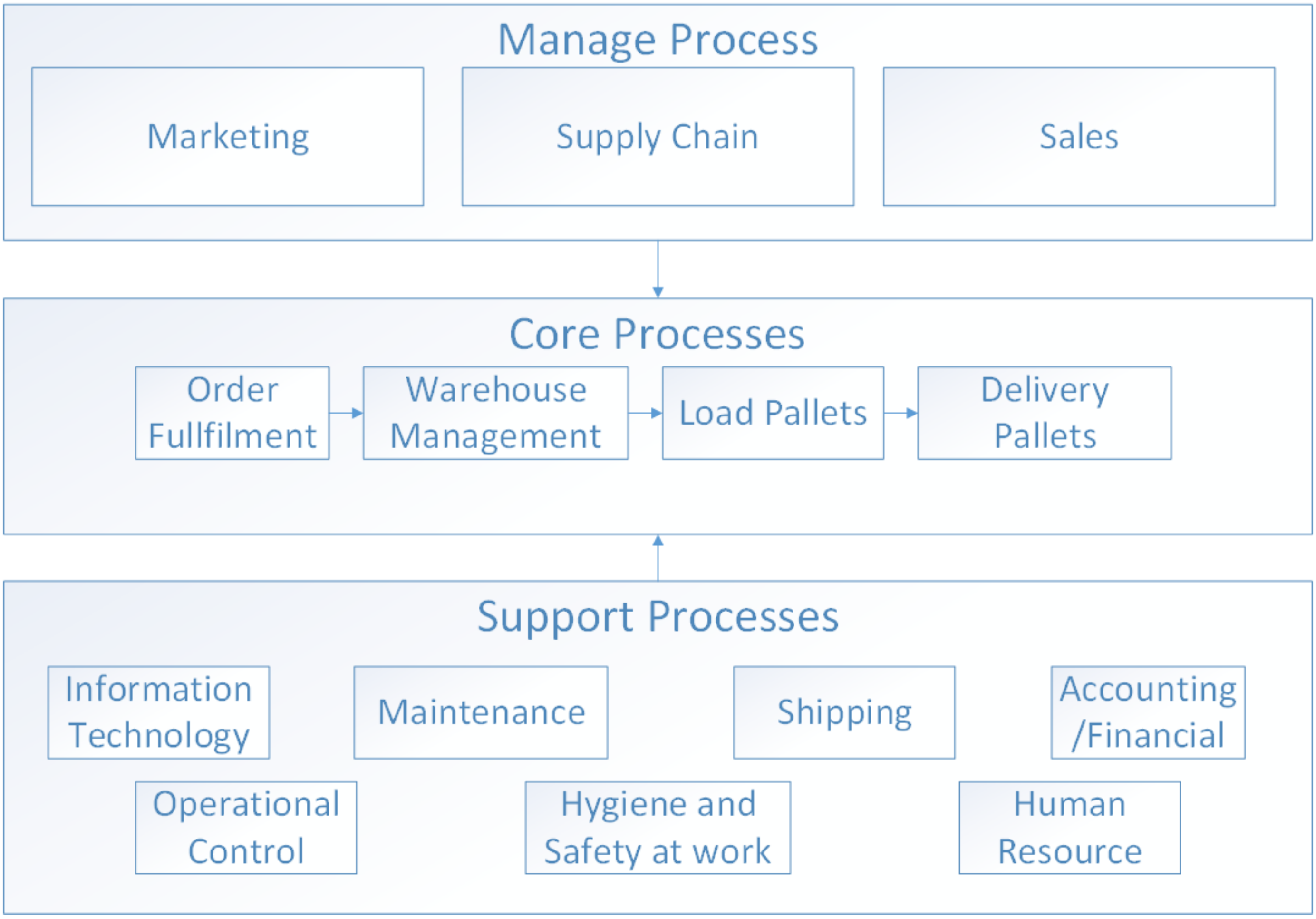
Model of Ship non-perishables goods

Current Week: 22

Activities	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Literature Review and the State of the Art	1	10	1	10	100%
Laúndos visit	1	1	1	1	100%
Guardeiras visit	2	1	2	1	100%
"Transports" visit	3	1	2	1	100%
Methodology definition	5	5	5	5	100%
Identify the requirements	5	3	5	3	100%
Collecting data	6	4	6	4	100%
Define models	10	3	10	3	100%
Evaluation about models	18	3	18	3	100%
Thesis writing	7	22	7	15	100%
Meetings	1	22	1	22	100%



APPENDIX B: Process Map of non-perishable goods.



APPENDIX C: Vehicle´s Cost (for TJA fleet)

Calculate Vehicle´s Costs TJA							
Vehicle Cost / Month							
	Total Vehicle	**Fixed Cost**	**Drivers**	**Scuts**	**Km**	**Cost of Km**	**Total Cost / Vehicle**
19 Ton	18	3 750,00 €	1 900,00 €	222,22 €		0,37 €	5 872,22 €
40 Ton	9	4 250,00 €	2 000,00 €	444,44 €		0,47 €	6 694,44 €
				8 000,00 €			

Put the kilometers here and calculate the sum.

APPENDIX D: Vehicle´s Cost (for ZAS fleet)

Vehicle´s Cost (ZAS)								
Vehicle´s Cost / Month								**Days / Month (26)**
Type of Vehicle	**Quantity of vehicle**	**€ not fixed**	**Km /Month**	**€ not fixed / Vehicle**	**€ Not fixed / Vehicle**	**€ Fixed / Vehicle**	**Month Cost**	**Cost / Day**
12	11	3 526,70 €	10 409	0,34 €	2 821,49 €	1 392,87 €	85 151,58 €	2 746,83 €
22	33	4817,33 €	15 147	0,35 €	3 301,30 €	1 598,20 €	155 108,10 €	5 003,48 €
24	18	5 044,35 €	11 260	0,45 €	3 111,31 €	1 283,31 €	169 901,31 €	5 480,69 €
33	23	6 512,43 €	22 794	0,29 €	3 834,01 €	1 880,75 €	281 225,36 €	9 071,79 €
Total	**85**	**24 718,13 €**	**74 755,14 €**	**0,33 €**	**16 369,40 €**	**7 753,32 €**	**846 494,42 €**	**27 306,27 €**

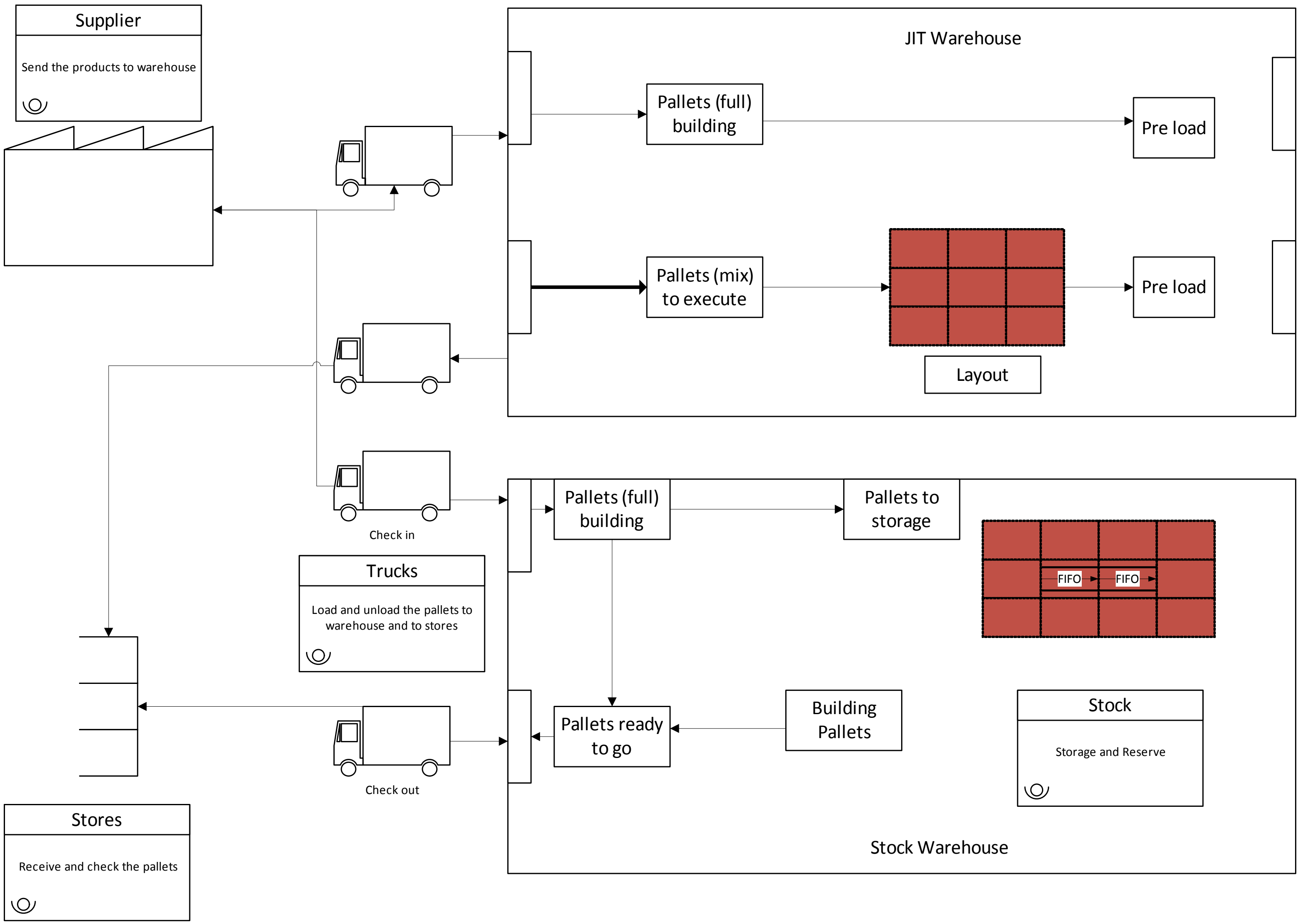
Vehicle´s Cost/Day (ZAS)							
Type of Vehicle	**Quantity of vehicle**	**€ not fixed**	**Km /Month**	**€ Not fixed / Vehicle**	**€ Fixed / Vehicle**	**Month Cost**	**Cost / Day**
12	11	113,76 €		91,02 €	44,93 €	85 151,58 €	2 746,83 €
22	33	155,40 €		106,50 €	51,56 €	155 108,10 €	5 003,50 €
24	18	162,72 €		100,36 €	41,40 €	169 901,31 €	5 480,69 €
33	23	210,08 €		123,68 €	60,67 €	281 225,36 €	9 071,79 €
Total	85	797,36 €		528,05 €	250,11 €	**846 494,42 €**	**27 306,27 €**

Put the kilometers here and calculate the sum.

APPENDIX E: Coordinates (latitude and longitude) of the stores.

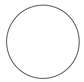
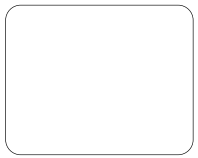
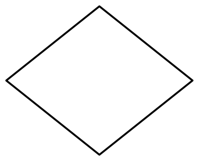
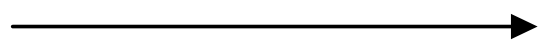
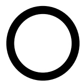
Loja	Descrição Loja	Latitude	Longitude	Loja	Descrição Loja	Latitude	Longitude
302	MATOSINHOS AF.	41,18113	-8,68261	606	ILHAVO	40,60359	-8,66169
303	AMEAL	41,1786	-8,614	609	ARCOZELO	41,06162	-8,62871
304	BARCELOS	41,5313	-8,6236	610	OLIV. BAIRRO	40,50769	-8,48606
305	MAIA 5 Out	41,2248	-8,61266	612	PEROSINHO	41,06336	-8,5971
308	LOUROSA VENDAS	40,9886	-8,5391	613	S. FELIX MARINHA	41,02684	-8,63669
310	FERNAO MAGALHA	41,14991	-8,59838	614	COIMBRÕES	41,12891	-8,63004
311	SALGUEIROS	41,16841	-8,5989	615	OLIVEIRA DO DOURO	41,12738	-8,58132
313	BRAGA AV LIBERD	41,54736	-8,42209	621	BRAGA MACHADO V	41,54906	-8,41144
314	CANIDELO AZAME	41,11619	-8,64754	624	CEDOFEITA	41,1529	-8,6183
315	PRACA REPUBLICA	41,1537	-8,6134	625	ESPINHO	41,00814	-8,64329
316	FAMALICAO D SAI	41,40377	-8,52073	627	FOZ	41,15175	-8,67748
317	SERPA PINTO	41,16674	-8,62026	629	LAMEGO	41,0991	-7,8038
320	POVOA VARZIM II	41,3819	-8,7621	630	MAIA	41,23321	-8,6247
321	OLIV. AZEMEIS CC	40,83943	-8,47996	632	MARQUES	41,16089	-8,60633
322	SA DA BANDEIRA	41,14939	-8,60745	633	MATOSINHOS	41,18449	-8,69221
324	SANTA COMBA DÃ	40,39963	-8,13332	634	PASSOS MANUEL	41,14666	-8,60485
325	CONCORDIA	41,18178	-8,63015	636	VELASQUES	41,1626	-8,5934
327	AROUCA	40,92856	-8,24832	651	BRAGA HIPER	41,55731	-8,40467
328	GUARDA GARE	40,55053	-7,24749	652	AVEIRO HIPER	40,65044	-8,61981
329	VIANA CASTELO	41,69632	-8,82607	654	P. DO VARZIM HIPER	41,37786	-8,73872
330	TROFA SHOPPING	41,33932	-8,56077	657	SANTA MARIA HIPEI	40,92061	-8,56563
331	S.MAMEDE INFEST	41,19282	-8,61139	660	CERVEIRA	41,92317	-8,75292
332	CAMINHA	41,87886	-8,83816	661	FAFE	41,44619	-8,16497
334	N. SR. FATIMA	41,1589	-8,62706	662	LOUSADA	41,26977	-8,2881
335	SANTA LUZIA	41,1763	-8,6262	663	MONÇÃO	42,06262	-8,50621
336	BRAGA SHOPPING	41,55368	-8,42265	664	PENAFIEL	41,19429	-8,30799
337	RAMALDE S. JOÃO	41,16669	-8,6486	665	RIO TINTO	41,17148	-8,54891
338	PASTELEIRA	41,14835	-8,6587	666	SANTO TIRSO	41,3386	-8,4953
339	AFONSO V	41,15903	-8,66592	667	TROFA	41,32706	-8,56815
340	GONDOMAR DIRE	41,13481	-8,53512	668	VALONGO	41,1887	-8,4985
342	OVAR AQUILINO R	40,86032	-8,62345	669	VILA VERDE	41,64425	-8,43383
344	CARREGAL SAL	40,43649	-7,98877	670	VIZELA LUGAR DO PO	41,36983	-8,30568
345	NELAS	40,53825	-7,85556	671	AGUEDA	40,59085	-8,45579
346	VISEU RUA MEND	40,6526	-7,91383	672	BRANGANCA	41,7885	-6,7781
347	VILA DAS AVES	41,367	-8,4063	675	GRIJO	41,04519	-8,56851
348	CASTELO DA MAIA	41,26492	-8,61546	676	GUARDA BAIRRO S. I	40,5582	-7,25038
349	S.GENS	41,19088	-8,6361	677	MIRANDELA	41,4975	-7,17891
350	GUIMARÃES ALAM	41,44662	-8,29833	678	SEIA	40,4268	-7,7134
351	OLIVEIRA DE FRAD	40,71856	-8,17682	679	TONDELA EM 627	40,53002	-8,08804
353	CANIDELO LAVAD	41,1302	-8,65198	680	VALADARES	41,08894	-8,62903
355	S PEDRO DA COVA	41,15167	-8,51603	681	VISEU	40,66175	-7,91541
357	COSTA CABRAL	41,17558	-8,58478	722	FAMALICÃO CALEND	41,40163	-8,52047
361	SEVER DO VOUGA	40,72457	-8,36351	724	VIZELA INFIAS	41,39289	-8,31805
362	VALE DE CAMBRA	40,84595	-8,3985	725	FELGUEIRAS	41,36076	-8,19979
363	ERMESINDE PRAC	41,21323	-8,55866	726	LOUROSA TRAVANC	40,97286	-8,53559
364	ARCOS DE VALDEV	41,82855	-8,41552	728	FAFE ALIADOS	41,45437	-8,18002
367	FAFE	41,44827	-8,17592	729	MOREIRA DA MAIA	41,25499	-8,65016
368	CHAVES	41,7424	-7,4731	730	CARVALHOS	41,0569	-8,56801
369	VIEIRA DO MINHO	41,63557	-8,15026	731	PÓVOA DE LANHOSO	41,57191	-8,26169
373	Braga Pachancho	41,55853	-8,41665	732	TAIPAS GUIMARÃES	41,48759	-8,3554
374	Lavra	41,25447	-8,70769	733	PAÇOS DE FERREIRA	41,27621	-8,38293
375	ANTUNES GUIMAR	41,17057	-8,65906	734	LEÇA DA PALMEIRA A	41,1965	-8,69279
376	CUSTOIAS	41,1978	-8,63734	735	LORDELO	41,23182	-8,40722
378	VILA REAL	41,30646	-7,74493	736	OVAR LAVOURAS	40,86599	-8,61019
379	REGUA	41,16838	-7,80289	737	MARCO DE CANAVEZ	41,1777	-8,151
380	MANGUALDE	40,61489	-7,75876	739	OLIVEIRA DE AZEMÉI	40,84575	-8,47682
381	ARRIFANA OUTEIR	40,92204	-8,49896	740	VILA DO CONDE	41,36445	-8,74958
382	S JOAO DA MADEI	40,89822	-8,49127	741	VALONGO SUSÃO	41,20179	-8,50705
383	CONSTITUICAO	41,16241	-8,61557	742	ESMORIZ	40,95389	-8,62451
386	AVEIRO RIA	40,647	-8,64646	743	GAIA MADALENA	41,11058	-8,6317
387	VILA REAL 2	41,29575	-7,74788	744	AMARANTE	41,28706	-8,09591
395	ANADIA AV. JOSÉ	40,44205	-8,44099	745	S. PEDRO DA COVA	41,15314	-8,50633
467	ESTARREJA	40,76258	-8,57078	747	VIANA DO CASTELO	41,70924	-8,77636
470	S.J.MADEIRA CUCU	40,89496	-8,50294	748	BRAGA FROSSOS	41,56452	-8,44933
489	PRELADA	41,17269	-8,63905	749	MAIA ÁGUAS SANTA	41,21248	-8,56326
493	AVEIRO VERA CRU	40,64151	-8,64183	774	RAMALDE EZEQUIEL	41,17284	-8,65225
494	MARECHAL GOMES	41,15773	-8,66475	779	PD-VISEU-ABRAVESE	40,68514	-7,92819
496	MATOSINHOS SUL	41,17551	-8,68821	781	MATOSINHOS SENHO	41,1814	-8,65071
497	OLIVEIRA DO HOSI	40,36028	-7,85443	2002	RECHEIO VISEU	40,65232	-7,88519
510	MIRANDA DO DOU	41,50698	-6,28875	2003	RECHEIO AVEIRO	40,6717	-8,6023
511	SÃO PEDRO DO SU	40,75741	-8,0671	2004	RECHEIO VILA REAL	41,2768	-7,705
512	CELORICO DE BAST	41,40058	-7,98832	2007	RECHEIO BRAGA	41,53286	-8,42249
513	AVINTES	41,1098	-8,55187	2008	RECHEIO MIRANDELA	41,49725	-7,16799
514	MIRA	40,43539	-8,72765	2012	RECHEIO VALENCA	41,97793	-8,65174
517	S.ROMÃO CORONA	41,28189	-8,5626	2013	RECHEIO ERMESINDE	41,20359	-8,54851
518	VILA MEÃ	41,24778	-8,17594	2014	RECHEIO MERCADO	41,16428	-8,57848
519	ALBERGARIA	40,71319	-8,48277	2015	RECHEIO AMARANTE	41,26248	-8,06035
522	TAROUCA	41,02982	-7,7715	2016	RECHEIO V DO COND	41,36435	-8,74516
523	SÁTÃO	40,74954	-7,73533	2021	RECHEIO BARCELOS	41,5347	-8,6131
524	VALPAÇOS	41,60207	-7,31102	2028	RECHEIO PT CIDADE	41,17598	-8,65168
601	BOAVISTA	41,15953	-8,63955	2037	RECHEIO STª MARIA	40,93285	-8,52749
602	V.N. GAIA	41,12753	-8,60719	6002	COZINHA CENTRAL D	40,65028	-8,61965
603	AVEIRO	40,63034	-8,64432	6003	COZ GAIA	41,12761	-8,60723
605	LEÇA DA PALMEIRA	41,19938	-8,69684				

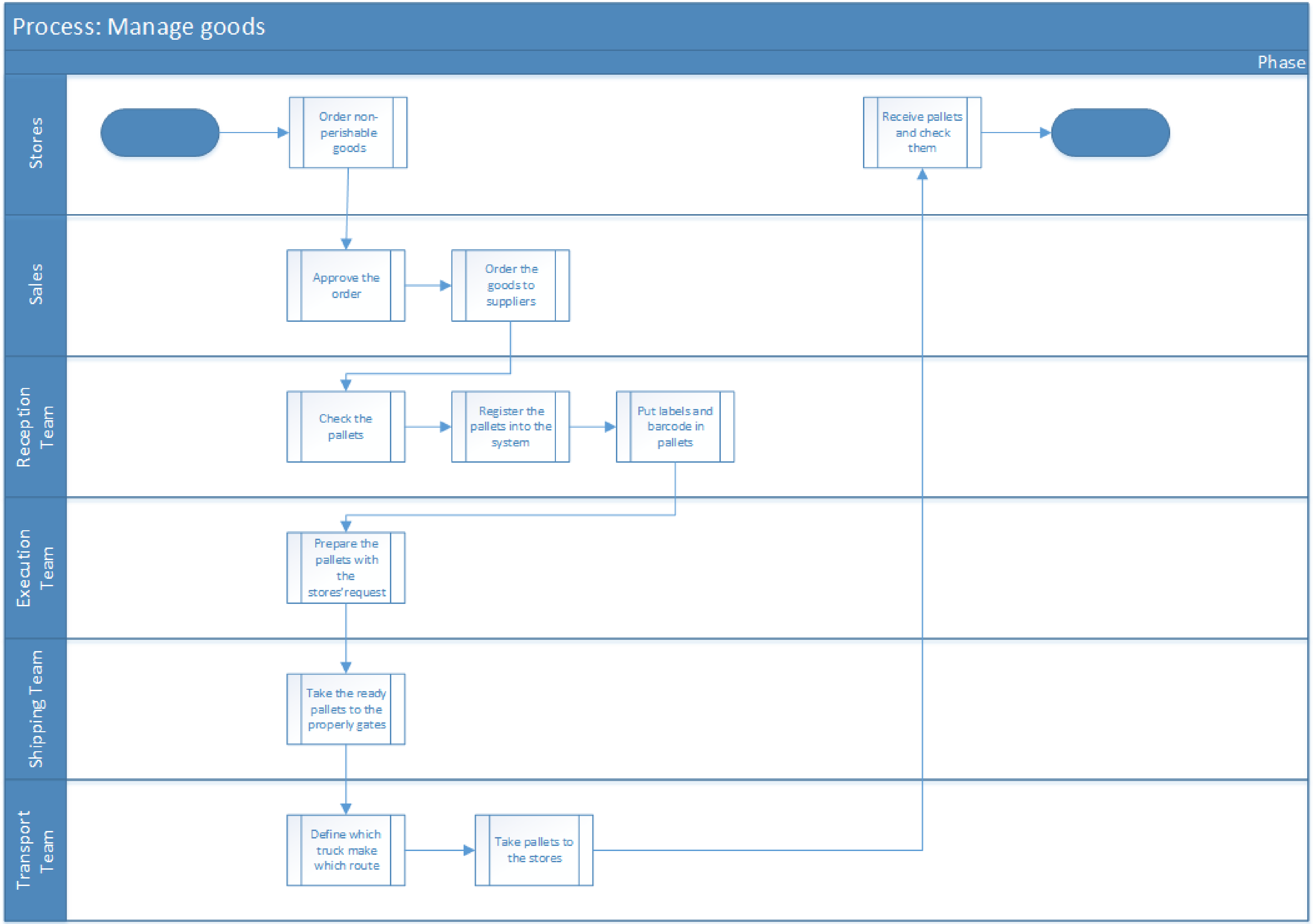
APPENDIX F: Workflow Diagram of warehouses interactions.



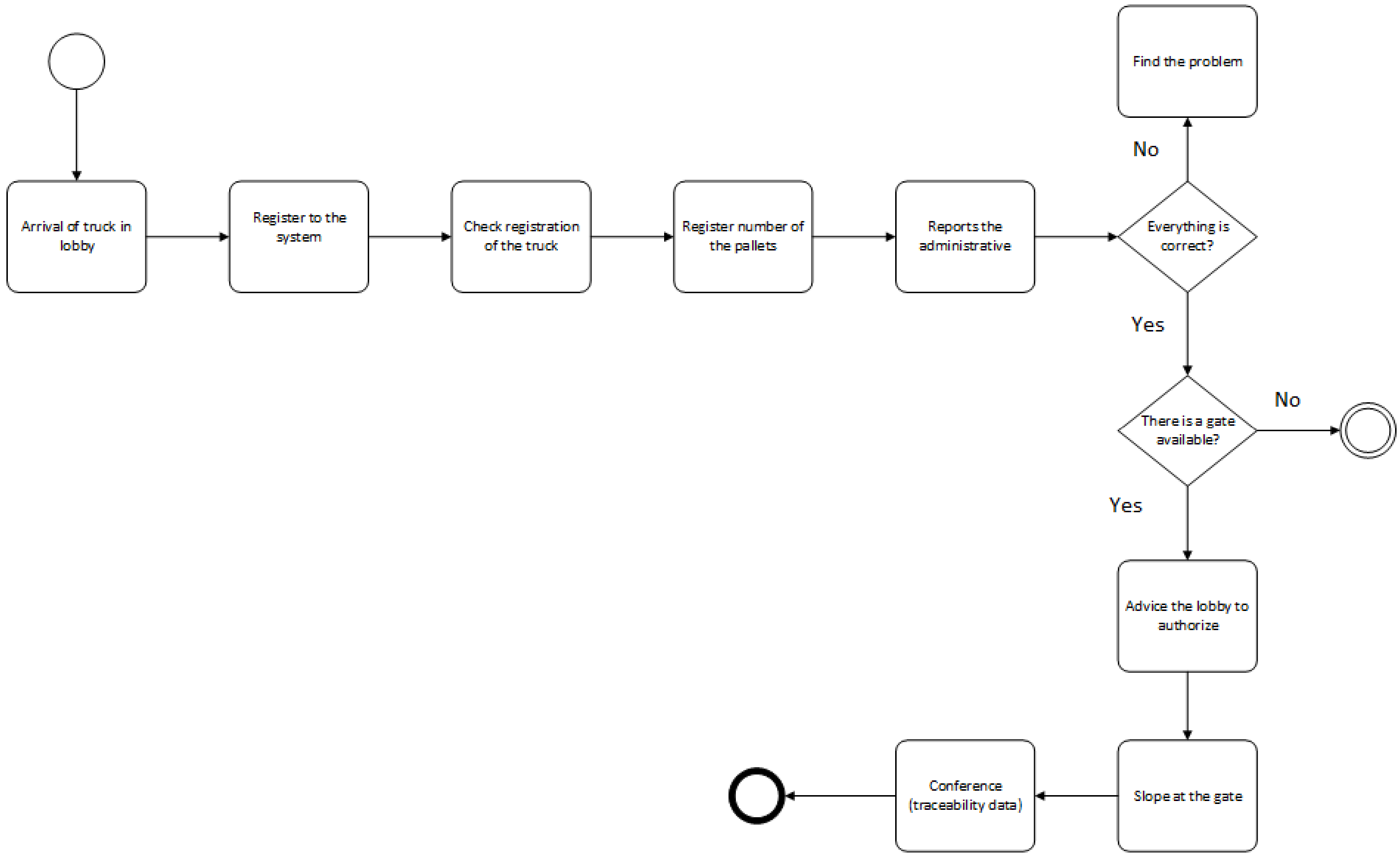
APPENDIX G: Process Map of Manage goods.

For the Processes it was used the notation:

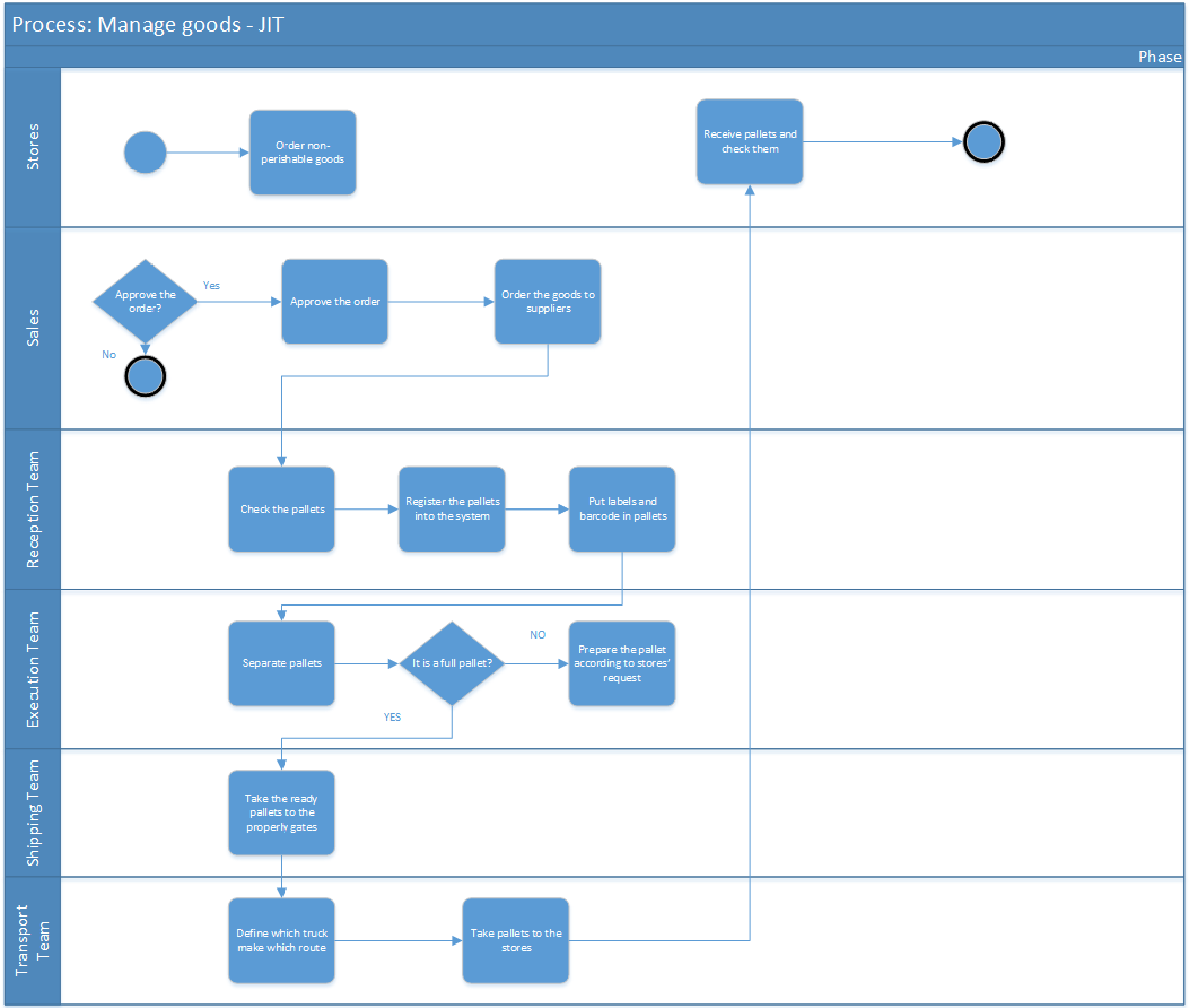
Notation	Description
	Start of the process
	Activity
	Option box: **Yes** or **No**, establishing only one connection according to the choice
	Sequential binding activities
	End of the process


Process: Manage goods
Phase
Stores
Sales
Reception Team
Execution Team
Shipping Team
Transport Team
Order non-perishable goods
Receive pallets and check them
Approve the order
Order the goods to suppliers
Check the pallets
Register the pallets into the system
Put labels and barcode in pallets
Prepare the pallets with the stores' request
Take the ready pallets to the properly gates
Define which truck make which route
Take pallets to the stores

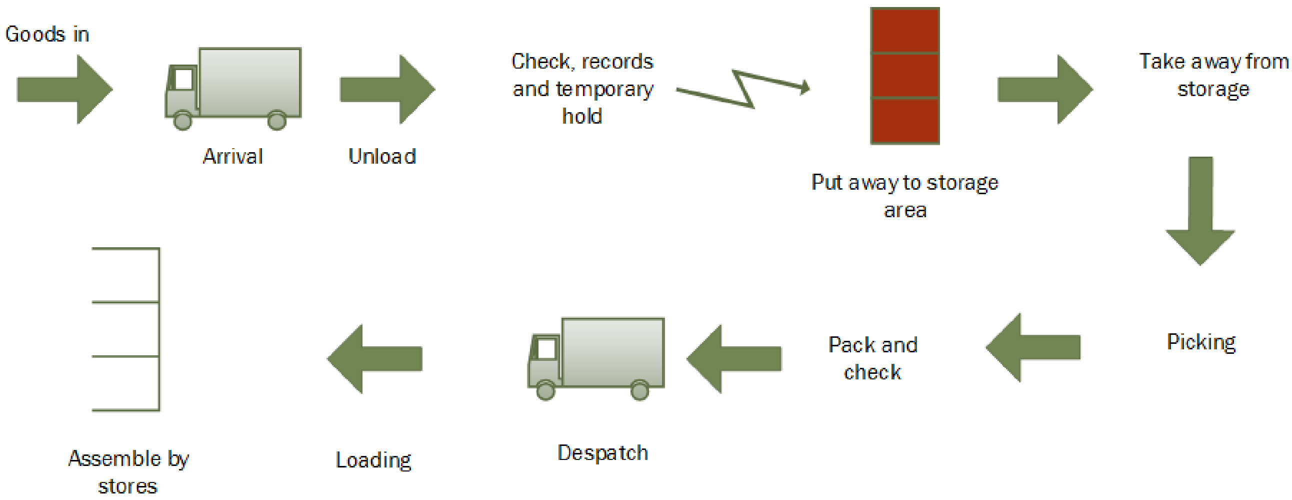
APPENDIX H: Workflow Diagram - Suppliers Arrive at JIT Warehouse.



APPENDIX I: Process Map - Shipping on JIT warehouse.



APPENDIX J: Workflow diagram of Operations in Stock Warehouse.



APPENDIX K: Current Workload of the stores (time-window).

Workload of North of Portugal stores					
Cod	Type	Name	Warehouse JIT (5501)	Warehouse Stock (5507)	Warehouse Stock (5512)
302	PD	MATOSINHOS AF.HENRIQUES	20:00-20:29	20:00-20:29	20:00-20:29
303	PD	AMEAL	16:30-16:59	19:30-19:59	16:30-16:59
304	PD	BARCELOS	16:30-16:59	19:30-19:59	16:30-16:59
305	PD	MAIA 5 Out	16:30-16:59	20:30-20:59	16:30-16:59
308	PD	LOUROSA VENDAS NOVAS	12:15-12:44	19:45-20:14	12:15-12:44
310	PD	FERNAO MAGALHAES	13:00-13:29	20:30-20:59	13:00-13:29
311	PD	SALGUEIROS	13:15-13:44	20:30-20:59	13:15-13:44
313	PD	BRAGA AV LIBERDADE	00:00-23:59	00:00-23:59	00:00-23:59
314	PD	CANIDELO AZAMBOEIRA	16:30-16:59	20:30-20:59	16:30-16:59
315	PD	PRACA REPUBLICA	12:30-12:59	20:00-20:29	12:30-12:59
316	PD	FAMALICAO D SANCHO	16:30-16:59	19:00-19:29	16:30-16:59
317	PD	SERPA PINTO	12:15-12:44	20:30-20:59	12:15-12:44
320	PD	POVOA VARZIM II	09:00-09:29	09:00-09:29	09:00-09:29
321	PD	OLIV. AZEMEIS CC RAINHA	13:30-13:59	20:30-20:59	13:30-13:59
322	PD	SA DA BANDEIRA	12:00-12:29	20:00-20:29	12:00-12:29
324	PD	SANTA COMBA DÃO	19:15-19:44	19:15-19:44	19:15-19:44
325	PD	CONCORDIA	11:45-12:14	20:00-20:29	11:45-12:14
327	PD	AROUCA	13:15-13:44	20:00-20:29	13:15-13:44
328	PD	GUARDA GARE	00:00-23:59	00:00-23:59	00:00-23:59
329	PD	VIANA CASTELO	17:00-17:59	19:30-19:59	17:00-17:59
330	PD	TROFA SHOPPING	16:30-16:59	20:30-20:59	16:30-16:59
331	PD	S.MAMEDE INFESTA	00:00-23:59	00:00-23:59	00:00-23:59
332	PD	CAMINHA	13:30-13:59	13:30-13:59	13:30-13:59
334	PD	N. SR. FATIMA	13:00-13:29	20:30-20:59	13:00-13:29
335	PD	SANTA LUZIA	16:30-16:59	20:30-20:59	16:30-16:59
336	PD	BRAGA SHOPPING	08:30-08:59	08:30-08:59	08:30-08:59
337	PD	RAMALDE S. JOÃO DE BRITO	16:30-16:59	20:30-20:59	16:30-16:59
338	PD	PASTELEIRA	14:00-14:29	20:30-20:59	14:00-14:29
339	PD	AFONSO V	14:00-14:29	19:30-19:59	14:00-14:29
340	PD	GONDOMAR DIRECCIONAL	12:45-13:14	20:30-20:59	12:45-13:14
342	PD	OVAR AQUILINO RIBEIRO	00:00-23:59	00:00-23:59	00:00-23:59
344	PD	CARREGAL SAL	20:00-20:29	20:30-20:59	20:00-20:29
345	PD	NELAS	00:00-23:59	00:00-23:59	00:00-23:59
346	PD	VISEU RUA MENDONÇA	11:30-11:59	20:30-20:59	11:30-11:59
347	PD	VILA DAS AVES	16:00-16:59	20:30-20:59	16:00-16:59
348	PD	CASTELO DA MAIA	16:30-16:59	20:30-20:59	16:30-16:59
349	PD	S.GENS	00:00-23:59	00:00-23:59	00:00-23:59
350	PD	GUIMARÃES ALAMEDA	16:00-16:29	20:00-20:29	16:00-16:29
351	PD	OLIVEIRA DE FRADES	00:00-23:59	00:00-23:59	00:00-23:59
353	PD	CANIDELO LAVADORES	16:30-16:59	20:00-20:29	16:30-16:59

355	PD	S PEDRO DA COVA EST.D.MIGUEL	00:00-23:59	00:00-23:59	00:00-23:59
357	PD	COSTA CABRAL	14:30-14:59	20:30-20:59	14:30-14:59
361	PD	SEVER DO VOUGA	00:00-23:59	00:00-23:59	00:00-23:59
362	PD	VALE DE CAMBRA	13:00-13:59	20:30-20:59	13:00-13:59
363	PD	ERMESINDE PRACETA MOÇAMBIQUE	00:00-23:59	00:00-23:59	00:00-23:59
364	PD	ARCOS DE VALDEVEZ BARREIRO	18:00-18:59	20:30-20:59	18:00-18:59
367	PD	FAFE	16:30-16:59	20:30-20:59	16:30-16:59
368	PD	CHAVES	20:30-20:59	20:30-20:59	20:30-20:59
369	PD	VIEIRA DO MINHO	16:00-16:29	20:30-20:59	16:00-16:29
373	PD	Braga Pachancho	16:30-16:59	20:30-20:59	16:30-16:59
374	PD	Lavra	16:30-16:59	20:30-20:59	16:30-16:59
375	PD	ANTUNES GUIMARAES	16:00-16:29	20:30-20:59	20:30-20:59
376	PD	CUSTOIAS	16:30-16:59	20:30-20:59	16:30-16:59
378	PD	VILA REAL	20:00-20:29	20:30-20:59	20:00-20:29
379	PD	REGUA	00:00-23:59	00:00-23:59	00:00-23:59
380	PD	MANGUALDE	00:00-23:59	00:00-23:59	00:00-23:59
381	PD	ARRIFANA OUTEIRO	15:30-15:59	20:30-20:59	15:30-15:59
382	PD	S JOAO DA MADEIRA R VISCONDE	15:45-16:14	15:45-16:14	15:45-16:14
383	PD	CONSTITUICAO	19:00-19:59	20:30-20:59	19:00-19:59
386	PD	AVEIRO RIA	13:30-13:59	20:30-20:59	13:30-13:59
387	PD	VILA REAL 2	20:30-20:59	20:30-20:59	20:30-20:59
395	PD	ANADIA AV. JOSÉ LUCIANO CASTRO	13:30-13:59	20:30-20:59	19:15-19:44
467	PD	ESTARREJA	00:00-23:59	00:00-23:59	00:00-23:59
470	PD	S.J.MADEIRA CUCUJÃES	00:00-23:59	00:00-23:59	00:00-23:59
489	PD	PRELADA	16:30-16:59	20:30-20:59	16:30-16:59
493	PD	AVEIRO VERA CRUZ	13:30-13:59	20:30-20:59	13:30-13:59
494	PD	MARECHAL GOMES DA COSTA	12:00-12:29	20:30-20:59	12:30-12:59
496	PD	MATOSINHOS SUL BRITO E CUNHA	10:30-10:59	20:00-20:29	10:30-10:59
497	PD	OLIVEIRA DO HOSPITAL	11:00-11:29	20:30-20:59	11:00-11:29
510	PD	MIRANDA DO DOURO	09:00-09:29	09:00-09:29	09:00-09:29
511	PD	SÃO PEDRO DO SUL	13:00-13:29	20:00-20:29	13:00-13:29
512	PD	CELORICO DE BASTO	14:30-14:59	10:00-10:29	14:30-14:59
513	PD	AVINTES	13:00-13:29	20:30-20:59	13:00-13:29
514	PD	MIRA	20:00-20:29	20:00-20:29	20:00-20:29
517	PD	S.ROMÃO CORONADO	00:00-23:59	00:00-23:59	00:00-23:59
518	PD	VILA MEÃ	00:00-23:59	00:00-23:59	00:00-23:59
519	PD	ALBERGARIA	18:45-19:14	20:00-20:59	18:45-19:14
522	PD	TAROUCA	20:30-20:59	20:30-20:59	20:30-20:59
523	PD	SÁTÃO	11:00-11:29	20:00-20:29	11:00-11:29
601	PD	BOAVISTA	00:00-23:59	00:00-23:59	00:00-23:59
602	PD	V.N. GAIA	16:00-16:29	20:30-20:59	16:00-16:29
603	PD	AVEIRO	18:45-19:14	20:30-20:59	18:45-19:14
605	PD	LEÇA DA PALMEIRA	16:30-16:59	20:30-20:59	16:30-16:59
606	PD	ILHAVO	00:00-23:59	00:00-23:59	00:00-23:59
609	PD	ARCOZELO	20:30-20:59	20:30-20:59	20:30-20:59
610	PD	OLIV. BAIRRO	00:00-23:59	00:00-23:59	00:00-23:59

612	PD	PEROSINHO	00:00-23:59	00:00-23:59	00:00-23:59
613	PD	S. FELIX MARINHA	16:00-16:59	20:30-20:59	16:00-16:59
614	PD	COIMBRÕES	20:30-20:59	20:30-20:59	20:30-20:59
615	PD	OLIVEIRA DO DOURO	00:00-23:59	00:00-23:59	00:00-23:59
621	PD	BRAGA MACHADO VILELA	15:30-15:59	20:30-20:59	15:30-15:59
624	PD	CEDOFEITA	07:30-07:59	07:30-07:59	07:30-07:59
625	PD	ESPINHO	08:30-08:59	08:30-08:59	08:00-08:59
627	PD	FOZ	14:00-14:29	20:30-20:59	14:00-14:29
629	PD	LAMEGO	20:30-20:59	20:30-20:59	20:30-20:59
630	PD	MAIA	20:30-20:59	20:30-20:59	20:30-20:59
632	PD	MARQUES	12:45-13:14	20:00-20:29	12:45-13:14
633	PD	MATOSINHOS	10:30-10:59	10:30-10:59	10:30-10:59
634	PD	PASSOS MANUEL	12:30-12:59	20:30-20:59	12:30-12:59
636	PD	VELASQUES	14:15-14:44	20:30-20:59	14:15-14:44
651	PD	BRAGA HIPER	00:00-23:59	00:00-23:59	00:00-23:59
652	PD	AVEIRO HIPER	00:00-23:59	00:00-23:59	00:00-23:59
654	PD	P. DO VARZIM HIPER	00:00-23:59	00:00-23:59	00:00-23:59
657	PD	SANTA MARIA HIPER	00:00-23:59	00:00-23:59	00:00-23:59
660	PD	CERVEIRA	10:30-10:59	20:30-20:59	10:30-10:59
661	PD	FAFE	18:00-18:29	20:30-20:59	18:00-18:29
662	PD	LOUSADA	17:30-17:59	20:30-20:59	17:30-17:59
663	PD	MONÇÃO	13:00-13:29	20:30-20:59	13:00-13:29
664	PD.	PENAFIEL	21:00-21:29	21:30-21:59	21:00-21:29
665	PD	RIO TINTO	18:00-18:29	20:30-20:59	18:00-18:29
666	PD	SANTO TIRSO	00:00-23:59	00:00-23:59	00:00-23:59
667	PD	TROFA	18:30-18:59	20:30-20:59	18:30-18:59
668	PD	VALONGO	18:30-18:59	20:30-20:59	18:30-18:59
669	PD	VILA VERDE	18:15-18:44	20:30-20:59	18:15-18:44
670	PD	VIZELA LUGAR DO POÇO QUENTE	18:30-18:59	20:30-20:59	18:30-18:59
671	PD	AGUEDA	18:30-18:59	20:30-20:59	18:30-18:59
672	PD	BRANGANCA	20:30-20:59	20:30-20:59	20:30-20:59
675	PD	GRIJO	20:30-20:59	20:30-20:59	20:30-20:59
676	PD	GUARDA BAIRRO S. DOMINGOS	20:30-20:59	12:30-12:59	20:30-20:59
677	PD	MIRANDELA	20:30-20:59	20:30-20:59	20:30-20:59
678	PD	SEIA	00:00-23:59	00:00-23:59	00:00-23:59
679	PD	TONDELA EM 627	20:30-20:59	20:30-20:59	20:30-20:59
680	PD	VALADARES	20:30-20:59	20:30-20:59	20:30-20:59
681	PD	VISEU	13:30-13:59	13:30-13:59	13:30-13:59
722	PD	FAMALICÃO CALENDÁRIO	17:00-17:59	20:30-20:59	17:00-17:59
724	PD	VIZELA INFIAS	18:30-18:59	20:30-20:59	18:30-18:59
725	PD	FELGUEIRAS	17:30-17:59	20:30-20:59	17:30-17:59
726	PD	LOUROSA TRAVANCA	18:30-18:59	20:30-20:59	18:30-18:59
728	PD	FAFE ALIADOS	18:30-18:59	20:30-20:59	18:30-18:59
729	PD	MOREIRA DA MAIA	16:30-16:59	20:30-20:59	16:30-16:59
730	PD	CARVALHOS	13:00-13:29	20:30-20:59	13:00-13:29
731	PD	PÓVOA DE LANHOSO	17:30-17:59	20:30-20:59	17:30-17:59

732	PD	TAIPAS GUIMARÃES	17:30-17:59	20:30-20:59	17:30-17:59
733	PD	PAÇOS DE FERREIRA	17:30-17:59	20:30-20:59	17:30-17:59
734	PD	LEÇA DA PALMEIRA AMOROSA	16:30-16:59	20:30-20:59	16:30-16:59
735	PD	LORDELO	17:30-17:59	20:30-20:59	17:30-17:59
736	PD	OVAR LAVOURAS	20:00-20:59	20:30-20:59	20:00-20:59
737	PD	MARCO DE CANAVEZES	00:00-23:59	00:00-23:59	00:00-23:59
739	PD	OLIVEIRA DE AZEMÉIS FARRAPA	13:00-13:29	20:30-20:59	13:00-13:59
740	PD	VILA DO CONDE	16:30-16:59	20:30-20:59	16:30-16:59
741	PD	VALONGO SUSÃO	17:30-17:59	20:30-20:59	17:30-17:59
742	PD	ESMORIZ	13:00-13:29	20:30-20:59	13:00-13:29
743	PD	GAIA MADALENA	17:30-17:59	20:30-20:59	17:30-17:59
744	PD	AMARANTE	20:30-20:59	20:30-20:59	20:30-20:59
745	PD	S. PEDRO DA COVA ENG. F. ALM	20:30-20:59	20:30-20:59	20:30-20:59
747	PD	VIANA DO CASTELO PORTUZELO	17:30-17:59	20:30-20:59	17:30-17:59
748	PD	BRAGA FROSSOS	00:00-23:59	00:00-23:59	00:00-23:59
749	PD	MAIA ÁGUAS SANTAS	20:00-20:59	20:30-20:59	20:00-20:59
774	PD	RAMALDE EZEQUIEL DE CAMPOS	16:00-16:29	20:00-20:29	16:00-16:29
779	PD	PD-VISEU-ABRAVESES	11:00-11:29	20:30-20:59	11:00-11:29
781	PD	MATOSINHOS SENHORA DA HORA	20:30-20:59	19:30-19:59	20:30-20:59
2002	RCH	RECHEIO VISEU	16:30-16:59	17:30-17:59	16:30-16:59
2003	RCH	RECHEIO AVEIRO	14:00-14:59	17:30-17:59	14:00-14:59
2004	RCH	RECHEIO VILA REAL	14:30-14:59	17:30-17:59	14:30-14:59
2007	RCH	RECHEIO BRAGA	00:00-23:59	00:00-23:59	00:00-23:59
2008	RCH	RECHEIO MIRANDELA	17:30-17:59	17:30-17:59	17:30-17:59
2012	RCH	RECHEIO VALENCA	12:30-12:59	17:30-17:59	12:30-12:59
2013	RCH	RECHEIO ERMESINDE	16:00-16:29	17:30-17:59	16:00-16:29
2014	RCH	RECHEIO MERCADO	16:00-16:29	17:30-17:59	16:00-16:29
2015	RCH	RECHEIO AMARANTE	14:30-14:59	17:30-17:59	14:30-14:59
2016	RCH	RECHEIO V DO CONDE	16:30-16:59	17:30-17:59	16:30-16:59
2021	RCH	RECHEIO BARCELOS	16:00-16:29	17:30-17:59	16:00-16:29
2028	RCH	RECHEIO PT CIDADE	16:00-16:29	17:30-17:59	16:00-16:29
2037	RCH	RECHEIO STª MARIA DA FEIRA	00:00-23:59	00:00-23:59	00:00-23:59
2101	RCH	CATERPLUS	14:15-14:44	14:30-14:59	14:15-14:44
6003	PD	COZINHA CENTRAL DE GAIA	16:00-16:29	23:30-23:59	16:00-16:29

APPENDIX L: Maximum capacity of truck for each store.

Maximum Capacity of Truck	Number of stores
12	1
20	17
22	2
24	28
33	62
Total	110

APPENDIX M: Average of occupation and use of each truck.

Registration Number	Shifts	Average Descharge	Average Charge	Km (planned)	Km (real)	Work time (h)	Use (%)	Ocupation (%)	STOPS
98QF11	3	0:15:00	0:36:00	1367,32	697,5	19:17:00	80	60	6
98CV73	3	0:03:00	0:16:00	166,96	133,07	9:12:00	38	71	3
98CV68	3	0:10:00	0:25:00	581,43	533,73	21:46:00	91	74	7
98CV67	2	0:29:00	0:11:00	294,89	225,84	12:42:00	53	137	9
97LF49	1	0:17:00	0:10:00	114,48	114,29	8:12:00	34	75	3
97LF48	3	0:22:00	1:02:00	353,43	348,3	18:55:00	79	87	13
97LF47	3	0:09:00	0:36:00	400,18	399,55	19:19:00	81	69	7
97LF46	5	0:15:00	0:12:00	355,23	272,41	16:32:00	69	70	12
97LF45	3	0:12:00	0:43:00	384,97	429,49	15:54:00	66	90	7
97LF44	4	0:09:00	0:34:00	327,66	287,58	16:43:00	70	62	8
97LF43	3	0:16:00	0:57:00	442,89	401,81	17:26:00	73	85	7
97LF39	1	0:23:00	0:24:00	49,35	49,35	3:14:00	13	42	1
97LF37	5	0:33:00	0:20:00	281,57	287,97	17:17:00	72	74	8
97LF36	4	0:28:00	0:19:00	316,05	286,87	17:22:00	72	104	7
97LF35	5	0:22:00	0:22:00	520,13	488,95	19:30:00	81	93	8
97LF34	3	0:25:00	0:30:00	243,5	218,73	11:15:00	47	58	4
9327XP	1		0:39:00	0	0	6:52:00	29	97	1
93PU29	3	0:21:00	0:30:00	312,29	246,15	14:30:00	60	74	15
93PU28	1	0:21:00	0:23:00	106,11	106,85	8:13:00	34	40	1
93PU27	3	0:18:00	0:27:00	514,98	518,91	20:18:00	85	110	9
91DD31	4	0:14:00	0:54:00	287,1	281,33	17:20:00	72	82	11
91DD30	3	0:05:00	1:01:00	180,15	178,6	18:52:00	79	77	9
91DD29	3	0:51:00	0:17:00	256,69	139,37	17:16:00	72	84	6
91DD28	2		0:33:00	154,88	156,84	9:04:00	38	93	5
87PD16	2	0:03:00	0:40:00	1039,89	796,18	20:22:00	85	84	7
87PD15	2	0:02:00	1:01:00	1113,23	953,6	19:37:00	82	71	6
79BT91	3	0:05:00	0:22:00	199,63	178,91	12:53:00	54	63	10
78EP63	1	0:19:00	0:05:00	86,99	91,98	5:22:00	22	48	2
78EP61	1	0:25:00	0:14:00	0	266	10:40:00	44	12	1
74JM49	2	0:23:00	0:33:00	227,11	197,02	9:01:00	38	83	4
73NL57	2	0:57:00	0:24:00	93,4	77,5	7:34:00	32	93	5
73NL56	4	0:21:00	0:25:00	424,09	405,8	15:47:00	66	88	8
73NL55	2	0:20:00	0:32:00	409,12	495,87	17:33:00	73	98	10
71GI73	3	0:34:00	0:23:00	509,13	493,94	20:42:00	86	89	7
71GI72	3	0:25:00	0:44:00	488,83	460,95	17:58:00	75	38	4
71GI70	3	0:16:00	1:15:00	301,7	293,42	17:54:00	75	78	8
69NL44	2	0:02:00	0:39:00	84,26	100,82	8:08:00	34	108	7
66QB46	1		0:18:00	334,48	334,48	4:02:00	17	39	1
66QB45	1	0:10:00	0:26:00	189,34	185,57	5:27:00	23	56	3
60IN46	1	0:27:00	0:14:00	295,62	195,2	9:11:00	38	94	8

60IN45	3	0:21:00	0:37:00	533,1	486,69	17:26:00	73	90	8
5449VX	3		0:38:00	368,65	0	21:59:00	92	103	5
52OF98	3	0:10:00	0:30:00	403,85	372,58	17:41:00	74	95	6
51JG04	3	0:04:00	0:56:00	225,61	244,76	17:21:00	72	94	12
50MC52	4	0:02:00	0:35:00	382,43	384,71	16:36:00	69	93	7
50JG94	4	0:11:00	0:52:00	304,15	256,75	21:35:00	90	53	11
50JG92	4	0:10:00	0:35:00	306,59	262,84	17:44:00	74	81	12
4951XG	3	0:14:00	0:52:00	418,84	415,61	20:18:00	85	96	9
47OG59	5	0:13:00	0:28:00	295,01	304,34	19:06:00	80	75	12
47OG56	3	0:11:00	0:49:00	209,51	205,33	14:59:00	62	87	9
47NG41	4	0:32:00	0:27:00	203,43	182,69	13:58:00	58	80	9
47NG40	2	0:17:00	0:17:00	525,25	519,06	16:24:00	68	94	9
47NG38	4	0:29:00	0:24:00	270,29	207,58	14:47:00	62	88	11
47LF85	4	0:09:00	0:29:00	451,71	425,43	18:13:00	76	95	8
47LF83	3	0:11:00	0:51:00	514,56	521,92	20:31:00	86	69	5
47LF81	4	0:07:00	0:20:00	349,25	239,75	17:27:00	73	84	11
47LF79	3	0:20:00	0:13:00	356,04	335,56	16:26:00	69	85	7
47LF65	1	0:17:00	0:03:00	157,38	157,28	4:54:00	20	42	1
46GA30	1	0:34:00	0:08:00	558,9	503,92	9:56:00	41	82	3
46DU33	3	0:32:00	0:24:00	526,63	525,56	20:08:00	84	75	5
4472XM	1	0:03:00	1:33:00	353,59	376,54	9:07:00	38	81	3
42HX89	3	0:07:00	1:10:00	210,78	199,41	16:24:00	68	73	8
42HX67	3	0:38:00	1:02:00	270,85	289,22	14:49:00	62	94	8
40JU75	3	0:20:00	0:41:00	191,58	155,84	15:24:00	64	91	7
38EQ23	3	0:02:00	0:54:00	278,09	256,01	16:59:00	71	61	8
38EQ22	2	0:16:00	0:14:00	316,28	503	16:23:00	68	63	4
38EQ21	2	0:03:00	0:46:00	161,18	149,44	8:11:00	34	58	3
38EQ20	1	0:14:00	0:21:00	160,09	165,08	9:46:00	41	52	3
38EQ19	2	0:11:00	0:11:00	187,87	169,73	7:50:00	33	48	5
38EQ13	1	0:05:00	0:58:00	197,14	197,14	7:01:00	29	64	3
36OF47	1	0:48:00	0:18:00	75,99	124	8:37:00	36	58	3
36OF46	1	0:27:00	0:23:00	301,08	297,55	11:47:00	49	85	2
36BX65	2	0:07:00	0:41:00	304,58	308,58	15:28:00	64	83	6
36BX59	1	0:10:00	0:37:00	295,22	295,22	8:51:00	37	100	1
36BC76	2	0:16:00	0:31:00	321,93	321,93	11:51:00	49	60	6
34QD10	2	0:34:00	0:24:00	630,4	577,26	22:12:00	93	77	9
34FE43	2		0:44:00	284,93	0	8:00:00	33	81	6
3310UP	3	0:13:00	0:36:00	352,53	252,94	12:25:00	52	87	7
33QD99	2	1:26:00	0:50:00	706,11	604,09	16:17:00	68	86	7
33QD98	1	0:32:00	1:20:00	216,69	155,68	9:42:00	40	88	6
33QD97	1	1:40:00	1:16:00	126,71	126,71	7:25:00	31	108	3
33QD96	2	0:29:00	0:23:00	833,95	837,56	23:23:00	97	91	6
33QD95	2	0:11:00	0:44:00	830,66	677,46	21:40:00	90	95	7
32OG80	3	0:33:00	0:24:00	458,53	447,55	13:33:00	56	79	3
32OG67	3	0:12:00	0:37:00	659,93	560,11	18:51:00	79	79	7

32OG53	3	0:29:00	0:48:00	572,98	383,9	20:32:00	86	93	8
32OG51	2	0:41:00	0:51:00	414,91	337,18	11:14:00	47	96	6
32OG48	2	0:06:00	0:45:00	586,95	440,3	15:13:00	63	93	3
32DR81	3	0:14:00	0:29:00	465,47	438,36	15:57:00	67	79	9
32DR77	3	0:28:00	1:02:00	373,12	341,46	17:22:00	72	73	11
32DR76	3	0:23:00	0:29:00	387,06	326,71	13:35:00	57	87	7
32DR75	3	0:45:00	0:24:00	388,28	373,41	17:10:00	72	69	9
2968UX	2		0:37:00	245,96	0	7:43:00	32	91	5
28GH13	3	0:22:00	0:46:00	354,74	568,38	19:38:00	82	60	6
23LO02	2		0:38:00	277,36	0	7:57:00	33	80	6
20AS81	3	0:04:00	0:46:00	231,62	228,13	15:47:00	66	76	8
17BU34	2	0:07:00	0:54:00	284,03	294,1	14:10:00	59	79	6
17BU30	1	0:03:00	0:08:00	550	550	11:03:00	46	85	1
17BU18	3	0:21:00	0:58:00	256,77	271,13	14:22:00	60	105	8
14OG18	4	0:12:00	0:37:00	258,59	269,82	17:37:00	73	77	10
12HU84	2	0:11:00	0:51:00	392,18	398,57	16:28:00	69	62	6
12HU83	3	0:10:00	0:48:00	342,47	254,51	17:39:00	74	53	7
12HU82	4	0:40:00	0:51:00	279,4	184,62	21:02:00	88	81	10
12HU81	3	0:21:00	0:31:00	281,23	263,94	15:15:00	64	48	9
12HU80	1	0:04:00	1:44:00	178,07	178,16	6:34:00	27	55	2
1159XN	1	0:03:00	2:31:00	185,06	163,45	12:12:00	51	95	5
1158XN	2		0:31:00	162,81	117,32	6:29:00	27	88	4
1157XN	1	0:14:00	1:00:00	199,08	150,25	7:05:00	30	108	4
1155XN	2	0:18:00	0:16:00	321,84	298,27	15:30:00	65	89	9
03CE64	3	0:19:00	0:34:00	513,27	472,04	15:57:00	67	80	8
03CE63	2	0:05:00	0:25:00	730,03	748,79	17:50:00	74	70	5
03CE62	4	0:29:00	0:50:00	404,82	426,96	21:07:00	88	84	9
03CE61	3	0:03:00	0:58:00	316,97	301,74	18:03:00	75	82	8
02OH22	1	0:19:00	0:17:00	41,37	47,7	6:59:00	29	90	9
02OH20	2	0:51:00	0:35:00	498,85	494,27	14:18:00	60	77	4
0022XH	2		0:42:00	445,92	0	8:40:00	36	89	6

APPENDIX N: Diagram of Relationships between stakeholders, warehouses and transports in the new Warehouse.