Optimization of Returnable Packaging Flows Planning

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Abstract

As result of globalization and with very few ways to differentiate itself, the commodity-like nature of the container and packaging industry requires exceptional operational efficiency to achieve above-average returns. In a company where costs related to packaging reach up to 9% of the total costs, returnable logistical packaging systems can offer significant cost savings.

This dissertation focuses on improving the overall efficiency of the Returnable Packaging Management, which consists in returning pallets with more than one cycle of utilization. To accomplish this, the corresponding process was analysed, inefficiencies were highlighted and opportunities for improvement identified.

A distinct focal point of the project was to streamline the planning activity of the return flows of wooden pallets, reducing routine packaging purchase and, therefore, minimizing packaging related costs. To tackle this challenge and to support medium term planning, a mathematical optimization model was developed to consider the production needs of the different types of pallets in the existing plants and to define the best strategy to fulfil them. As it is not possible to fulfil all material requirements with cost effective returns, the aim of the model is to find a trade-off between the two supplying options to guarantee that production needs are met, while minimizing the total costs of the activity, which include purchasing, transportation, transferring and sorting and repair costs.

In the first analysis, the identified improvement opportunities consisted in the elimination of activities that do not add value, in the reduction of the number of actors, in the responsibility definition and lastly, in the creation of key performance indicators to support process control. In the second approach, the defined strategy to fulfil production needs, besides serving as a more accurate guide to operational activity, would potentially result in significant cost reductions. Furthermore, the second proposal offers the possibility to plan and act according to different scenarios, which positively impacts the company's responsiveness to external factors.

Resumo

Devido à globalização e crescente competitividade, indústrias como a vidreira, onde a diferenciação como estratégia competitiva é limitada, requerem uma elevada eficiência operacional. Numa empresa onde os custos relacionados com a embalagem atingem 9% dos custos totais, um sistema de retorno deste componente essencial pode apresentar uma boa oportunidade para redução de custos.

Esta dissertação teve como foco principal o aumento da eficiência do processo de gestão de Embalagem Retornável, que consiste no retorno de paletes com mais do que um ciclo de utilização. Para esse efeito, o respetivo processo foi analisado, de forma a evidenciar as ineficiências e posteriormente identificar oportunidades de melhoria.

Outro aspecto fulcral do projecto foi a otimização, ao nível do planeamento, dos fluxos de embalagem retornável, de forma a minimizar a compra de estrados de madeira e, consequentemente, promover uma redução dos custos. Face a este problema e para suportar o planeamento a médio prazo, foi desenvolvido um modelo matemático de otimização que define qual a melhor forma de responder às necessidades de produção de cada fábrica. Uma vez que não é possível satisfazer toda a procura exclusivamente com retornos rentáveis, o objetivo do modelo é encontrar uma solução de compromisso que minimize os custos totais da actividade. Estes custos incluem custos de transporte relativos ao retorno e transferência entre fábricas, compra a fornecedores, classificação e reparação.

Na primeira análise, as oportunidades de melhoria identificadas consistiam, maioritariamente, na eliminação de atividades que não criam valor, na redução do número de intervenientes, definição de responsabilidades e criação de indicadores de desempenho para suportar o controlo do processo. Na segunda abordagem, a estratégia definida para suprir as necessidades produtivas das fábricas, para além de constituir um melhor guia operacional, resultaria numa potencial redução dos custos. Adicionalmente, o modelo desenvolvido possibilita o planeamento e adaptação a diferentes cenários, o que impacta positivamente a capacidade de resposta perante a alteração de factores externos.

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Maria

" If we wait until we're ready,
we'll be waiting for the rest of our lives."

Lemony Snicket

Contents

1 Introduction **1**
1.1 BA Glass Presentation . . . 2
1.2 Motivation and Aim of the Project . . . 3
1.3 Dissertation Structure . . . 3

2 Literature Review **5**
2.1 Logistics Management and Reverse Logistics . . . 5
2.1.1 Reverse Logistics Network . . . 7
2.1.2 Planning and Control . . . 9
2.2 Scenario Planning . . . 10
2.3 Consideration . . . 11

3 Returnable Packaging Management **13**
3.1 Returnable Packaging Management . . . 14
3.1.1 RP Management Process *AS IS* . . . 14
3.1.2 Opportunities for Improvement . . . 20
3.1.3 Proposed Improvements . . . 21

4 Optimization Mathematical Model for Packaging Planning **25**
4.1 Model Definition . . . 25
4.1.1 An illustrative example . . . 29
4.1.2 Dealing with uncertainty . . . 33

5 Improving Packaging Planning - Results **35**
5.1 Main Differences between the two approaches . . . 35
5.2 Returns . . . 37
5.2.1 Confronting planning results with the real scenario . . . 43
5.3 Planning in a continuously growing company . . . 46
5.3.1 Scenario Planning . . . 47

6 Conclusions and future work **51**

References **59**

Abbreviations

APA	Finished Product Warehouse
AV	Avintes
CLSC	Closed-Loop Supply Chain
CR	Central Replenisher
JE	Jedlice
LE	Léon
MG	Marinha Grande
RL	Reverse Logistics
RP	Returnable Packaging
SA	Sales Assistant
SI	Sieraków
VF	Villafranca de los Barros
VN	Venda Nova

List of Figures

1.1 Location of the different plants of BA Group 2

2.1 Reverse Logistics according to type of returns 6
2.2 Basic Activities and Flows in RL (source Srivastava) 7
2.3 Outline of the general framework for hybrid simulation-analytic modelling (Suyabatmaz et al., 2014) 9

3.1 Finished Product Pallet 13
3.2 Returnable Packaging Management Process Model *AS IS* 15
3.3 Recovery Facility Process Model in Avintes 18
3.4 Characteristics to search for when classifying and sorting pallets 18
3.5 Proposed Returnable Packaging Management Process Model 22

4.1 Schematic representation of the flow of materials 27

5.1 Forecasted Production Needs and Returns in AV plant 39
5.2 Forecasted Production Needs and Returns in MG plant 40
5.3 Pareto chart and heat map representing the proposed yearly returns to AV plant . 41
5.4 Pareto chart and heat map representing the proposed yearly returns to MG plant . 41
5.5 Pareto chart and heat map representing the proposed yearly returns to LE plant . 42
5.6 Maps representing the returns to all Iberian plants 42
5.7 Total Costs of Returnable Packaging 43
5.8 Deviation between the forecasted and actual needs and returned quantity in AV plant 44
5.9 Deviation between the forecasted and actual needs and returned quantity in LE plant 44
5.10 Expected costs vs Real costs of Returnable Packaging in Spain 45
5.11 Expected costs vs Real costs of Returnable Packaging in Portugal 46
5.12 Map of the expected proportion of yearly returns to Polish Plants 47
5.13 Map of the expected proportion of yearly returns to Iberian Plants 48
5.14 Returnable Packaging Costs of the best, expected and worst case scenarios 49
5.15 Proportion of yearly returns to JE plant with variation of transportation costs . . . 50

1 ERP Interface for Packaging Material Needs 53
2 Operational sheet used in the Recovery Operator - before 54
3 Operational sheet used in the Recovery Operator - after 55
4 Forecasted Production Needs and Returns in VF plant 56
5 Forecasted Production Needs and Returns in LE plant 56
6 Forecasted Production Needs and Returns in VN plant 56
7 Pareto chart and heat map representing the proposed yearly returns to VF plant . 57
8 Pareto chart and heat map representing the proposed yearly returns to VN plant . 57

List of Tables

3.1 Client Segments according with their obligation to return pallets 14
3.2 Opportunities for Improvement and Targeted KPIs 20
3.3 Summary of the proposals with the evaluated level of difficulty and impact for the organization 23

4.1 Notation 26
4.2 Plants' needs per type of pallet and period $D^t_{j,p}$ 30
4.3 Purchasing costs per type of pallet, supplier and destination plant $Cf_{f,j}$ 30
4.4 Boolean variable to identify connections with unit cost per pallet $Ut_{i,j}$ and Fixed Transportation Costs between the different regions and plants $Tc_{i,j}$. 31
4.5 Available Stock of pallets in each region in the beginning of the period to study . 31
4.6 Number of pallets sent to each region as a palletized unit load of finished product $y^t_{i,p}$ 32
4.7 Transferring Transportation Costs between different plants $Tt_{j,k}$ 32
4.8 Minimum unitary cost of returns between the different regions and plants 32
4.9 Number of pallets returned from all regions to all plants in each period $X^t_{i,j,p}$ . . . 32
4.10 Number of vehicles allocated to returns from the different regions to all plants per period $nv^t_{i,j}$ 33
4.11 Number of pallets purchased to each supplier per plant and period $Xn^t_{f,j,p}$ 33
4.12 Number of vehicles allocated to transfers between plants per period $nt^t_{j,k}$ 33
4.13 Total Costs 34

5.1 Percentage of stock that should be returned per region to each plant according to the budget activity of 2016 36
5.2 Percentage of Stock returned from Barcelona to the different Iberian Plants . . . 38
5.3 Number of vehicles needed to assure the returns between Region ES08 and all the Iberian plants 39
5.4 Unitary Pallet Cost of the Returns between ES08 and all the Iberian Plants . . . 39
5.5 Minimum Cost of Purchasing the different types of pallets for each plant 39

Chapter 1

Introduction

Advances in communication and transportation technology, combined with free-market ideology, have given goods, services, and capital unprecedented mobility. This increasing economic integration and the interdependence of economies across the world created a global marketplace that fosters new competition, demands higher levels of efficiency and requires true expertise in supply chain optimization across all industries.

The glass industry comprises five sectors covering different glass products, applications and markets. The container glass sector, the industry where BA Glass is inserted, accounts for 70% of the total EU glass production. Other sectors comprise the production of flat glass, representing 25% of the EU glass production and serving the construction, automotive and solar energy industries, the production of continuous-filament glass fibre known as fibre-reinforced polymers, the manufacturing of domestic glass, tableware and cookware and, lastly, special glass such as lighting, laboratory and ophthalmic glass (GAE).

As result of globalization and with very few ways to differentiate itself, the commodity-like nature of the container and packaging industry requires exceptional operational efficiency to achieve above-average returns.

In a company where costs related to packaging reach up to 9% of the total costs, returnable logistical packaging systems can offer significant cost savings over traditional single use packaging by reducing routine package purchase (Rosenau et al., 1996).

The present thesis, developed in the Strategic Procurement Department of BA Glass, had its focus on the optimization of reverse logistics flows of reusable packaging materials, as a way to reduce the overall packaging costs without jeopardizing the inherent quality of the materials. To tackle this challenge and to support medium term planning, a mathematical model that considers the production needs for each type of pallet in the existing plants, as well as the expected quantity held by the customers, was developed.

Another focal point was to evaluate the operational activity of Returnable Packaging Management, look for inefficiencies, suggest improvements and develop a standard procedure to be used in the several plants of the group.

1.1 BA Glass Presentation

BA was founded on the 5th of April 1912 as Barbosa & Almeida, Lda and had as its main purpose the commercialization of glass bottles. In 1930, the company started its industrial activity in Campanhã and changed its name to "Fábrica de Vidros Barbosa e Almeida, Lda". The year of 1993 was marked by the acquisition of 94,5% of "CIVE - Companhia Industrial Vidreira, SA, a company located in Marinha Grande that would be merged two years later. In 1998, occured the incorporation of the Spanish company 'BA - Fabrica de Envases de Vidrio Barbosa & Almeida, SA', (90,15% of the capital held by BA), and the construction of new a factory in Villafranca de los Barros. One year later, in 1999, BA acquired 54,3% of 'Vidriera Leonesa, SA' (VILESA), a company with an industrial unit in Léon (Spain). In 2001, these two companies were merged and the company's name was changed to 'BA Vidro, SA'. In 2008, the mother company now called 'BA Glass I - Serviços de Gestão e Investimentos, SA' acquired the Sotancro Group which allowed BA to broaden its product range and client portfolio to include the pharmaceutical and cosmetics sectors. The acquisitions continued with the Polish group Warta Glass, in 2012, and with HNG Global, a German glass packaging company in 2016. Later in the same year, BA acquired the glass packaging businesses of Yioula Glass in Greece, Romania and Bulgaria.

With the above-mentioned acquisitions, BA expanded its market to Eastern and Central Europe, consolidating its international customer base and reinforcing its position on the spirits segment.

Currently, BA Group comprises twelve plants in seven countries, Portugal, Spain, Germany, Poland, Greece, Bulgaria and Romania, as it is illustrated in figure 1.1 and has a daily production of more than 14 million units - bottles and jars - for customers operating in the Food & Beverage industries.

Figure 1.1: Location of the different plants of BA Group

1.2 Motivation and Aim of the Project

Due to increasing environmental concerns, countries have gathered efforts to reduce and prevent the production of packaging waste. Through the European Parliament and Council Directive 94/62/EC on Packaging and Packaging Waste (1994), producers became, to some extent, accountable for returning, collecting and recovering packaging waste from the final user.

As Fleischmann et al. (1997) highlighted, attaining a "sustainable" economy requires combining both ecological and economical advantages. Driven by this focus on environmental protection and by the opportunity for cost reduction and value recapturing, BA started collecting packaging materials such as pallets and plastic layers from some of its customers.

As an area that potentially provides competitive advantage, Reverse Logistics is a strategic decision that must be thoroughly evaluated. The aim of the project is, therefore, to optimize the planning of the return flows of pallets from customers, in order to maximize cost savings related to packaging.

Although the expansion strategy boosts long term competitiveness, provides new opportunities for market growth and consolidates the international customer base, it also significantly increases complexity in what concerns management and planning activities. With all the previous acquisitions and to ensure a sustainable exercise, the purpose of the company is no longer to contemplate operations of siloed plants but to consider them as a whole. Hence, to achieve global efficiency, all returns have to be coordinated and scheduled centrally. With twelve plants spread across Europe, it is now fundamental to develop a thorough and critical stance towards the Returnable Packaging Activity.

To attain this, the current project was developed in the Strategic Procurement Department which is divided in two major areas: Central Purchasing and Transport. The Returnable Packaging Operation, inserted in the Transport segment, is responsible for analysing and scheduling the returns of packaging materials (plastic layers and wooden pallets) from certain customers to the different plants. To assure the return of these materials, RP works closely with the Procurement, Sales and Transport teams, as will be depicted further ahead.

1.3 Dissertation Structure

The structure of this dissertation is organized as follows. In order to properly frame the problem and proposed solution, Chapter 2 presents a literature review on Reverse Logistics networks. Chapter 3 describes the Returnable Packaging Management process, during which inefficiencies are highlighted and improvement proposals identified. Chapter 4 presents the proposed mathematical optimization model to streamline the mid term planning of returnable packaging flows and its functioning with the aid of an illustrative example. Chapter 5 includes an evaluation of the results when compared with both the previous planning approach and reality of 2016. This chapter also comprises a brief insight into possible scenario planning strategies and the advantages that could rise from this. Finally, in Chapter 6 the main conclusions are drawn and future enhancements to the work developed are discussed.

Chapter 2

Literature Review

In this chapter, a general review on reverse logistics, hereafter referred as RL, is presented in order to understand the significance of this matter and how it has been studied. Many authors, when approaching this subject, focus on environmental aspects, but the primary purpose of this review lies on economic and supply chain matters. In this context, and to properly frame the problem, reverse logistics is defined and analysed through different perspectives. Afterwards, uncertainty and various ways to approach it are discussed. In conclusion, different perspectives to tackle the RL problems are mentioned with special focus on network design and planning and control.

2.1 Logistics Management and Reverse Logistics

According to the Council of Supply Chain Management Professionals (CSCMP):

> "Logistics management is that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements."

Increasing interest on the reverse flows of goods led to the need of separately defining the concept of Reverse Logistics. The Reverse Logistics Association (RLA) defines it as:

> "The process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of value recapturing or proper disposal."

If we consider forward and reverse supply chains simultaneously, the result network will construct a closed-loop supply chain (CLSC). Atasu et al. (2008) defines CLSC as the design, control, and operation of a system to maximize value creation over the entire life cycle of a product with dynamic recovery of value from different types and volumes of returns over time. Govindan et al. (2015) explains the importance of the explicit business point of view instead of other factors like legal, social responsibilities, or even operational and technical details.

Due to increasing environmental concerns, opportunity for value recapturing and legislations that require manufacturers to establish networks for product recovery, reverse logistics systems have gained special attention in the past years (Gupta et al., 2013).

Reverse Logistics System is defined by Lu and Bostel (2007) as a series of activities, which form a continuous process to treat return-products until they are properly recovered or disposed of.

A holistic view of Reverse Logistics is presented by Ilgin and Gupta (2013), supported several different studies from literature on these activities. The authors state that the stages in a RL process are mainly determined by the type of returns, as can be observed in Figure 2.1.

These returns might be *Commercial Returns* due to false or misleading claims, defective goods or other circumstances covered by consumer rights; *Repair or Service Returns* when products fail to perform their function and are within the warranty period; *End Of Life (EOL) Returns*, a type that has been receiving growing attention by virtue of rapid technology developments, for products that have reached their useful life; *Reusable Container Returns* such as bottles and cans in the beverage and food industry and *Leased Product Returns* for products with a rental agreement under which the owner allows to make use of the equipment in exchange for periodic payments (Equ)

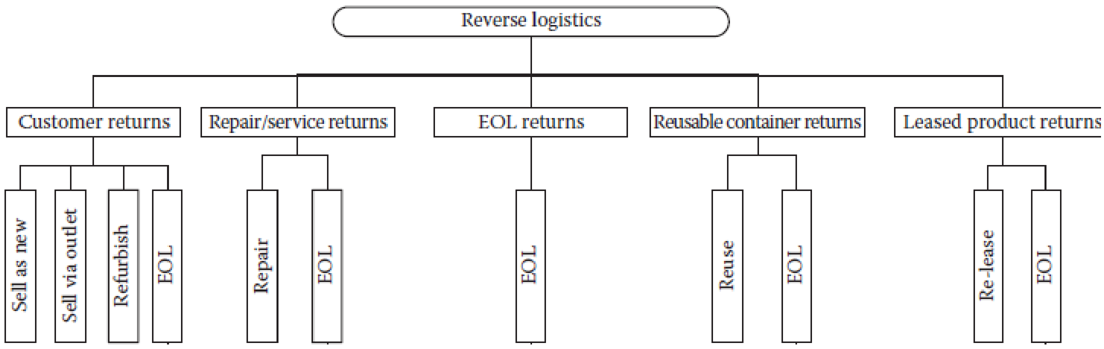


Figure 2.1: Reverse Logistics according to type of returns

However, regardless of their final destination, all products in the reverse flow must be collected and sorted before being sent on to their next destinations (Rogers and Tibben-Lembke, 1998). Hence, the product recovery option is also determinant in the resulting reverse logistics system.

Commonly, these options are reuse, repair, refurbish, remanufacture, and recycle. *Reuse* refers to products that can be used more than once after being cleaned or reprocessed; *Repair* contemplates products that can be restored to a good condition by finding the source of the defect and, either, recovering it or replacing minor components; *Refurbishment*, on the other hand, considers the replacement of major components (Ghoreishi et al.); *Remanufacturing* implies the disassembly of the product into its cores that are subsequently stored and used in the production of a new product; *Recycling* focuses on extracting raw materials without conserving any product structure.

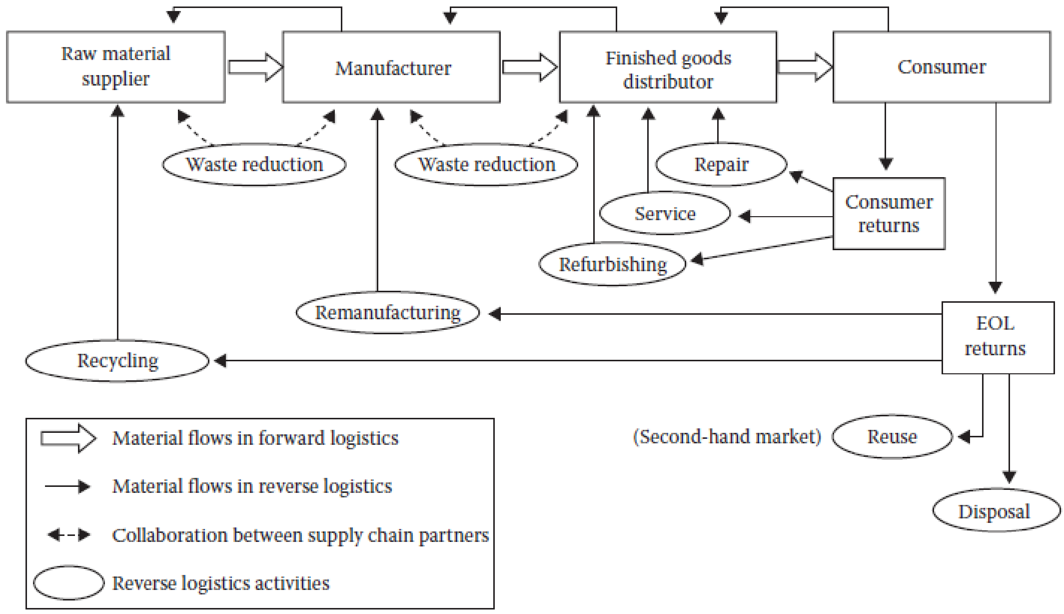


Figure 2.2: Basic Activities and Flows in RL (source Srivastava)

Figure 2.2 shows the basic flow diagram of the aforementioned activities where the complexity of operations and the value recovered increase from bottom left to top right, Srivastava (2008).

Reverse Logistics differs from Forward Logistics in many aspects, being the fundamental one the level of uncertainty, which is not solely related with the timing and quantity of returns, but also with processing times that highly depend on the condition of the returned goods. Owing to this uncertainty, Reverse Supply Chains tend to be relatively more stochastic than Forward Supply Chains.

Nevertheless, RL Problems can be tackled in several different ways. Ilgin and Gupta (2013) present an overview of the different perspectives by referring to several authors and research topics such as: Network Design, Transportation, Facility Layout, Information Technology, Forecasting, Production Planning, Capacity Planning, Inventory Management, Performance Measurement, among others.

2.1.1 Reverse Logistics Network

The efficient implementation of reverse logistics requires appropriate logistics network structures to be set up for the arising products flow (Yongsheng and Wang, 2008). Logistics network design refers to the more traditional elements of logistics strategy. These include aspects related to the physical flow of the product through a company's operation, such as the manufacturing location from which a product should be sourced, the inventory that should be held, the number and location of depots, etc (Rushton et al., 2010). In what Reverse Logistics is concerned, these decisions involve the location of collection centres, recovery and disposal facilities, the flow of returned products, inventory level, among others.

On this topic, Pishvaee et al. (2010) propose a mixed integer linear programming model for the design of a multi-stage reverse logistics network. The model considers not only the subset of facilities to be opened, but also a transportation strategy to satisfy the demand of the manufacturing centres minimizing transportation and fixed opening costs. As Network design problems were proved to belong to the class of NP-hard problems (Non-deterministic Polynomial time problems) which makes solving to optimality an extremely time-consuming task, the authors further propose a simulated annealing (SA) algorithm with special neighbourhood search mechanisms to find a near optimal solution. The performance of the algorithm is then evaluated by comparing the associated numerical results to the exact solutions obtained by a tool for optimization modelling - Lingo.

Considering a certain degree of uncertainty in terms of capacity, demand and quantity of product, Hosseinzadeh et al. (2012) also propose a probabilistic mixed integer linear programming model (MILP) that minimizes both fixed and transportation costs for the design of a multi-stage, multi-product logistics network. Additionally, the authors developed a priority based genetic algorithm to be able to solve large dimension problems.

The same problem is again addressed by Ayvaz and Bolat (2014), who introduced the quality uncertainty factor in a multi-product, multi-stage recycling network. In the first stage, the model aims to define the location of inspection and recycling centres and to assign collection points to inspection centres. In this stage, an expected value for the uncertain parameters is considered, thus making the model deterministic. The second stage, in contrast, addresses the optimization of product flows between the different centres contemplating the uncertainty of both quantity and quality of the returns.

Additional research on this topic is presented by Suyabatmaz et al. (2014) with two hybrid simulation-analytical models that incorporate the uncertainties in the reverse logistics design problem. The analytical model, developed for a third-party logistics provider, intends to optimally determine the locations of the test centres under a set of parameters and constraints, whereas the simulation model validates and verifies the previous decisions under a stochastic environment where the amount of returned products is random.

As it can be seen in figure 2.3, the procedure is initialized by solving the optimization model with the given deterministic data. The solution is used in the simulation model and then evaluated according with certain performance measures relative to capacity utilization and collected return volume. If the criteria is met the solution is accepted and the model terminates. Otherwise, the analytical model is revised via updates in the parameters or constraints iteratively until a solution is accepted.

On the second approach, instead of exchanging problem-specific parameters between the analytical and simulation models, the interaction is governed by reflecting the impact of uncertainty obtained via simulation in the objective function of the analytical model.

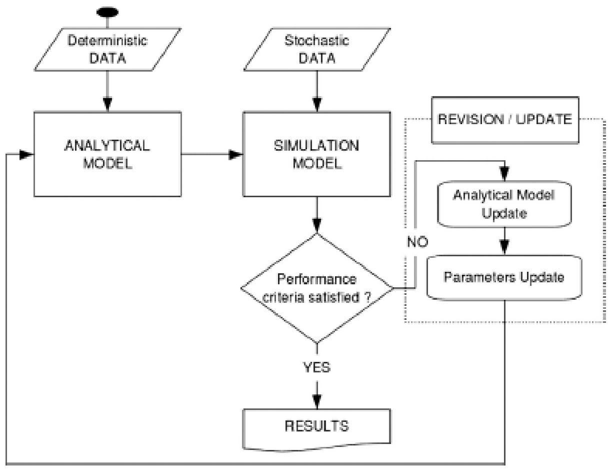


Figure 2.3: Outline of the general framework for hybrid simulation-analytic modelling (Suyabatmaz et al., 2014)

2.1.2 Planning and Control

Bozarth and Handfield (2008) define Planning as a "set of tactical- and execution-level business activities that includes master scheduling, material requirements planning, and some form of production activity control and vendor order management."

According to the authors, the Master Scheduling determines when specific products will be produced, in order to fill specific customer orders. Once the Master Scheduling is complete, the Material Requirements Planning calculates the timing and quantities of detailed material orders to support it.

Traditional planning would only consider materials manufactured in-house or materials purchased to other supply chain partners and suppliers. Recently, some authors, aware of the cost savings and increased competitiveness of RL, presented models that, besides procurement, contemplate the return flows of materials.

Kim et al. (2006) propose a general framework and mathematical model for a remanufacturing system with two alternatives for supplying parts: either ordering the required parts to external suppliers or overhauling returned products. The mathematical model maximizes the total costs savings by optimally deciding the quantity of parts to be processed and the number of parts to be purchased from a subcontractor. The developed model is then validated through a set of experimental data reflecting a practical business situation.

Considering that competitiveness rises not only from companies but from entire supply chains, Zuluaga and Lourenço (2002) propose a model to a multi plan production environment to take advantage of the coordination and integration of several plants. The authors developed an extension to a medium term production planning model by considering, not only the plants, suppliers and distribution centre, but also a central recovery plant through which returns are made. Additionally, some other aspects such as the uncertainty in the quality and quantity of the products returned, the possibility of manufacturing a product with both new and reusable parts and consequently the need to take into account different new processes were considered. In a Optimization - Simulation perspective, Zuluaga and Lourenço (2002) developed an optimization model, taking the expected returns and quality, to obtain the number of units to produce, the purchasing strategy and the estimation of inventories. Then, with the optimal production scheduled and purchasing strategy as inputs, the authors simulated the quantity and quality of the returns, with the purpose of analysing the inventory behaviour of the returned materials and the total cost of the system.

Within the subject of production planning and control for closed-loop supply chains, Jayaraman (2006) presents an analytical approach for an intermediate to long-range planning environment that aims to support production planning, inventory control and other tactical decision making. The model, validated in a mobile phone remanufacturer, minimizes inventory holding costs, costs of disassembling, remanufacturing, purchasing and disposal.

2.2 Scenario Planning

Scenario is defined by Schoemaker (1991) as script-like characterization of a possible future presented in considerable detail, with special emphasis on causal connections, internal consistency, and concreteness.

By accepting the notion of uncertainty, it is possible to open up the idea that there are several courses of action that an organization may choose. Scenario planning is, therefore, an effective approach to discuss and explore the factors creating state uncertainty, through the development of a number of plausible, coherent scenarios that reveal the antecedents and potential outcomes of the factors creating uncertainty (Van der Heijden, 2005). Indeed, several authors agree that the best way to cope with uncertainty is to try and include it in the planning process (Chermack and Nimon, 2009).

According with van der Merwe (2008), there are several different applications for scenarios and although the general framework remains the same, the uses and applications can shift the timetable and depth and reduce or amplify other important components of the process. Among others, the author refers to *Decision scenarios*, used to improve the quality of decision making by testing the robustness of decisions and *Environmental Scanning* focused on external dynamics and how they might unfold, which enables organizations to learn about and take a position on specific assumptions on which their strategy is based.

In what concerns uncertainty, Milliken (1987) identifies three types of perceived uncertainty in the contextual environment: (a) state, (b) effect, and (c) response uncertainty. State uncertainty occurs when the organizational environment or a particular component of that environment is perceived to be unpredictable. Effect uncertainty is defined as an inability to predict what the nature of the impact of the future state of the environment or environmental change will be on the organization. Response uncertainty is characterized by a lack of knowledge about the response options and/or an inability to predict the likely consequences of a response choice as follows.

To anticipate changes it is necessary to start by looking at the driving forces that may have an impact on factors affecting the business of the organization (Lindgren and Bandhold, 2009). Once, the forces are known, the amplitude of the impact is studied and multiple scenarios can be created to characterize the range within which the factors are likely to evolve. Schoemaker (1991) argues that scenarios, in this sense, are not states of nature nor predictions. because the focus is not on forecasting the future, or fully characterizing its uncertainty, but rather on bounding it.

2.3 Consideration

In order to ensure that the concept of total logistics is put into practice and that suitable trade-offs are achieved, it is essential that a positive planning approach is adopted. This approach should be undertaken according to a certain hierarchy that reflects different planning time horizons. These are generally classified as strategic, tactical and operational (Rushton et al., 2010).

As all strategic decisions of this RL system, specially in what concerns the location of recovery facilities, had already been taken, the present thesis focus on mid-term or tactical planning. Hence, Network design is only studied to get an insight about the physical flows of materials and to develop a transportation strategy to satisfy the demand of all plants.

In another perspective, Planning and Control was contemplated to consider the other supplying option of externally purchasing materials while maximizing the overall cost savings when both options are taken into account.

Lastly, Scenario Planning is studied to tackle the uncertainty related with both the quantity and quality of the reverse logistics system and to ponder the impact of external factors such as transportation and purchasing costs in the overall chain.

Chapter 3

Returnable Packaging Management

Packaging is defined in (Bramklev, 2001) as "All products, independent of material, that are produced in order to contain, protect, handle, deliver and present goods, from raw material to final product and from producer to user and consumer".

It can be classified to reflect its different levels as primary, secondary or tertiary (Hellström and Saghir, 2014). Primary Packaging is the one in direct contact with the product, in this case, BA's core product - a glass container. Secondary Packaging is a set of primary packages and Tertiary Packaging is conceived so as to facilitate the safe movement, storage and transport of goods, in order to prevent physical damage due to inappropriate handling. This project tackles the management and planning activities of tertiary packaging,

In BA, after the production, the containers are assembled in pallets with several tiers divided by plastic layers as can be observed in figure 3.1. This elements of Tertiary Packaging and its management are the object of this study.

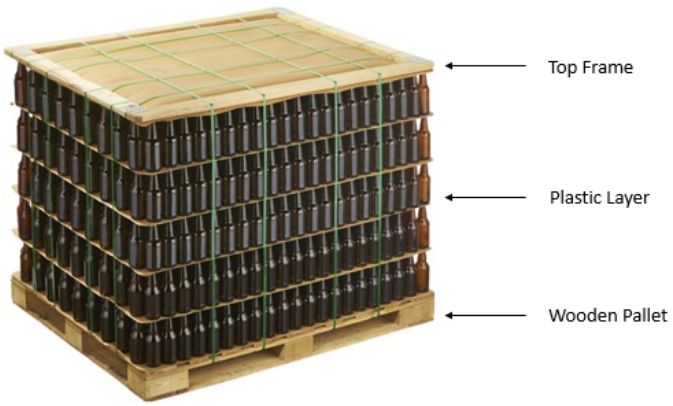


Figure 3.1: Finished Product Pallet

3.1 Returnable Packaging Management

With the increasing number of plants and consequently rise of material requirements, BA found in Returnable Packaging an opportunity for significant cost savings as it considerably reduced routine packaging purchasing. Although BA returns both plastic layers and wooden pallets, only wooden pallets are considered in this process as plastic layers lie under the responsibility of a third-party supplier and are thus seen as rented materials.

Despite providing a competitive advantage by reducing packaging related costs, assuring the quality of returned pallets is not BA's core competence. Hence, the activity of sorting and repairing packaging materials is carried out by a third-party recovery operator that in some cases shares BA's facilities.

Even though BA would benefit with increasing returns, not all customers are required to do so. This means that undertaking a contract, BA's customers are divided into different segments in what concern their obligation to return packaging materials as can be observed in table 3.1.

Table 3.1: Client Segments according with their obligation to return pallets

Client Segment	**Description**	**Mandatory Return**	
		Pallets	Plastic Layers
TD	Packaging Materials are charged and credited after return		
ND	Packaging Materials are neither charged nor credited	x	x
KD	Pallets are not charged but Plastic Layers are	x	
PD	Pallets are charged but Plastic Layers are not		x

The aim of the Returnable Packaging Management Process is to assure that packaging materials are available to supply the production lines in every plant of the group while minimizing the overall costs of this activity. All returns are, therefore, coordinated and scheduled centrally, taking into consideration the MRP, the available stock in each plant, the available stock in each recovery facility, the transportation costs, the transferring costs between plants and the costs of purchasing new materials.

3.1.1 RP Management Process *AS IS*

As is, the Returnable Packaging Management Process has several activities and participants allocated to different functional areas. Figure 3.2 depicts the flow of activities and the responsibilities of each actor throughout the process. The different tasks and interactions are analysed in detail and suggestions for improvement are proposed.

A. Reviewing Packaging Necessities and B. Analysing Packaging Stock

Based on the Master Production Schedule, the ERP system creates a plan of packaging material needs which includes current stock and forecasted out-of-stock (**OOS**) date for all the different packaging materials and plants of the group.

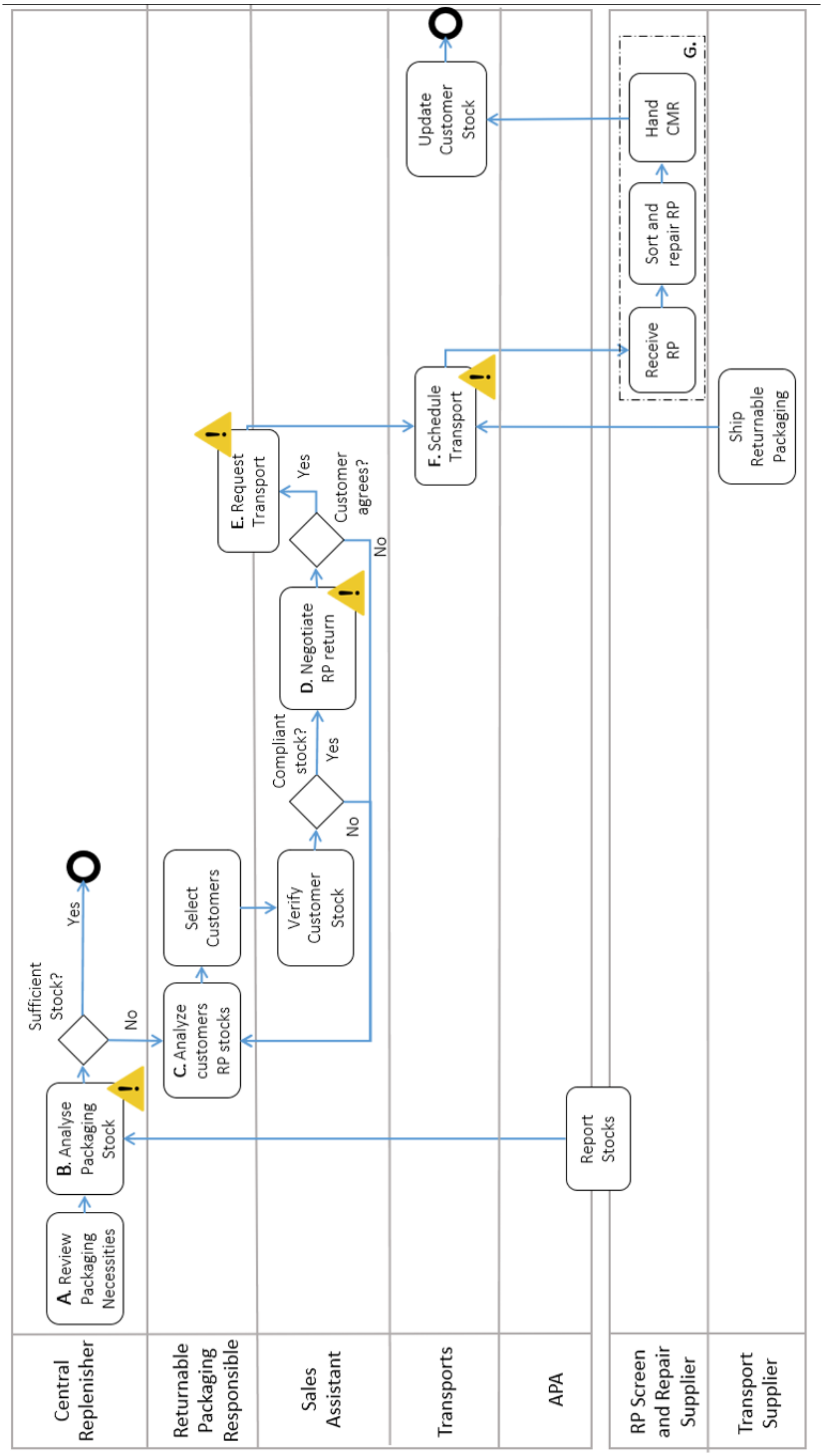


Figure 3.2: Returnable Packaging Management Process Model *AS IS*

As the reception and storing of packaging material is not always performed by an entity that belongs to BA, the current stock of wooden pallets in each plant is not updated. Hence, three times a week the Central Replenisher receives an email per plant with the actual stock, either from the Recovery Operator, in case it shares the same facilities as BA, or from the APA, the finished product warehouse, otherwise.

This is an highly inefficient activity as it does not take advantage of the ERP system and obliges the Central Replenisher to manually calculate the stocks and quantities to buy and/or return for each type of pallet. Furthermore, as it is dependent of other actors, the task is not only time-constrained but also more prone to errors.

C. Analysing Stock in Clients

In order to accomplish the aforementioned cost savings, returns have to be analysed and constrained based on several factors such as distance, transportation costs, costs of purchasing new pallets and costs of recovery.

After receiving non detailed information about the needs of each plant, the Returnable Packaging Responsible performs a preliminary analysis of the clients' stock of pallets and, based on their condition, selects which clients should be notified. At this stage, the RP Responsible generates single reports and contacts the assigned sales assistant to request the return.

The reports consist of different transactions of materials between BA and each customer and include information regarding the shipping point, destination, date, quantity and consequently the total amount in stock. This balance is automatically generated by the ERP system every time a sales order is fulfilled or a return is carried out.

D. Negotiating and Scheduling Returns with customers

After receiving the request from the RP responsible, the sales assistant informs the client about BA's interest in collecting the pallets. The client either confirms the quantity in the report and accepts the collection of the pallets or states that the materials are still in use and, therefore, are not yet available to be returned. In the first situation, the collection is scheduled and the Transports team is contacted by the RP Responsible or the Sales Assistant to assure the return. In the second case or if the Sales Assistant or customer do not reply, the RP responsible needs to once again analyse the list of potential clients and repeat the process.

As it has been shown, most delays occur at transition points from one process step to another (Arunagiri and Annamalai, 2013). Involving the Sales Assistant in this process, creates two transitions, which does not simply cause delays but also hinders the flow of information.

E. Requesting Transportation

So far, it has not been clearly defined who should perform the request to the Transports Team. This lack of delimitation results in Sales Assistants directly contacting the transport team requesting the collection of materials in certain clients. In this case, besides not being evaluated if the return is profitable, information about the destination of the wooden pallets is not provided. Hence, another request from the RP responsible with information regarding the destination plant has to be made. In some other cases, the SA directly contacts the transport supplier with the Transport Team in carbon copy (cc). This usually occurs with clients that are located closer to plants and therefore is self-evident where the return should be carried out to. However, this does not take into consideration possible stock-outs in other plants, where either purchases or transfers, options that incur in greater costs, will be needed to supply production lines.

Scheduling Returns

After being notified about the need to return pallets, the Transport Team is responsible to select a transport supplier and agree the conditions of the service.

⚠ As the quantity and condition of the pallets are often unknown, the transportation order does not contain information on this matter. This lack of information in what concerns the quantities to arrive at each plant hampers the work of the Central Replenisher as he cannot make an informed decision about the quantity to purchase.

⚠ Another issue lies on the fact that an interface to preview future returns is not available which makes it impossible to schedule other returns with regard to recovered facility's capacity, resulting in an unbalanced number of trucks arriving each day.

Recovery Facility Operation

As previously mentioned, the recovery operation is not performed by BA, but by a subcontracted company. The processes of its operation in two different contexts, the first when the outsourced company is located in BA's facilities and the second when it is not, were mapped and analysed.

In the first case, the Recovery Operator is not only responsible for receiving, sorting, repairing and shipping the returned wooden pallets but also for receiving all packaging material, including new pallets and plastic layers, storing them in the warehouse and feeding the production lines. This process is depicted in Figure 3.3 and will be explained hereinafter.

When a truck of returnable packaging arrives, the Recovery Operator is responsible for unloading it, dividing per type, counting and validating the quantity of pallets present in the dispatch note (CMR).

⚠ After this, the operator stores the pallets in a buffer that feeds the selection line. As the available space is limited, the wooden pallets are stored without regard to their origin and sometimes even directly unloaded to the selection line. This fact entirely compromises the traceability of the packaging materials which has a significant impact for BA. As a proper and careful handling of Returnable Packaging is not on customers' top priorities, the returned pallets are sometimes not compliant with BA's specifications or arrive in a non repairable condition.

This lack of control does not allow BA to take preventive or corrective measures such as informing customers about the overall condition of the shipment, invoicing damaged pallets or in

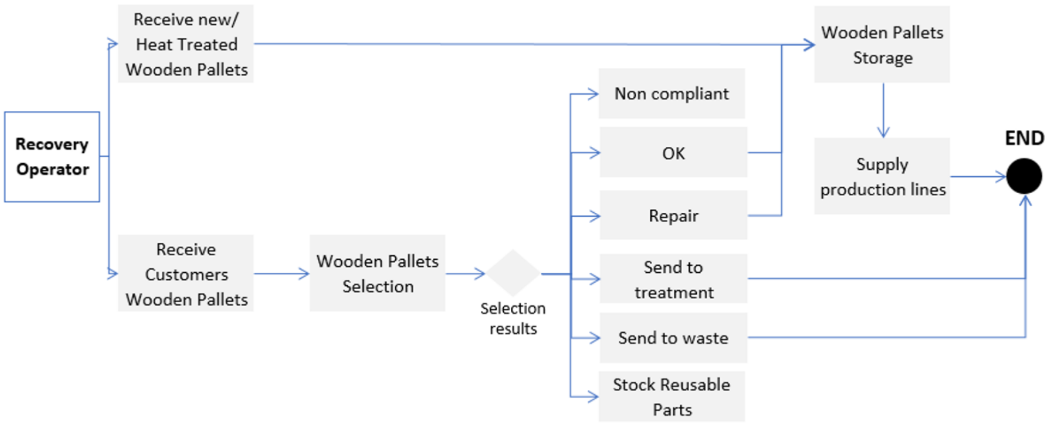


Figure 3.3: Recovery Facility Process Model in Avintes

last resort, changing the customer to a different segment where pallets are invoiced and returns are not mandatory.

The classification and subsequent sorting of these pallets consists in checking for the presence of broken or loose bars, broken or loose cubes, protruding nails, traces of stretch wrap, sharp edges, mould/fungus, misaligned parts, dirtiness, and lastly non compliant dimensions. These characteristics are schematically represented in Figure 3.4.

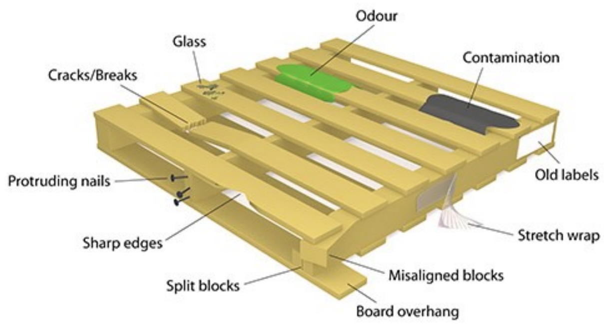


Figure 3.4: Characteristics to search for when classifying and sorting pallets

The pallets are then sorted according with their characteristics in non compliant, good, repairable, requiring heat treatment or non repairable within which they can be considered scrap or dismantled to stock reusable parts, as can be seen in figure 3.3.

Non Compliant Pallets belong to other competitors and because of dimensional characteristics are not suitable to enter the production line;

Good Pallets are ready for reuse if:

- Immediate cleaning is accomplished in the selection line;

- Visible heat treatment stamps are exhibited;
- The components are aligned and dimensions are compliant with BA specifications;
- There are no traces of broken or loose elements, protruding nails and contaminants.

Repairable Pallets are pallets that can be overhauled and reinserted in the supply chain with minor changes. Pallets are considered repairable, if their mechanical and functional characteristics do not compromise one extra cycle of use, when:

- A maximum number of three components are misaligned and/or broken
- Visible heat treatment stamps are exhibited;
- Dimensions are compliant with BA specifications;
- There are no traces of mould/fungus or other contaminants.

Requiring Heat Treatment Pallets need to be subjected to Heat Treatment because of International Standards For Phytosanitary Measures. ISPM 15 is a standard developed by the International Plant Protection Convention that directly addresses the need to treat wood materials to reduce the risk of introduction and spread of quarantine pests associated with the movement in international trade of wood packaging material made from raw wood (IPPC, 2009). The pallets are required to undergo Phytosanitary treatment if:

- Do not exhibit any heat treatment stamps;
- Exhibit only one heat treatment stamp;
- The heat treatment stamp is barely visible;
- The number in the stamp is not composed by four digits.

Non repairable pallets can either be dismantled to obtain reusable parts or can be considered scrap. The pallets are considered scrap if:

- There are traces of contaminants or mould/fungus;
- Immediate cleaning is not possible;

and are dismantled if:

- There are no traces of contaminants and mould/fungus;
- The number of misaligned or broken components is greater than three.

At the end of each week, the RP operator hands all the CMR documents from returning trucks to the Transport Team that manually creates return orders that update each customers' stock. Additionally, and for billing purposes, the subcontracted company creates and forwards a report with all the classified and repaired pallets.

3.1.2 Opportunities for Improvement

For most logistics operations it is possible to identify certain key measures or metrics that provide an appropriate summary measurement of the operation as a whole and of the major elements of the operation. These are very often called key performance indicators (KPIs) (Rushton et al., 2010). Table 3.2 depicts an overview of the Opportunities for Improvement that have emerged from the diagnosis and the corresponding KPIs that would be affected.

Table 3.2: Opportunities for Improvement and Targeted KPIs

Activity	Agent	Impacted KPI
B. Analysing Packaging Stock	Central Replenisher	- Average completion time
D. Scheduling Returns	Sales Assistant	- Negotiation lead time
E. Request Transport	Undefined	- Number of emails exchanged with the Transport team - Unit cost of returned pallet
F. Schedule Transport	Transport Team	- Number of shipments per unloading period - Average wait time until unloading
G. Receive RP	Recovery Operator	- Scrap Rate - Repairable Rate - Non compliant Rate

Currently, as it is dependent of other actors, analysing packaging stock can reach up to four hours when it could be performed in less than twenty minutes. The responsibility for this inefficiency does not lie in the Central Replenisher but on the other parties that are required to send a report with the RP stock and do not manage to do it on time.

The negotiation lead time is also a very important factor which is being delayed by the number of transitions between actors in both BA and the client side. If the contact was established solely between agents directly in charge of returning wooden pallets, it would be possible to reduce this lead time and routine purchases would be minimised.

Defining the responsibility for the activity of requesting the return will reduce the number of emails exchanged with transport team but will also ensure that only cost effective returns are performed. Returns are considered cost effective, when the unit cost per returned pallet, which comprises transportation, classification and repair costs, is lower than the cost of externally purchase one pallet.

In the company perspective there are three periods for loading and unloading materials and products throughout the day. Having information on this matter, which is not currently being materialized in what concerns returnable packaging, will result in a more even number of trucks arriving per period and consequently in a lower average wait time between arrival and unloading.

Finally, as when pallets reach the classification line their origin is not known, there is no accurate information about the condition in which pallets are sent from specific customers. As previously stated, this lack of information, hinders the possibility of reporting non compliances and directly tackling the lack of commitment of certain clients in what concerns returnable packaging.

3.1.3 Proposed Improvements

All proposals aim to eliminate inefficiencies and smooth the flow of activities, reducing delays and enhancing communication and exchange of information between the different actors.

The majority of the proposals focus on taking further advantage of ERP's features and functionalities. As stated by Bozarth and Handfield (2008), Enterprise Resource Planning (ERP) systems have the utmost importance for the organization as they pull together all of the classic business functions, such as accounting, finance, sales, and operations, into a single, tightly integrated package that uses a common database.

To fully exploit and benefit from the current ERP interface related with packaging material production needs (see Appendix 1) the available quantity of pallets for production should be reset and posteriorly updated every time new packaging materials arrive from external suppliers or every time compliant and ready to reuse returnable packaging is transferred from the recovery operator. A regular reckoning and consequent update would still have to be carried out by the APA because of sudden changes in production or material requirements. These changes would be translated in a more thorough monitoring of wooden pallet stock and, therefore, a leaner analysis of what should be purchased.

The most ambitious proposal lies on the creation of a new ERP interface for monitoring Returnable Packaging Returns. This interface would be available for all actors of the process and would, primarily, contain information such as collection point, collection date, type of pallets, quantity to return, destination and forecasted date of arrival. Once the returned pallets were sorted in the Recovery Operator, fields like percentage of good, non compliant, repairable and non repairable pallets could be filled in to provide further information on the returns.

With this new feature, the RP Responsible would be able to better balance the arrivals of Returnable Packaging, while the Central Replenisher could make a more informed decision with regard to what to purchase from suppliers. Another potential advantage could rise from prioritizing the selection and repair of certain shipments according with the type of pallet to better match production needs. Together with the previous proposal, this feature would eliminate the need to manually create return orders to update customers' balance of RP materials. This interface would also pose as an advantage for the Recovery Facility as it would provide additional information on returns which would result in a better planning of the overall operation. Besides it would eliminate the need of creating weekly reports of classified and repaired pallets and the responsibility of so often counting the number of pallets in stock either by the APA or the Recovery Facility Operator.

Furthermore, the continuous use of this platform would result in more accurate data related with returns that would positively influence the overall process. By knowing the historic condition rates of the clients, the Central Replenisher could, for instance, purchase a larger quantity of

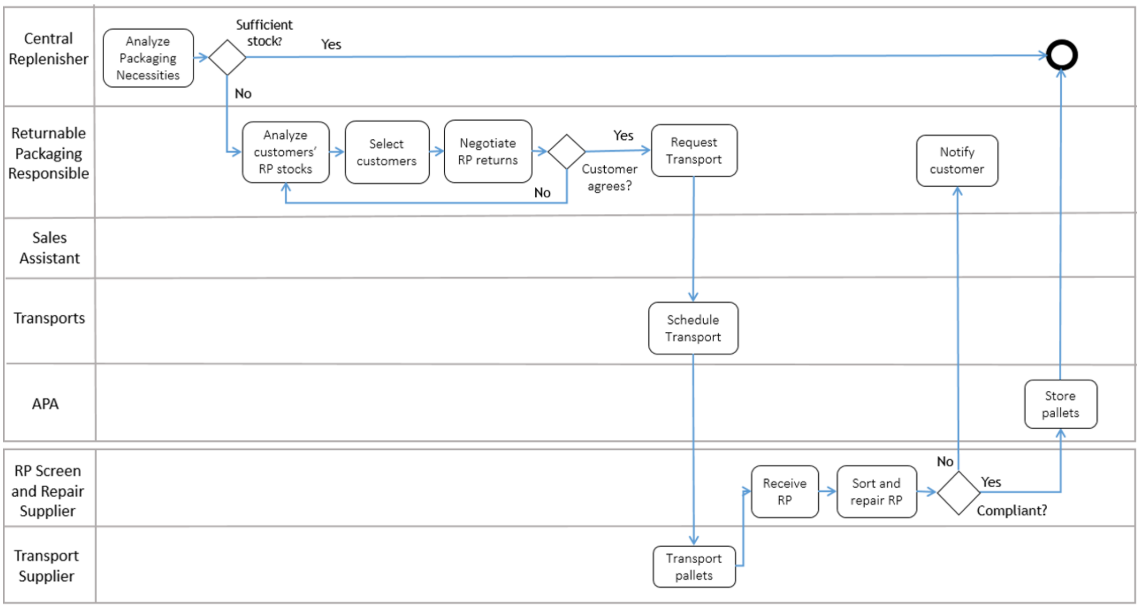


Figure 3.5: Proposed Returnable Packaging Management Process Model

wooden pallets because an expected shipment comes from a client that usually returns 20% of scrap.

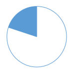
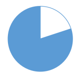
To accomplish this, traceability of returned pallets is a crucial factor. As previously mentioned, it was observed that the handling of the returned pallets did not assure the origin was known at all points prior to selection. Hence, several solutions were discussed with the Recovery Operator and it was established that the pallets would have to be stored and identified per shipment with an internal number and settled that the sorting lines could only be fed with pallets from the same shipment. For this to happen and in order to guarantee a defined and limited space for each shipment, some changes in the layout of the buffer of pallets to classify had to occur. In addition, the operational sheets used to track the number of classified and sorted pallets, previously changed once a day, had to be discontinued and a new version for each shipment was developed. Both sheets can be consulted in Appendix

Lastly, another improvement point would be to reduce the number of transitions, which could be pulled off if the responsibility of the Sales Assistant was absorbed by the RP Responsible whom would directly contact someone accountable for the packaging materials on the client side. This reduction in the number of actors would result in well defined responsibilities, improved communication and consequently in a reduction of negotiation time with the client.

To sum up, in the proposed process model, represented in figure 3.5, activities like reporting the stocks, individually analysing packaging inventory of each plant, weekly handing over CMR and manually updating customer stock would cease to exist; The number of transitions between actors would be reduced and new responsibilities would be created, such as contacting the customer with a report.

Table 3.3 summarizes the improvement proposals and their impact for the different actors and

Table 3.3: Summary of the proposals with the evaluated level of difficulty and impact for the organization

Proposal	Difficulty	Impact
Update RP Stock directly on SAP		- Reduce average completion time of analysing packaging stock -Eliminate e-mails
Develop an ERP interface for monitoring RP Returns		-Eliminate e-mails between the RP manager, Sales Assistant and Transport Team -Eliminate activities of manually updating customers' stock -Increase visibility to all actors -Balance returns
Create a database with contacts directly responsible for RP on the customers' side		-Absorb responsibility of Sales Assistant - Reduce Negotiation Lead Time
Assure traceability of all returned pallets in the classification process		-Possibility of applying corrective measures with specific clients - Reduce scrap and non compliant rates
Increase the overall percentage of demand fulfilled with cost effective returns		

overall organization. Although there is a general structure for having information related to stock directly in the ERP interface of packaging material needs (Appendix 1), another intermediate module would have to be created to allow either the recovery operator or the APA to update the stock every time there is a transfer of material between the outsourced company and the finished product warehouse. Currently, as the Information Technology workforce is focused on the integration of the recently acquired plants, the development of new modules and interfaces is not a priority. Despite providing advantages, ERP related matters cannot be tackled immediately, therefore both the first and second suggestions were put on hold.

In a large company as BA where the organizational structure and external points of contact are well defined, the creation of a database with contacts directly responsible for RP on the client side, although recognized as advantageous, is a proposal that needs to be further discussed with the several departments.

Still, the Returnable Packaging Procedure was reviewed and some changes were implemented in the activities of requesting returns and updating customer stock. Return requests are mostly performed through an order that can only be generated by the RP responsible which reduces the number of e-mails sent to the Transport Team, assures all returns are cost effective and are accomplished taking into consideration production needs. Moreover, this order eliminates the need of manually updating the customer stock as the different quantities of compliant, repairable, non repairable and non compliant pallets can be altered directly in the transportation order. Furthermore, traceability in all Portuguese Recovery Facilities was ensured through small changes in the layout of storing space and internal processes.

All the accomplished improvements enhanced the global smoothness and efficiency of the process and will in the mid term expectedly increase the percentage of demand that is fulfilled with cost effective returns.

Chapter 4

Optimization Mathematical Model for Packaging Planning

Traditionally, it has been considered that suppliers compete against suppliers, factories against factories, distributors against distributors and retailers against retailers. This consideration has changed; companies have realized that the competition in the market is not between companies, but rather between supply chains (Zuluaga and Lourenço, 2002). Now more than ever, cooperation between different companies within a supply chain is fundamental to increase competitiveness.

Besides purchasing goods from external suppliers, this cooperation brought to the table a new option for fulfilling production needs while reducing costs: returning and overhauling materials from customers.

However, this new source of supply can only be translated in cost savings when thoroughly analysed and planned. The proposed model was developed to reach an optimal solution to support medium term planning and serve as a guide to daily operations of returnable packaging materials. This solution aims to bring the planning activity closer to the operational reality and to increase the percentage of demand fulfilled with cost effective returns.

In the current framework, BA is interested in minimizing packaging related costs, while meeting the demand of all different plants by determining, per period, the number of pallets that should be returned, purchased from external suppliers or transferred between plants.

4.1 Model Definition

The following model was developed to consider all the customers that are bound to return pallets, the activity of seven plants, the respective Recovery Operator of each plant, eleven different types of pallets and seven suppliers during the planning horizon of one year divided in 12 periods.

In a first phase, the model was tested considering the production needs of the five plants located in Iberia and the returns of 4 different types of pallets. Later, this approach was used for the plants for which Returnable Packaging is centrally managed, namely the Iberian and Polish plants.

As some customers do not have a sizeable flow of materials to assure monthly or even yearly profitable returns, clusters of clients were defined. In other words, instead of specifically considering a single customer's location as a collection point, regions where several customers can be positioned are contemplated. The different regions were defined based on an already existing field in the transports industry, which comprises the code of the country and the first two digits of the postal code. For instance, ES28 represents the region of Madrid, DE10 the region of Berlin and IT00 the region of Rome. Portugal is an exception to this rule and is represented with the country code(PT) followed by an internal code for each region.

This multi-period, multi-product model represents the essential aspects of the existing Returnable Packaging System and the notation used is as follows:

Table 4.1: Notation

Indices	
i	Region index i={1,2,...,I}
j,k	Plant index j={1,2,...,J} ; k={1,2,...,K}
p	Pallet index p={1,2,...,P}
f	Supplier index f={1,2,...,F}
t	Period index t={1,2,...,T}
Decision Variables	
$X^t_{i,j,p}$	Number of pallets p returned from region i to plant j at period t
$Xn^t_{f,j,p}$	Number of pallets bought from supplier f for plant j at period t
$Xt^t_{j,k,p}$	Number of pallets p transferred from plant j to plant k at period t
$I^t_{j,p}$	Available Stock of pallet p in plant j at the end of period t
$S^t_{i,p}$	Available Stock of pallet p in region i at the end of period t
$nv^t_{i,j}$	Number of trucks allocated to returns between region i and plant j at period t
$nt^t_{j,k}$	Number of trucks allocated to transfers between plants j and k at period t
Parameters	
$D^t_{j,p}$	Needs of plant j per pallet p and period t
$y^t_{i,p}$	Number of pallets p sent to region i as finished products
$rr_{i,t}$	Return rate of region i in period t
suc_i	Percentage of non repairable pallets sent from region i
tl	Maximum capacity of truck (in number of pallets)
Costs	
Utc	Unitary Cost of transport (€/pallet)
$Tc_{i,j}$	Transportation Cost per truck between region i and plant j
$Tt_{j,k}$	Transportation Cost per truck between plant j and plant k, with $k \neq j$
Cs_j	Classification and Sorting cost per plant j
$Cf_{f,j}$	Cost of buying a new pallet p from supplier f to plant j
$Ut_{i,j}$	Boolean unit cost $Ut_{i,j}$={0,1}
Hc	Inventory holding cost (per unit)

The **objective function** 4.1: aims to minimize the overall costs of packaging, which include minimizing transportation costs, sorting and repair costs, purchasing costs, costs of transferring materials between plants and inventory holding costs.

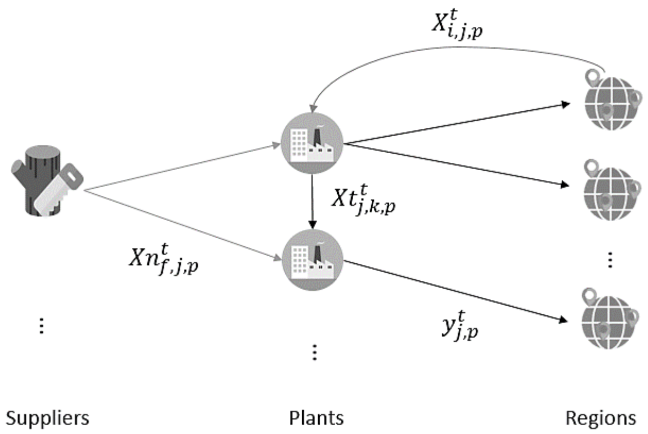


Figure 4.1: Schematic representation of the flow of materials

Transportation costs are divided in two segments, the first when returns occur in Portuguese territory and the second otherwise. This is due to a previous settlement with a transport supplier that, instead of charging a fixed rate as is common in the industry, agreed on charging a unit cost per transported pallet. To identify the different types of payment, a binary variable ($Ut_{i,j}$) was created. This variable takes the value 1 when both origin and destination are located in Portugal and zero otherwise. In the second scenario, based on the number of returned pallets ($X^t_{i,j,p}$), and considering the maximum capacity of trucks (tl) the number of vehicles is generated and multiplied by the fixed rate of the corresponding trip. In what concern sorting costs, the payment criteria is based on the number of sorted and classified pallets, regardless of their condition. This means that all pallets that arrive at a certain plant with more than one cycle of use, will be invoiced by the Recovery Facility. Besides the differences in costs among suppliers, purchasing costs depend, not only on the type of product, but also in which plant they will be consumed.Transferring costs are grouped inside the majority of transportation costs, which means the transport supplier charges a fixed value per trip in which different types of pallets can be carried. Lastly, Inventory Holding Costs represent the associated costs of storing inventory that, at the end of a certain period, remain unsold.

$$\begin{aligned} Min \quad & \sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{p=1}^{P} X^t_{i,j,p} \times Utc_{i,j} \times Ut \quad + \quad \sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{j=1}^{J} nv^t_{i,j} \times TC_{i,j} \times (1-Ut) \\ & + \sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{p=1}^{P} X^t_{i,j,p} \times Cs_j \quad + \quad \sum_{t=1}^{T}\sum_{f=1}^{F}\sum_{j=1}^{J}\sum_{p=1}^{P} Xn^t_{f,j,p} \times CF_{f,j,p} \\ & + \sum_{t=1}^{T}\sum_{\substack{j=1 \\ j\neq k}}^{J}\sum_{k=1}^{K} nt^t_{j,k} \times TT_{j,k} \quad + \quad \sum_{t=1}^{T}\sum_{j=1}^{J}\sum_{p=1}^{P} I^t_{j,p} \times Hc \end{aligned} \tag{4.1}$$

The constraints of the model are introduced below.

The set of constraints (4.2) guarantees that all plants' needs are fulfilled: The inventory of pallet type p at plant j in period t is equal to the inventory of this type of pallet, in this plant, at the end of the previous period (*t-1*), minus the sum of what was consumed and transferred to other plants plus the sum of the returned, purchased and transferred quantity to this plant j. To assure that the demand of each plant is being fulfilled it is essential to secure that the inventory level of each pallet cannot take negative values.

Stock in plant:

$$\begin{aligned} I^t_{j,p} &= I^{t-1}_{j,p} - D^t_{j,p} - \sum_{\substack{k=1\\k\neq j}}^{K} Xt^t_{j,k,p} + \sum_{\substack{k=1\\k\neq j}}^{K} Xt^t_{k,j,p} + \sum_{f=1}^{F} Xn^t_{f,j,p} + \sum_{i=1}^{I} X^t_{i,j,p} \\ I^t_{j,p} &\geq 0 \qquad \forall \quad j \in j = \{1,...,J\}, \quad p \in p = \{1,...,P\}, \quad t \in t = \{1,...,T\} \end{aligned} \tag{4.2}$$

Constraints (4.3) and (4.4) guarantee that the maximum capacity (in units) of a vehicle is not exceeded and that the necessary number of vehicles is properly computed: the number of vehicles connecting a certain region i and plant j each period is greater or equal to the nearest integer number of the total quantity of pallets returned from region i to plant j in period t divided by the maximum capacity in units.

Shipment Control:

$$\sum_{p=1}^{P} \frac{X^t_{i,j,p}}{tl} \leq nv^t_{i,j} \quad \forall \quad j \in j = \{1,...,J\}, \quad i \in i = \{1,...,I\}, \quad t \in t = \{1,...,T\} \tag{4.3}$$

Equally, the number of vehicles connecting two plants j and k in period t is greater or equal to the nearest integer number of the total quantity of pallets transferred between plant j and plant k region i in the same period t divided by the maximum capacity in units.

$$\sum_{p=1}^{K} \frac{X^t_{j,k,p}}{tl} \leq nt^t_{j,k} \quad \forall j \in j = \{1,...,J\}, \quad k \in k = \{1,...,J\}, \quad t \in t = \{1,...,T\} \tag{4.4}$$

Constraints (4.5) calculate the inventory level in each region at the end of each period and ensure that clients do not return more that what they have in stock: the sum of the quantity of pallet type p returned from region i to all plants must be lower than the quantity already in stock in the previous period (*t-1*) plus the quantity delivered, in the course of that period. It is, therefore, assumed that the quantity delivered as packaging material of finished product can be returned in the same period of the delivery.

Stock in Region:

$$\begin{aligned} S^t_{i,p} &= S^{t-1}_{i,p} - \sum_{j=1}^{J} (X^t_{i,j,p} - y^t_{i,j,p}) \quad \wedge \quad S^t_{i,p} \geq 0 \\ \forall \quad & i \in i = \{1,...,I\}, \quad p \in p = \{1,...,P\}, \quad t \in t = \{1,...,T\} \end{aligned} \tag{4.5}$$

Constraints 4.6 assure that the quantity returned to a certain plant j in period t varies up to a maximum (Δ_j) when compared with other periods. In this case, ´Δ_j was chosen to be the greatest variation in production needs.

Balancing Returns:

$$(1-\Delta_j)\sum_{i=1}^{I}\sum_{p=1}^{P} X_{i,j,p}^{l} \quad \leq \quad \sum_{i=1}^{I}\sum_{p=1}^{P} X_{i,j,p}^{t} \quad \leq \quad (1+\Delta_j)\sum_{i=1}^{I}\sum_{p=1}^{P} X_{i,j,p}^{l}$$
$$\forall \quad j \in j = \{1,...,J\}, \quad t \in t = \{1,...,T\}, \quad l \in l = \{1,...,T\} \quad \wedge \quad l \neq t \tag{4.6}$$

$$\Delta_j = \frac{\mid Min(\sum_{p=1}^{P} D_{j,p}^{t}) - Max(\sum_{p=1}^{P} D_{j,p}^{t}) \mid}{Min(\sum_{p=1}^{P} D_{j,p}^{t})} \forall \qquad j \in j = \{1,...,J\}$$

Finally, constraints 4.7 define the domain of the decision variables.

$$X_{i,j,p}^{t}, \quad Xn_{f,j,p}^{t}, \quad I_{j,p}^{t}, \quad Xt_{j,k,p}^{t} \geq 0 \quad and \quad \in \mathbb{Z} \tag{4.7}$$

4.1.1 An illustrative example

As performed in (Kim et al., 2006), a numerical example will be used to illustrate how the model works in the proposed framework.

To reflect the real situation, a small set of data was prepared not with actual values but approximately maintaining the real proportion between the different parameters. In this scenario, the returns are being held between 3 plants (A, B and C) and 5 regions, considering 3 different types of pallets (aa, bb and cc) and 2 distinct suppliers (x and y) over two periods.

Inputs

Considering there is no stock of pallets in all plants, Table 4.2 shows the forecasted quantity of pallets required per type (aa, bb or cc) in each plant along the planning period.

Table 4.3 provides information about the first option to supply the plants, depicting the purchasing unit cost of the different types of pallets from the two considered suppliers to each plant. It is important to notice that suppliers may not handle every type of pallet or guarantee their delivery to all plants ($Cff_{f,j}$=999). Additionally, as prices vary not only with the type of pallet but also with the plant, the supplier that guarantees the most competitive prices to a certain plant is not necessarily the best supplier to all plants or pallet types. As there are no restrictions related to the quantity suppliers can convey, it is possible to observe that a certain plant will always choose one supplier for one type of pallet in detriment of the other. For instance, plant A will always purchase pallets from supplier y, whereas plant B will choose supplier x for type aa and supplier y for the remainder.

Another source of supply is, as previously mentioned, to return pallets from customers that are clustered per region. When returning pallets, it is crucial to analyse both transportation costs and

Table 4.2: Plants' needs per type of pallet and period $D^t_{j,p}$

	t=1			t=2		
	aa	bb	cc	aa	bb	cc
Plant A	80	100	120	200	100	50
Plant B	90	30	50	60	150	80
Plant C	0	0	100	50	100	200

recovery costs. In the first place, Table 4.4 provides information about the location of plants and regions. As $Ut_{5,A}$ and $Ut_{5,B}$ take the value 1, it is possible to conclude that Region 5 and plants A and C are located in Portugal. This determines that returns between them are charged, not based on a fixed rate, but by the number of pallets that are actually transported. The unit cost of transport is, in this scenario, $Utc = 0.05$. Furthermore, Table 4.4 also shows the fixed rates to connect the regions and the plants. Regarding recovery costs, it is considered that all plants charge the same amount per classified and sorted pallet (Cs_j=0.04).

Table 4.5 displays the sum of not yet returned pallets from a region. This quantity can be obtained by adding all the pallets that get to customers in a certain region as packaging material for finished product deliveries and subtracting the quantity returned for a certain period prior to the period of analysis. Table 4.6, on the other hand, shows the quantity that is expected to be sold to customers during the period of analysis.

Lastly, there is still the possibility to buy or return pallets to one plant and then transfer them to another. Table 4.7 shows the fixed transportation costs between the different plants.

The minimum cost of return is accomplished when the truck is at its full capacity. In this case, the maximum capacity of the vehicle (in units) was considered to be 25 pallets (tl=25). As it is expected, the model will not accept returns when costs related to transportation and recovery imply a higher unit cost than the cost of purchasing a new pallet. Hence, when considering all types of pallets, we can anticipate that the shaded fields in table 4.8 will not be considered for returns.

Results

With this dimension, the problem was solved to optimality in 2.97 seconds. The results are shown in Tables 4.9 to 4.12. Table 4.9 displays the quantity of pallets returned between each region and

Table 4.3: Purchasing costs per type of pallet, supplier and destination plant $Cf_{f,j}$

	Plant A		Plant B		Plant C	
	x	y	x	y	x	y
Pallet aa	1	0.8	0.7	0.9	1	999
Pallet bb	1	0.85	2	1.25	1.3	0.95
Pallet cc	999	1	999	1.2	999	2

Table 4.4: Boolean variable to identify connections with unit cost per pallet $Ut_{i,j}$ and Fixed Transportation Costs between the different regions and plants $Tc_{i,j}$.

	A	B	C	A	B	C
Region 1	0	0	0	115	40	17
Region 2	0	0	0	25	46	100
Region 3	0	0	0	49	24	76
Region 4	0	0	0	16	24	120
Region 5	1	0	1	15	39	30

plant. It is possible to observe that, except for returns inside the Portuguese Territory (Region 5 and Plants *A* and *C*), this quantity is, in most cases, equal to the maximum capacity of the vehicle. In this scenario, there is one exception to this when, in the first period, only 72 pallets of type *cc* are returned from Region 1 to plant *C* albeit the quantity required for that type is 100. At first sight, this may appear to be a mistake as the cost of 3 extra pallets would be charged. A closer analysis reveals that region 1 is, in the course of the two periods, returning all the available stock of that type to plant *C*. However, this is not a rule, as a half or less loaded truck can still be profitable, when considering purchasing the same amount from an external supplier.

Table 4.10 shows the number of vehicles allocated to returns between the different regions and plants ($nv^t_{i,j}$) and Table 4.11 depicts the number of pallets bought to each supplier ($Xn^t_{f,j,p}$). It is important to notice that, in the second period, 118 new pallets of type *cc* are purchased and 25 are returned in a total of 143, when the forecasted need for plant *B* is only 80 units. Looking closely, it is possible to conclude that returning 25 pallets from region 4 will result in cost savings of 6 m.u. when compared with purchasing the same amount from an external supplier. In this scenario, considering all periods (t={0,1,2}), region 4 handles a total amount of 166 units, from which 75 are returned to plant *A* in period 1 and the sum of 75 (50+25) to plants *A* and *C*, respectively. In this scenario, region 4 would still be able to return 16 *cc* pallets. Notwithstanding, this would not be a viable option as the region could not take advantage of the maximum capacity of the vehicle as it only consumes type *cc* and the unit cost of solely returning 16 pallets would rise up to 1.6 m.u. when compared with 1.25 m.u. from the external supplier.

With regard to plant *C*, Table 4.8 shows that pallets can only be profitably returned from regions 1 and 5. When all available pallets are returned from these regions, two options arise:

Table 4.5: Available Stock of pallets in each region in the beginning of the period to study

	t=0		
	aa	bb	cc
Region 1	11	0	37
Region 2	19	25	10
Region 3	30	55	24
Region 4	0	0	12
Region 5	0	5	24

Table 4.6: Number of pallets sent to each region as a palletized unit load of finished product $y^t_{i,p}$.

	t=1			t=2		
	aa	bb	bb	aa	bb	bb
Region 1	20	0	50	24	0	60
Region 2	60	70	60	72	84	72
Region 3	80	35	0	96	42	0
Region 4	0	0	70	0	0	84
Region 5	0	25	30	0	0	36

Table 4.7: Transferring Transportation Costs between different plants $Tt_{j,k}$

	A	B	C
Plant A	999	25	64
Plant B	25	999	10
Plant C	70	25	999

Table 4.8: Minimum unitary cost of returns between the different regions and plants

	A	B	C
Region 1	4.6	1.6	0.68
Region 2	1	1.84	4
Region 3	1.96	0.96	3.04
Region 4	0.64	0.96	4.8
Region 5	0.05	1.56	0.05

Table 4.9: Number of pallets returned from all regions to all plants in each period $X^t_{i,j,p}$

	t=1									t=2								
	A			B			C			A			B			C		
	aa	bb	cc	aa	bb	cc	aa	bb	cc	aa	bb	cc	aa	bb	cc	aa	bb	cc
Region 1	0	0	0	0	0	0	0	0	72	0	0	0	0	0	0	50	0	75
Region 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Region 3	0	0	0	0	0	0	0	0	0	0	0	0	0	125	0	0	0	0
Region 4	0	0	75	0	0	0	0	0	0	0	0	50	0	0	25	0	0	0
Region 5	0	0	0	0	0	0	0	0	28	0	0	0	0	0	0	0	60	62

either to purchase or to transfer the remainder. In this case, the cost of purchasing 63 *cc* pallets for plant C is 126 m.u. (2×63), whereas the cost of transferring the same quantity from plant *B* is 108,75 ($3\times10+63\times1.25$). Hence, it is advantageous to transfer this quantity corresponding to 3 vehicles as depicted in Table 4.12.

The costs related with Returnable Packaging are depicted in Table 4.13 for all the different plants and periods and divided in transportation costs, transportation costs inside Portugal, transferring costs, classification costs, purchasing costs and inventory holding costs.

Table 4.10: Number of vehicles allocated to returns from the different regions to all plants per period $nv^t_{i,j}$

	t=1			t=2		
	A	B	C	A	B	C
Region 1	0	0	3	0	0	5
Region 2	0	0	0	0	0	0
Region 3	0	0	0	0	5	0
Region 4	3	0	0	2	1	0
Region 5	0	0	2	0	0	5

Table 4.11: Number of pallets purchased to each supplier per plant and period $Xn^t_{f,j,p}$

	t=1									t=2								
	A			B			C			A			B			C		
	aa	bb	cc	aa	bb	cc	aa	bb	cc	aa	bb	cc	aa	bb	cc	aa	bb	cc
Sup x	0	0	0	90	0	0	0	0	0	0	0	0	60	0	0	0	0	70
Sup y	80	100	45	0	30	50	0	0	0	200	100	0	0	25	118	0	40	0

Table 4.12: Number of vehicles allocated to transfers between plants per period $nt^t_{j,k}$

	t=1			t=2		
	A	B	C	A	B	C
Plant A	0	0	0	0	0	0
Plant B	0	0	0	0	0	3
Plant C	0	0	0	0	0	0

4.1.2 Dealing with uncertainty

As previously mentioned, Reverse Logistics is significantly affected by the uncertainty in what concerns both quality and quantity of the returns.

In the current context, in which a large quantity of non repairable pallets can be sent or in which clients may not accept/ schedule any returns during certain periods, uncertainty should definitely be taken into consideration. It is, therefore, decisive to somehow consider information such as the return rate and scrap rate of each region when planning the flows of returnable packaging in the future. To accomplish this, some adjustments to the previous presented model are necessary, namely in constraints (4.2) and (4.5). The uncertainty will be addressed in a deterministic setting, by imposing a buffer to assure that production needs are indeed fulfilled.

Firstly, it is important to consider the quality of the returns, especially the percentage of non repairable and non compliant pallets. For this, the parameter suc_i was incorporated in constraint (4.8) which guarantees that the production needs of all plants are met, this time expecting that not all returned pallets are in good condition or can be refurbished, which eventually will force the model to buy or return more pallets. Secondly, a correction in the level of inventory needs to be

Table 4.13: Total Costs

	Transporation costs		**Transportation costs PT**	
	t=1	t=2	t=1	t=2
A	48	32	0	0
B	0	144	0	0
C	51	85	1.40	6.10
	Transfer Costs		**Sort and Repair**	
	t=1	t=2	t=1	t=2
A	0	0	3	2
B	0	0	0	6
C	0	30	4	9.88
	Purchasing Costs		**Inventory Holding Costs**	
	t=1	t=2	t=1	t=2
A	194	245	0	0
B	160.50	214.85	0	0
C	0	38	0	0
Total			461.90	812.83
			1274.73	

made so that it does not take into consideration non repairable pallets.

$$I^t_{j,p} = I^{t-1}_{j,p} - D^t_{j,p} - \sum_{\substack{k=1 \\ j \neq k}}^{K} Xt^t_{j,k,p} + \sum_{\substack{k=1 \\ j \neq k}}^{K} Xt^t_{k,j,p} + \sum_{f=1}^{F} Xn^t_{f,j,p} + \sum_{i=1}^{I} (1 - suc_i) \times X^t_{i,j,p}$$
$$I^t_{j,p} \geq 0 \qquad \forall \quad j \in j = \{1,...,J\}, \quad p \in p = \{1,...,P\}, \quad t \in t = \{1,...,T\} \tag{4.8}$$

Thirdly, now regarding the quantity, the return rate per period and region is considered in constraints (4.9). The addition of these restrictions, in which the parameter $rr_{i,t}$ hinders a certain region to return all the available quantity in stock to simulate the lack of willingness of clients to do so in some periods.

$$\sum_{j=1}^{J} X^t_{i,j,p} \leq rr^t_i \times (S^{t-1}_{i,p} + \sum_{j=1}^{J} y^t_{i,j,p})$$
$$\forall \quad i \in i = \{1,...,I\}, \quad p \in p = \{1,...,P\}, \quad t \in t = \{1,...,T\} \tag{4.9}$$

Chapter 5

Improving Packaging Planning - Results

To better understand the application of the model and to validate its outputs, the year of 2016 was analysed. As the planning activities of Iberia and Poland were still performed separately in the period of analysis, only the practices and outcomes of Portuguese and Spanish operations will be evaluated.

All planning activities in BA depend, first and foremost, on the Annual Sales Plan. This plan, developed by the Market and Planning department and built over the sales forecast, is the basis of Production Planning, which later generates material and transportation requirements.

This chapter is divided in different sections, in which the differences between the two procedures are discussed and later, in which the results of the optimization model are compared with both the planning activity and reality of the period of analysis.

5.1 Main Differences between the two approaches

Once the Sales Budget is accomplished and there is information on planned shipments and estimated packaging requirements, it is possible to study and plan the flows of Returnable Packaging.

As this information is provided in an extensive document generated by the ERP System, the first step is to cross check the data to correct fields such as type of material, dispatch quantity and region of transport. This will allow the planner to foresee the quantity of pallets shipped to each region during the course of the following year. The Sales Plan also comprises information on the origin of each shipment, which gives an insight into the different plants' needs. Notwithstanding, since not all demand is directly fulfilled with production, material requirements still need to be revised.

So far, the reverse flows of returnable packaging in the planning context have been defined *a priori* based on factors, such as distance, transportation costs and past experience. The allocation of the different returns, in what concerns the Returnable Packaging budget is depicted in Table 5.1. This presents itself as a deficiency as it does not thoroughly consider the needs of each plant and the consumption of the different types of pallets in each region. It is thus assumed that, every period, the quantity shipped to certain regions minus an amount presumed lost is returned to specific plants. For instance, independently of what is required for production, all pallets shipped to clients in the Northern regions of Portugal and assumed returnable are, for the purpose of planning, divided between AV and MG plants with a 70/30 ratio.

Table 5.1: Percentage of stock that should be returned per region to each plant according to the budget activity of 2016

Market	**Plant**				
	AV	**MG**	**VF**	**LE**	**VN**
Porto Metropolitan Area	100%				
North of Portugal	70%	30%			
South of Portugal	10%	40%			50%
Madeira and Azores	100%				
Extremadura		10%	80%	10%	
Castilla and León				100%	
Galicia	40%	20%		40%	
Andalucia		20%	60%	0%	20%
Madrid	20%	25%	30%	25%	
La Mancha		30%	20%	50%	
Levante and Murcia		40%	30%	30%	
Basque Country	20%	30%	10%	40%	
Barcelona and Tarragona	10%	30%	20%	40%	
Asturias and Cantabria	30%	30%		40%	
Penedés	20%	30%		50%	
France	30%	35%			35%
UK	100%				
Italy	30%	35%			35%
Belgium	50%	25%			25%
Germany	100%				
Others	30%	30%			40%

Another inaccuracy comes with the limited number of regions considered, where it is assumed that returning the same number of pallets from Paris, in the north, and Bayonne, in the south of France represent the same cost, when these two cities are set apart by over 700 km.

These are the two major differences between the past planning activities and the proposed approach, where 220 regions and corresponding transportation costs are considered and in which the ratio of pallets returned in each period is not predetermined, but varies according with production needs and pallet types shipped to customers. This flexibility allows a constant trade-off between the two supplying options, deciding not to return pallets from certain regions when the cost of buying the same quantity is lower.

Table 5.2, obtained with the optimization model provides an example of this versatility. It represents the percentage of stock, calculted by means of expression (5.1), of the most common pallets (STD, ANIF and VMF) returned from the region of Barcelona to the different Iberian plants in the year of analysis.

$$\frac{X^t_{ES08,j,p}}{rr_{ES08} \times S^t_{ES08,p}} \tag{5.1}$$

Analysing Table 5.2, it is possible to see that the quantity available is not totally returned in every period because it does not represent the most cost effective option. In period 9, for instance, the whole quantity of pallets ANIF is returned, but only 73% and 76% of the actual stock of STD and VMF is transported back to the Iberian plants.

As there are no restrictions that constrain the simultaneous transportation of more than one type of pallet, the sum of 73% and 75% of STD and VMF pallets completes two vehicles to VF (Table 5.3). A similar situation can be observed in the same period, in what concerns the transportation of only 1% of VMF pallets to LE plant. This is proposed to optimize the transportation by ensuring the utilization of its full capacity and thus reducing the cost per returned pallet.

It is important to note that the opposite also occurs when the total quantity available is returned but the shipment space is not fully utilized. In period 3, for example, all ANIF pallets considered returnable are dived between AV and LE plants but the quantity is not enough to completely fill 21 trucks (Table 5.3).

It is also relevant to mention that Table 5.3 was not created to calculate costs, but only to highlight the usage of the vehicles' capacity. As can be observed, although the maximum capacity of the vehicles is not always utilized, it still proved to be profitable when compared with the cost of purchasing the pallets (Tables 5.4 and 5.5).

5.2 Returns

After discussing the main assumptions of the optimization model and the planning activity of 2016, the different outcomes will be compared hereinafter.

The following results were obtained with the MIP Solver, CPLEX 12.7.0.0. and the described model was run on a HP PAvilion dv6 Notebook PC with 8 GB of RAM memory and with the Intel(R) Core(TM) i7-3610QM CPU with 4 threads.

Figures 5.1 to 5.2 show, in both graphs, the forecasted plants' needs and the expected returned quantity of all pallets and months of analysis for the AV and MG plants. On the left graph the quantity returned is calculated based on the outputs of the model, while on the right it is calculated based exclusively in the return rates and proportion of sales present in Table 5.1.

In all plants, it is possible to see that the quantity that arrives in each period remains approximately constant through time. This aspect is extremely important in an operational point of view, so that the Recovery Facility can work at a continuous pace without experiencing periods of stock out and excess of inventory. Both situations are critical in very different aspects. The first case is related with starving in the sorting activity and the second concerns the storage location of the Recovery Facilities. This lack of indoor space to store pallets, boosts the risk of contamination and significantly increases the scrap rate.

Table 5.2: Percentage of Stock returned from Barcelona to the different Iberian Plants

Month		1	2	3	4	**5**	6	7	8	9	10	11	12
AV	STD		28%										
	ANIF		27%	67%	12%				14%	75%	76%		
	VMF		2%										
VF	STD					86%	86%	85%	89%	73%	83%	100%	
	ANIF					1%	1%	1%				34%	
	VMF					46%	39%	41%	25%	75%	97%	97%	
MG	STD												
	ANIF					6%						33%	
	VMF												
LE	STD	84%	5%	100%				1%	2%				
	ANIF	40%	73%	33%	77%	37%	99%	82%	80%	25%			
	VMF									1%			
VN	STD	16%											100%
	ANIF	58%									24%	33%	100%
	VMF	50%											36%
Total	STD	100%	34%	100%		86%	86%	86%	91%	73%	83%	100%	100%
	ANIF	98%	100%	100%	89%	44%	100%	83%	93%	100%	100%	100%	100%
	VMF	50%	93%	100%	16%	46%	39%	41%	25%	76%	97%	97%	36%

Table 5.3: Number of vehicles needed to assure the returns between Region ES08 and all the Iberian plants

	1	2	3	4	5	6	7	8	9	10	11	12
AV	0	7	13	2	0	0	0	1	3	3	0	0
VF	0	0	0	0	1	1	1	2	2	6	4	0
MG	0	0	0	0	0.9	0	0	0	0	0	2	0
LE	5	19	7.5	12.7	5.7	23.7	4.9	5.9	1	0	0	0
VN	7	0	0	0	0	0	0	0	0	0.9	2	8

Table 5.4: Unitary Pallet Cost of the Returns between ES08 and all the Iberian Plants

	1	2	3	4	5	6	7	8	9	10	11	12
AV		2.26	2.26	2.26				2.26	2.26	2.26		
VF					2.05	2.05	2.05	2.05	2.05	2.05	2.06	
MG					2.51						2.29	
LE	1.71	1.71	1.83	1.74	1.81	1.73	1.76	1.74	1.71			
VN	2.26									2.43	2.26	2.26

Table 5.5: Minimum Cost of Purchasing the different types of pallets for each plant

	AV	VF	MG	LE	VN
STD	5.62	6.26	5.96	6.21	5.9
ANIF	8.25	7.65	8.2	8.86	8.15
VMF	8.25	8.79	8.2	8.86	8.45

The right side of Figure 5.1 depicts a difference of 20% in the returned quantity between January and July, which in the corresponding plant, approximately represents 4 days of classification and sorting. This either means that in the beginning this operation is not being performed at its full capacity or that in July it is receiving more pallets than what can be classified and sorted.

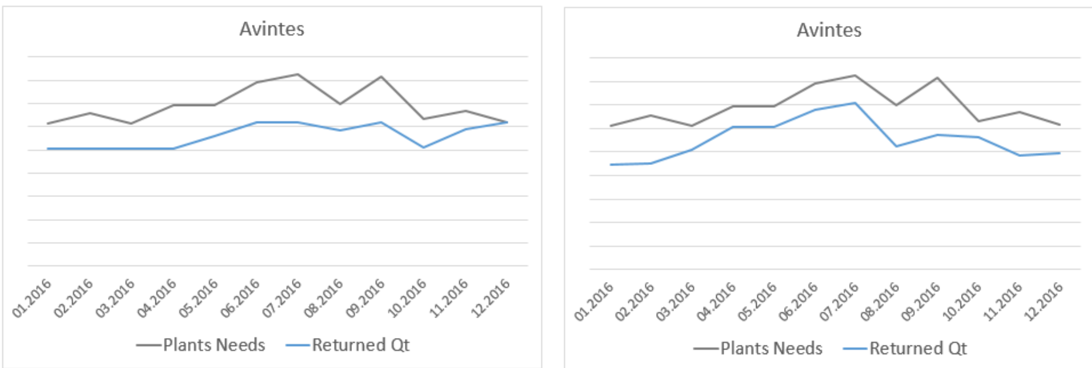


Figure 5.1: Forecasted Production Needs and Returns in AV plant

It is also important to highlight the expected quantity returned to MG in the planning activity

(Figure 5.2) which is greater than the production needs. This excess can be due to expectations of high scrap rate returns or simply to a large number of sales in regions that are constrained to return to MG. The comparison between the proposed and existing approach for remainder plants (VF, LE and VN) is portrayed in Appendix 3.

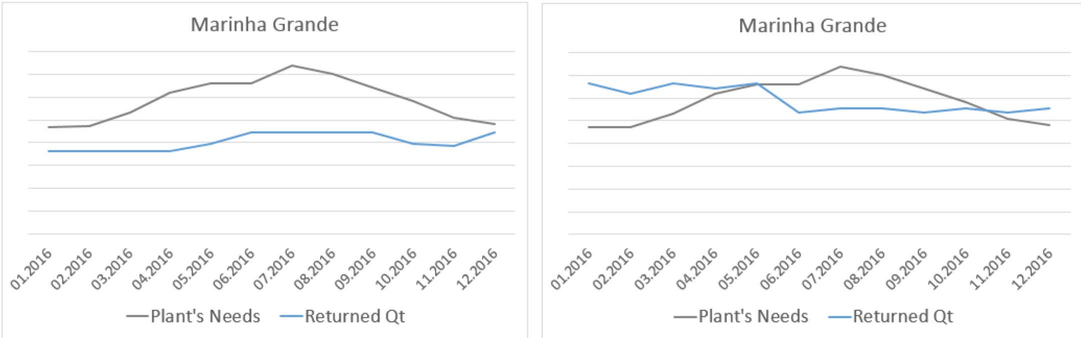


Figure 5.2: Forecasted Production Needs and Returns in MG plant

In what concerns the origin of the returns, Figures 5.3 to 5.5 exhibit the most cost effective and therefore, preferable regions from where to return pallets to AV, MG and LE plants. In this part, it is important to enhance that, although transporting a single pallet to AV plant from a customer located in the metropolitan region of Porto, in a radius of 20km, or in Algarve, over 500 km, represents the same cost to BA, this premise is not reasonable in an operational point of view. Hence, and in order to minimize illogical results such as customers in the metropolitan region of Lisbon supplying AV plant and clients in the metropolitan region of Porto supplying Venda Nova, in the context of optimization, transportation costs between regions where plants are located and adjacent areas were considered per truck and not per unit. Later, to calculate the overall costs of the activity, this consideration was set aside and the unit cost per pallet was used between all Portuguese regions and plants.

Figure 5.3 represents the total quantity planned to return in the full course of the year 2016, with the metropolitan region of Porto (PT13) covering over 40% of this quantity. Other regions, but summing a significant less percentage, are located in the North of Spain and spread through Portugal. Besides Iberia, several other regions in France, Italy and Belgium were selected to supply the needs of AV plant.

Marinha Grande (Figure 5.4) receives most of the pallets, close to 25% of the total, from the region of Santarém (PT34) and the remainder from regions spread through Portugal, Spain, France, Belgium and Italy.

Returns to Léon are exhibited in Figure 5.5 and consist predominantly of Spanish Regions like La Rioja (ES26), Léon (ES24), Barcelona (ES08) and Navarra and some others across France, Belgium and Italy.

The proposed model selects over 60 regions from where to return pallets to each plant, but as it can be observed in the Pareto Curves, only about 15 of which represent practically 90% of the

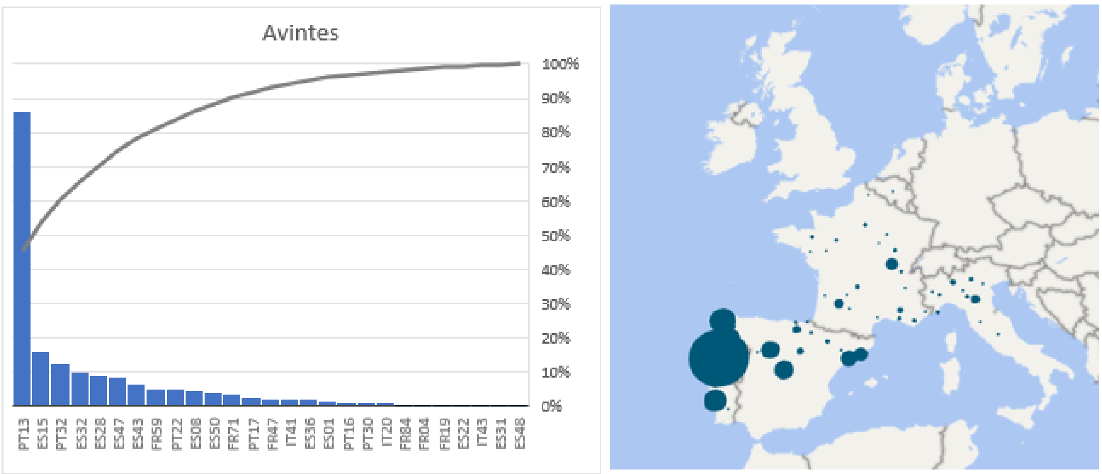


Figure 5.3: Pareto chart and heat map representing the proposed yearly returns to AV plant

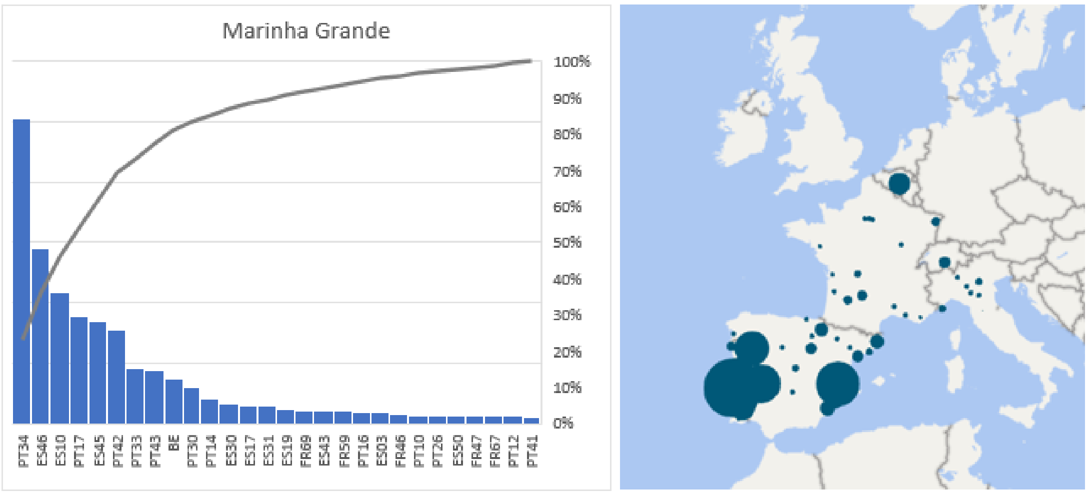


Figure 5.4: Pareto chart and heat map representing the proposed yearly returns to MG plant

quantity returned.

Figure 5.6 shows what BA expected to return in the period of 2016. It is possible to see that the overall quantities returned from each region do not vary significantly when compared with the previous model. The main aspects that stand out are relative to the lack of specificity when considering returns from Italy and Germany and perhaps the return of pallets from Madeira Island and Morocco to AV plant not considered before.

In what concerns costs, the proposed model comprises a 2% reduction in the overall costs when compared with the previous Returnable Packaging Budget. Figure 5.7 represents the total costs of returnable packaging, considering transportation costs, purchasing costs and sorting and repairing costs for both alternatives. In each month it is possible to see the deviation between the

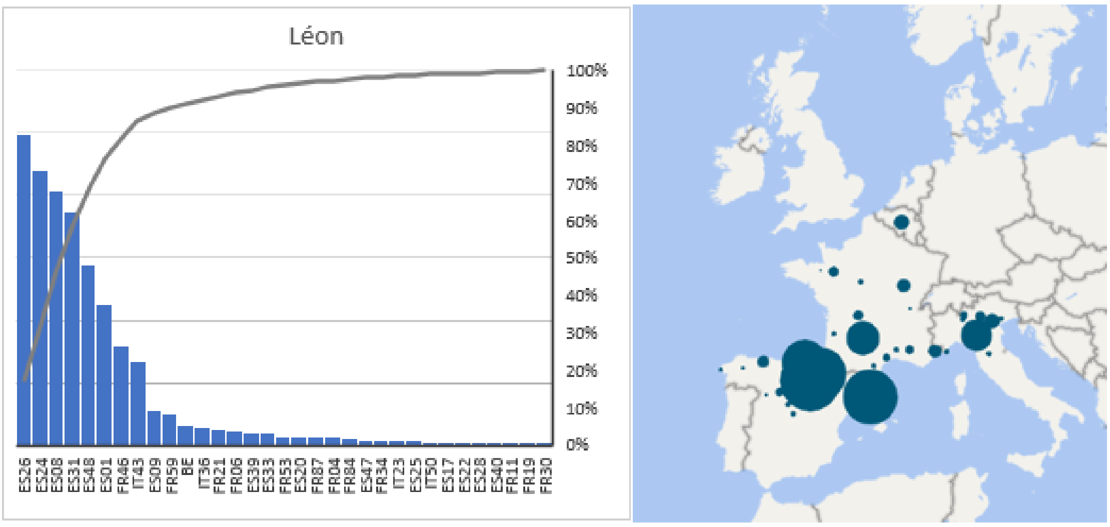


Figure 5.5: Pareto chart and heat map representing the proposed yearly returns to LE plant

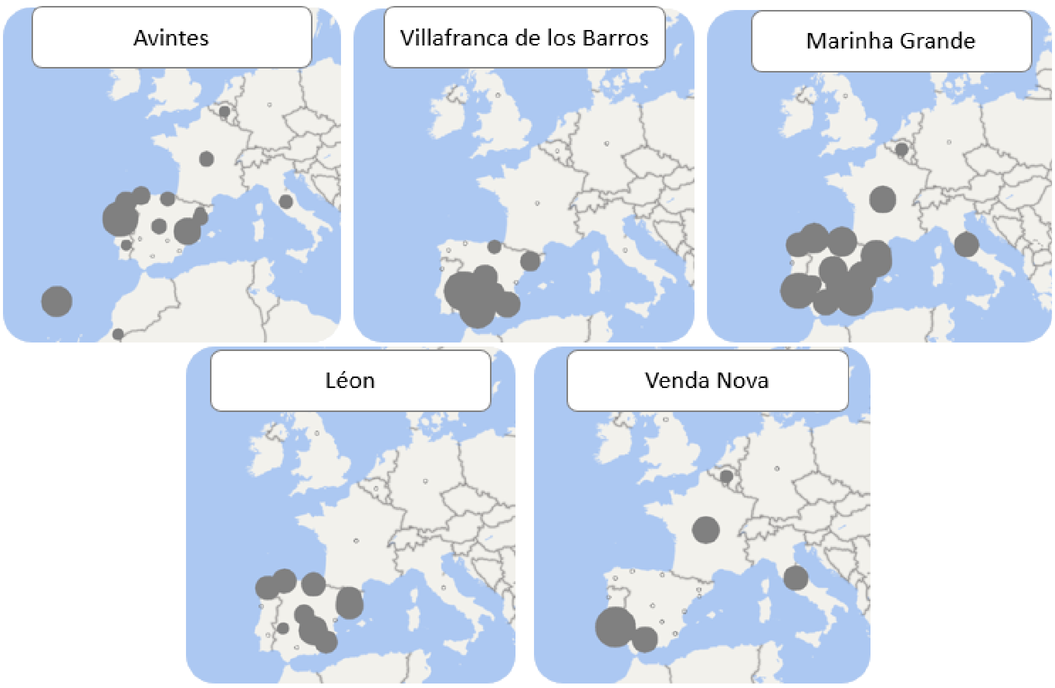


Figure 5.6: Maps representing the returns to all Iberian plants

expected costs of the model (bold black line) and the current solution (thin black line). A positive deviation is accomplished when the proposed solution guarantees less costs than the previously obtained, whereas a negative represents otherwise.

The negative deviation occurs mainly when the production needs rise, because the increase in returns is not as significant as the increment in demand for packaging itself. This happens since the previous approach does not consider the capacity of the recovery facility, its operation and the possibility of incurring in extra costs due to larger risks of contamination and consequent scrap rates.

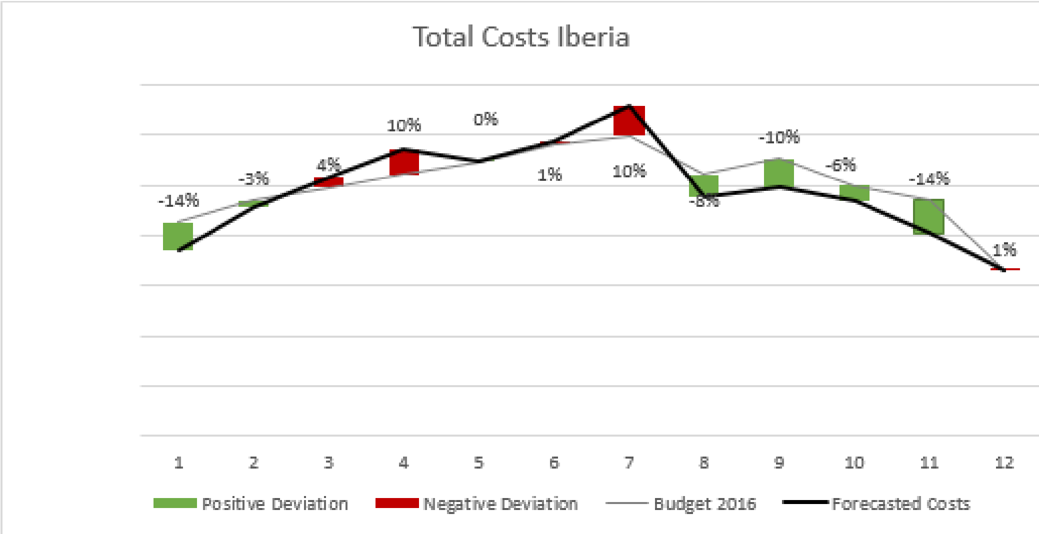


Figure 5.7: Total Costs of Returnable Packaging

5.2.1 Confronting planning results with the real scenario

It is essential, once the planning is done and in the course of time, to analyse any deviations from what it expected to happen. In other words, the objective is to find any discrepancies that might caused by non-conformities between the plan and the actual work that usually have either a positive or negative impact on the costs.

In this case, it is fundamental to analyse the deviations related with both quantity returned and plants' needs and to evaluate the overall effect on the costs. Figures 5.8 and 5.9 represent the percent deviation between the actual scenario and the one proposed with the optimization model for AV and LE plants.

In what concerns packaging material, deviations in plants' needs may occur not only because there was a shift in the sales plan, but also because of new and specific customer requirements, production decisions in what concerns the type of packaging and, lastly from errors in the source of the information, in this case the automatically generated ERP report.

In Avintes, in the months of January, February, June, July and September there was a negative deviation, which means the expected consumption was larger than the one that really occurred (Figure 5.8). However, this deviation did not convey a decrease in the returned quantity to this plant except for the seventh period, which may not represent the real circumstances. This will be further discussed when the overall costs are compared. In fact, in Avintes, half of the year is marked by the quantity of pallets returned in each period being greater than the actual consumption. Indeed, in the months of January, February, June, August, September and November returns were between 6% and 39% larger than the material requirements of that plant. As a consequence of this lack of control, BA incurs in non expected costs by transferring pallets from this plant to others and by eventually forfeit the excess due to poor weather conditions.

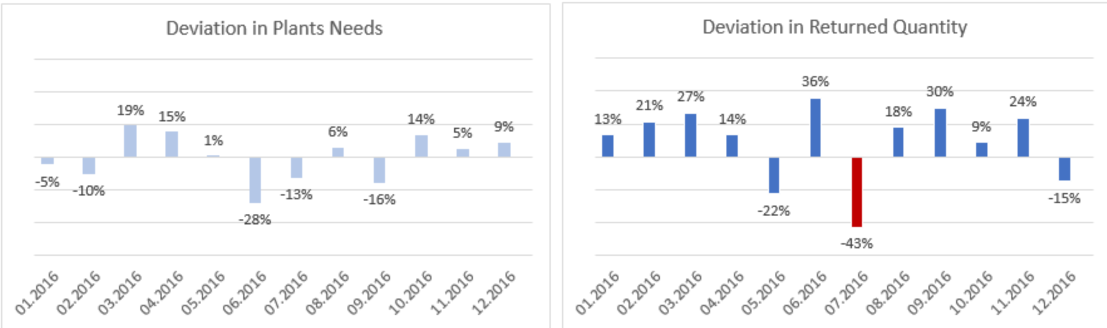


Figure 5.8: Deviation between the forecasted and actual needs and returned quantity in AV plant

In what concerns LE plant deviations (Figure 5.9), production needs vary between -15% to a maximum of 24% when compared with the expected material requirements. Deviations related with returns are positive in 8 out of 12 months, which means a larger quantity is being returned to the plant. In, at least, 5 of these months, the quantity returned was greater than the production needs. As previously mentioned, this has a negative impact since the non repairable rate of pallets increases and transfers between plants have to be carried out.

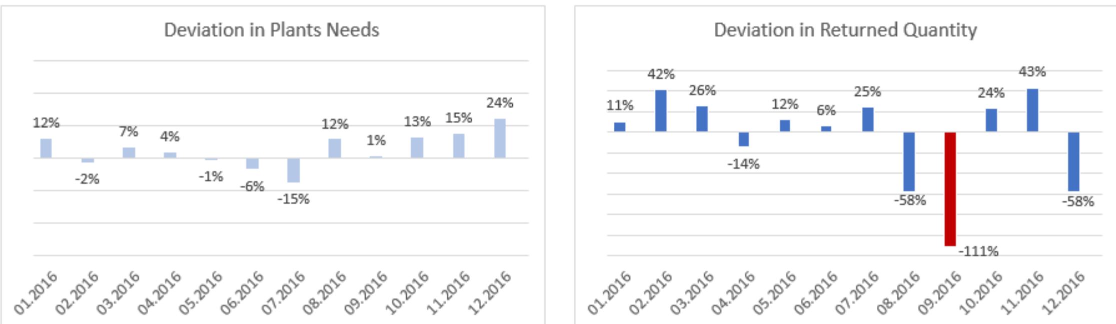


Figure 5.9: Deviation between the forecasted and actual needs and returned quantity in LE plant

The excess quantity returned to AV and LE plants negatively impact the returns to other plants, which ultimately, results in higher costs. This imbalance can be influenced by the lack of control and inefficiencies in the RP Management Process.

To sum up, the impact of these deviations in the overall returnable packaging costs was analysed in Figures 5.11 and 5.10. Both exhibit a comparison between the expected packaging related costs (bold black line) and the actual scenario (thin black line) and respective deviations.

In the first two months, BA plants located in Spain sum an increase of 18% and 15% when compared with the costs of the proposed model (Figure 5.11). This deviation can be predominantly explained by the deviation of the quantity returned to Léon of 11% and 42% when compared with the expected returns in those same periods (Figure 5.9). This divergence is more critical in the second month when approximately 44% more than the actual needs is returned. This excess can also explain the negative deviation visible in the third period since the quantity to purchase or return had to be smaller as there was still stock available to fulfil plants' demand. The rest of the periods, except perhaps for the month of September, should not be considered for the analysis as they were disrupted by operational circumstances. June, July and August are commonly months when there is a reduction in the workforce due to the preferential holiday season. This reduction directly influences information updating and billing activities that end up being performed in the following months. When costs are being considered, this is clearly depicted in both Figures 5.10 and 5.11, where it is possible to see a steep reduction during summer time followed by a large increase around November. The same is visible in the deviations related with the returned quantity for AV plant, in July, and in August and September to LE (Figures 5.8 and 5.9)

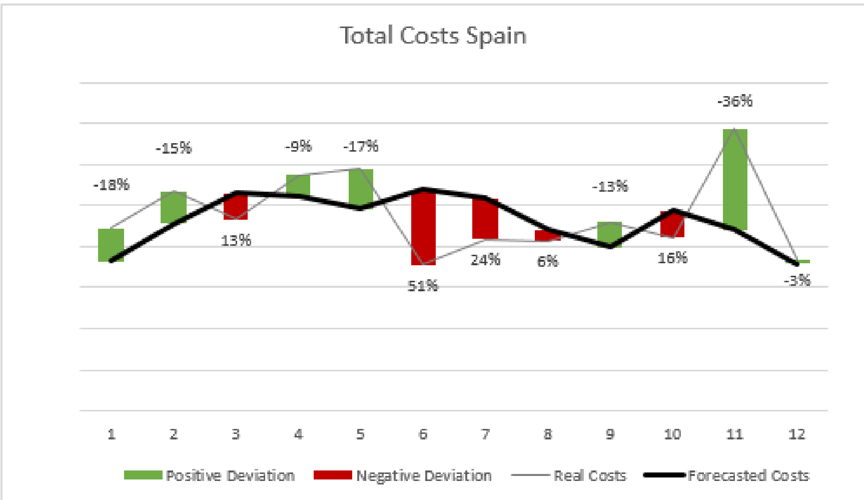


Figure 5.10: Expected costs vs Real costs of Returnable Packaging in Spain

Figure 5.11 also presents the deviation of costs, this time for the Portuguese plants. As previously mentioned, from July on, the costs cannot be compared and evaluated due to ineffectiveness in the operations. In what concerns the previous months, all three plants are returning more than what is considered optimal (Figure 5.8). Although this returns may represent larger costs to BA, the situation is only critical in AV plant because the quantity returned is exceeding production needs. As this situation takes place in two consecutive months, it is likely that transportation costs are not only considered when returning pallets but also when transferring them between AV and MG or VN plants.

In total, the results proposed by the model represent a potential 15% reduction in costs when compared with the reality. Although it only represents a 2% reduction when compared with the

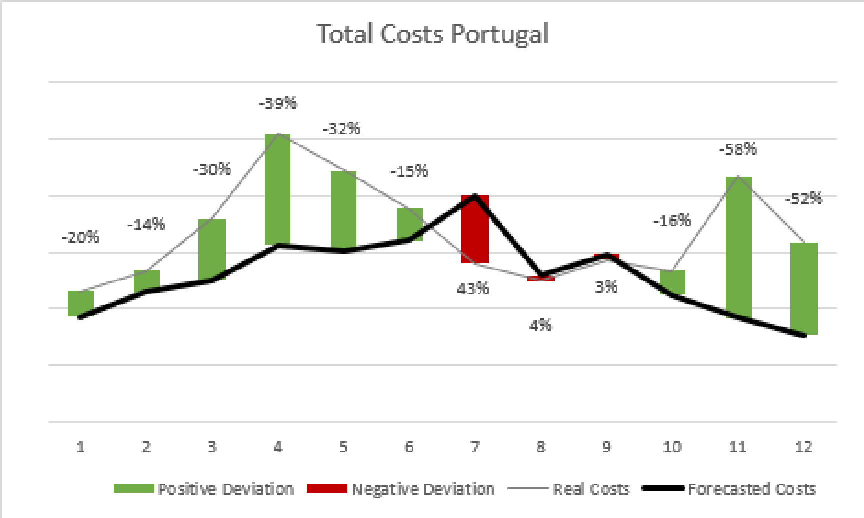


Figure 5.11: Expected costs vs Real costs of Returnable Packaging in Portugal

previous budget, this approach is significantly more accurate than the previous as it disaggregates regions, considers exact sales, per region and type of pallet and, finally, exact costs of purchasing new pallets from suppliers. Through the disaggregation of large regions and countries, the model now considers more precise transportation costs to 27 and 44 regions in Portugal and Spain when only 4 and 11 were previously considered. Moreover, France, Italy and Germany, considered beforehand as unique countries, were also divided in 63, 36 and 14 regions based on customers' locations. This features ensure that the proposed approach is not only more robust for the planning activity, but also promotes a more straightforward guide to the operational activity.

5.3 Planning in a continuously growing company

The recent acquisitions come to challenge an appropriate form of organization inherited from the past and operated by people who share a common tradition, who are accustomed to the organization and who thus form an entity which works with sufficient consistency but who also accumulate its share of inefficiencies (Penrose, 1956). Although growth brings to light these inefficiencies, it also surfaces potential efficiency gains and synergies.

In this context, it is of utmost importance for BA to challenge its prerequisites and premises and to build an operational infrastructure to sustain its growth over time. This infrastructure includes among others standardising procedures, performance measurement and planning.

In 2017, Returnable Packaging planning activities were performed combining the Iberian and Polish Markets but still leaving behind Germany and the southeastern countries (Bulgaria, Romania and Greece). Still, this brought to the table the aforementioned synergies - efficiencies that are merger specific, or in other words, that can only be achieved by merging and go beyond technical efficiencies (Farrel and Shapiro, 2016).

Due to production related restrictions and even though there are closer plants to specific regions, BA may need, for instance, to supply customers in Germany and Belgium with products produced in Portugal. Pallets, on the other hand, do not lie under these constraints and, although some might be considered, synergies rise because new collection points appear closer to large sales regions.

Figures 5.12 and 5.13 depict the expected returns for the year of 2017. When compared with the returns of 2016 (Figures 5.3 to 5.5), it is possible to see that Polish plants absorb a large proportion of returns of Italian customers. Despite the fact that demand of Italian regions is mostly supplied by Iberian plants (approx. 70%), the proposed approach suggests that 63% of the considered returnable pallets actually travel back to Polish plants (61% + 2% to SI and JE plants respectively). It is also important to note that considering these two plants in the planning activity allowed the model to recover pallets from Salerno and Foggia, southern regions of Italy from where returns were not profitable before (Figure 5.12).

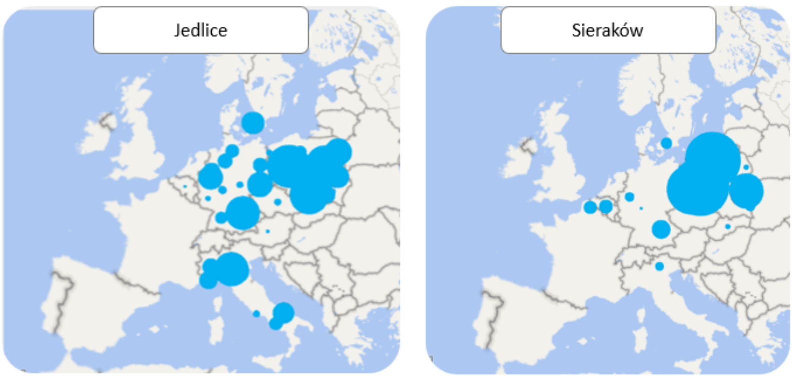


Figure 5.12: Map of the expected proportion of yearly returns to Polish Plants

A similar situation occurs with Belgium, as the Iberian production reaches up to 83% of the total demand of the country and pallets are expected to be returned with a proportion of 60/40 to Poland and Iberia respectively. These are examples of the aforementioned synergies: by acquiring the group Warta Glass and by jointly developing the Returnable Packaging Budget, BA defined routes that represent significant cost reduction. The previous examples constitute cutbacks in transportation costs of approximately 40% for the southern regions of Italy and of 30% for Belgium, cutbacks which would not be accomplished otherwise.

5.3.1 Scenario Planning

A scenario is defined by Kosow and Gaßner (2008) as a description of a possible future situation, including the path of development leading to that situation. The authors claim that scenarios are not intended to represent a full description of the future, but rather to highlight central elements of a possible future and to draw attention to the key factors that will drive future developments.

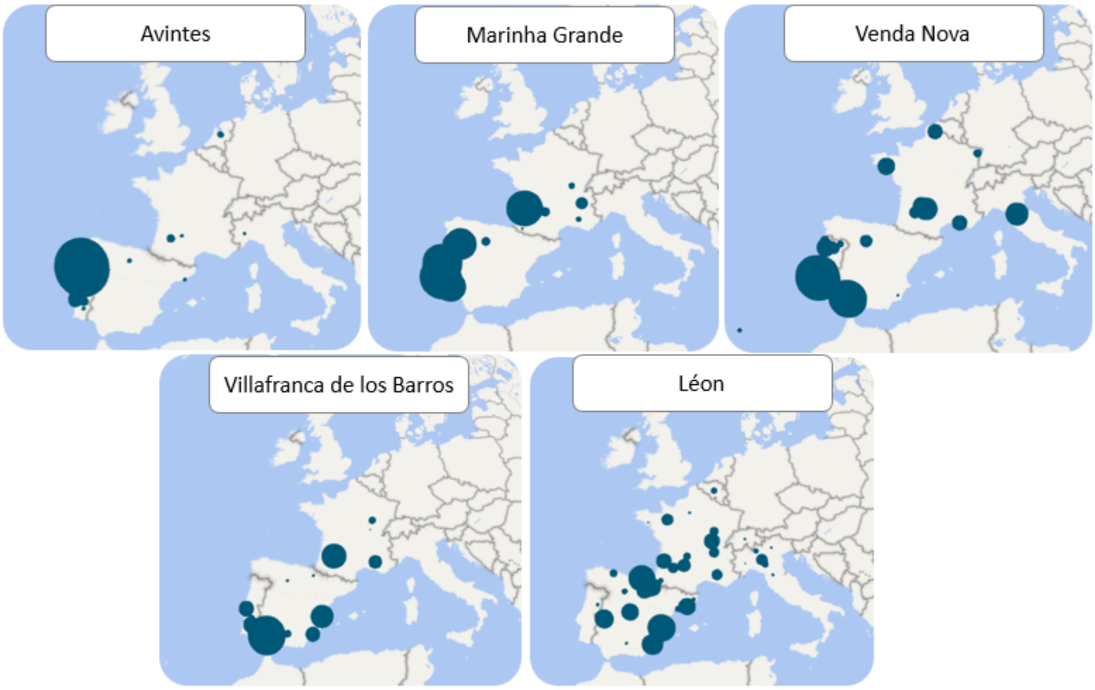


Figure 5.13: Map of the expected proportion of yearly returns to Iberian Plants

5.3.1.1 Impact of Return and Scrap Rates

As previously stated, the uncertainty related with the quality and quantity of the returns has a significant impact in the overall costs. Figure 5.14 portraits the total cost of the best, worst and expected scenario of the year of 2017.

The expected scenario was obtained with historic return and scrap rates, and although this is not the most reliable data, especially with regard to the non repairable rate, due to the lack of traceability discussed on Chapter 3, it is what BA considers for its planning activity. On the other hand, the best case scenario was obtained considering every region was able to return all pallets in good conditions. This is the targeted outcome as it would represent a 13% reduction in the costs related to returnable packaging. With this knowledge, BA can study and implement different strategies to enhance customers' commitment to a careful handling of wooden pallets. Lastly, the worst case scenario was obtained considering it would not be possible to return any pallets from customers, which would be translated in an increase of more than 50 % in the costs.

5.3.1.2 Alternative Scenarios

The proposed model can be used as a simple tool for more specific scenario planning by changing inputs, such as transportation costs, purchasing costs and expected return and scrap rates from certain regions. Assuming production needs as a reliable and fixed input, varying the aforementioned parameters will result in different scenarios in what concern returned, purchased and transferred and return routes.

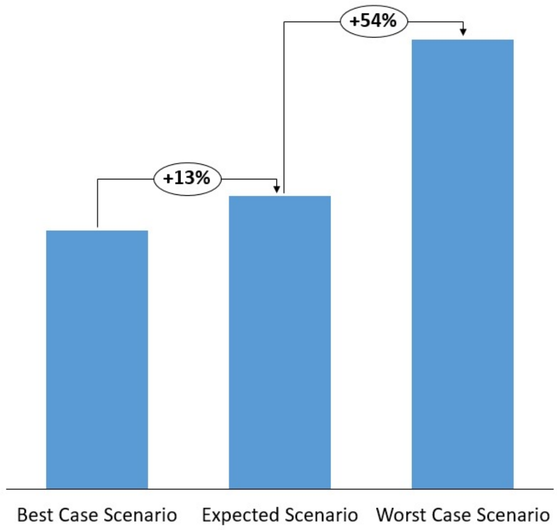


Figure 5.14: Returnable Packaging Costs of the best, expected and worst case scenarios

Figure 5.15 represents the expected proportion of returned pallets in the year of 2017 with variations in transportation costs. The column zero represents the expected situation with real transportation costs. To the right, the figure depicts an incremental reduction in transportation costs, whereas to the left it represents an augment. It is possible to see that with rising transportation costs the proportion of purchased pallets increases up to 1 which means all production needs are all fulfilled with resort to an external supplier. This situation represents a 60% increase in costs when compared with the actual situation. On the other hand, it is important to refer that the growth rate of the returned quantity stabilizes in a level of approximately 80%, reaching a maximum of 84% if one considers there are no transportation costs. This means that even if returns were free of charge or lying under the responsibility of clients, BA would still have to buy approximately 16% of the total production needs of Jedlice's plant in the year of 2017. This situation can be explained either by the return condition of customers, whether the pallets are invoiced or not, or by the return rate of customers located in regions from where returning pallets proves to be a cost effective solution. This may be useful, for instance, in a situation when it is predicted that crude oil prices will increase, thus affecting transportation costs and consequently the number of profitable returns. With the information regarding the difference between what was being externally purchased and the expected increase in this quantity, a better and more informed negotiation with the suppliers can be performed. This transportation cost evaluation can be used to to assess the potential outset of routes that were not being used before when costs decrease, and in the same perspective, the cease of already existing routes when costs rise.

The model can be used, in a distinct situation, to evaluate the impact of return rates of certain regions in plants. Let us imagine a situation in which there are reasons to believe that customers in the Metropolitan area of Porto (the region that in 2016 comprised 66% of all returns to AV plant) would stop returning pallets. This situation would represent a 68% increase in costs for the AV

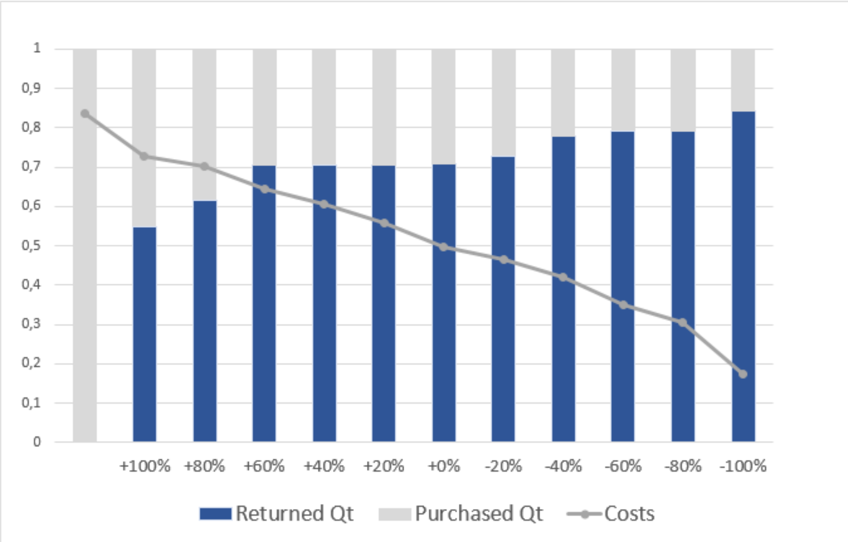


Figure 5.15: Proportion of yearly returns to JE plant with variation of transportation costs

plant as, for example, new return routes from Germany would be open. However, this would not be all, as regions like Santarém, Setúbal and Aveiro which mainly supplied MG and VN plants would now share a part with AV plant. The aforementioned plants, experiencing a reduction in returns from the closest areas, would have to find other sources of supply which would result in an increase in the overall costs of the activity reaching up to 10% when compared with the regular situation.

Chapter 6

Conclusions and future work

This dissertation presented the challenge faced by BA in what concerned the Returnable Packaging activity – an alternative way to fulfil production needs pertaining to packaging. This approach consists in returning pallets with more than one cycle of utilization and restore them to a good condition, thus minimizing the resort to external suppliers, a significantly costlier source of supply. The main objective was to streamline the planning activity of return flows of wooden pallets, optimizing purchases and, therefore, maximizing cost savings related to packaging.

Other proposals were to evaluate the operational activity, suggest improvements and develop a standard procedure to be used in the several plants of the group. In what concerned the everyday activity, the majority of proposals focus on taking further advantage of ERP's features and functionalities. The use of these features would smooth the flow of activities and eliminate inefficiencies by reducing delays and enhancing communication and exchange of information between the different actors.

As traceability is a crucial factor for the returnable packaging activity since it significantly reduces one of the components that generates uncertainty, a major accomplishment in this process was to ensure that at every point between the arrival and classification of the last pallet, the origin of the load was known and the defined procedure was followed in extreme cases. With this information, besides being able to directly report the return condition to customers, BA can improve the management activity of returnable packaging by analysing certain trends in an attempt to cope with the aforementioned uncertainty. Analysis related to the time interval between the shipment of pallets to customers and the respective return of those pallets would increase the precision of the planning activity, as currently it is considered that all retrievable pallets can be returned in the same month as they were shipped which may not represent the real situation. Furthermore, return, scrap and repairable rates can be updated not only to ensure a more rigorous planning but also to secure that more informed negotiations with the Recovery Facilities are carried.

In what concerns the streamlining of planning activity, a mathematical optimization model was developed to tackle this challenge. More than ensuring cost reductions that are not always attainable, as there is a lot of uncertainty associated to the returns, the proposed model provides more accuracy, as the proportion of returns is not established regardless of sales, production needs and types of pallets consumed, but varies from month to month based on these factors. The proposed approach also provides a simple structure to scenario planning, by changing present key factors such as transportation costs, return rates and purchasing costs to ensure adequate responses to potential forthcoming events.

In order to fully enhance the communication between all actors in the RP Management process, BA should develop the aforementioned ERP interface and benefit from a thorough monitoring of this specific type of packaging materials. Among other advantages, the RP Responsible would be able to better balance the arrivals of pallets from customers, while the Central Replenisher could make a more informed decision with regard to the quantity to purchase. Furthermore, certain returns could be prioritized in the classification process to better match production needs and certain activities, such as creating weekly reports of classified and repaired pallets and orders to update customers' balance of RP materials, would be eliminated.

To further evaluate to what extent uncertainty impacts the overall process of RP Management, Stochastic Optimization should be studied in the context of this problem. Another possibility would be, as proposed by Zuluaga and Lourenço (2002) to validate the proposed solution through simulation, where iteratively the available quantity and quality of the returns would be altered with the purpose of analysing the inventory behaviour of the returned materials and the total cost of the system.

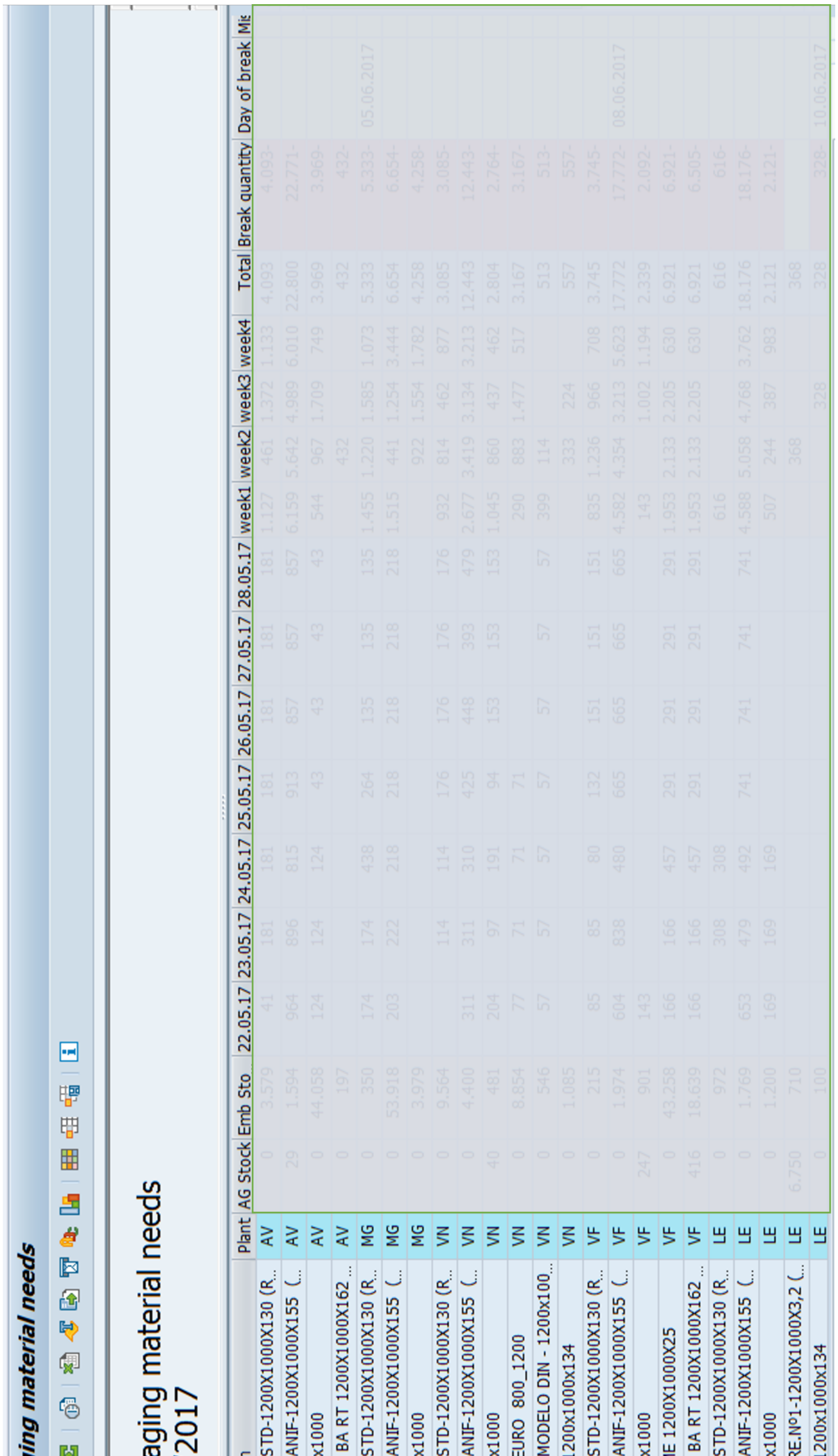


Figure 1: ERP Interface for Packaging Material Needs

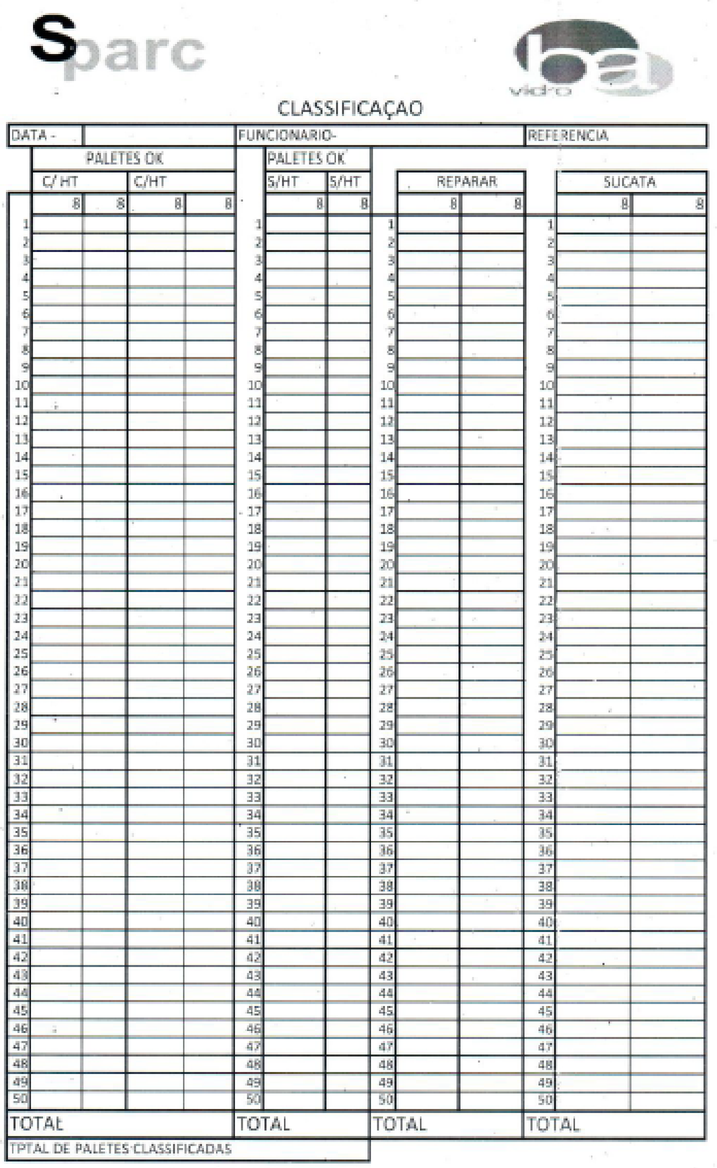
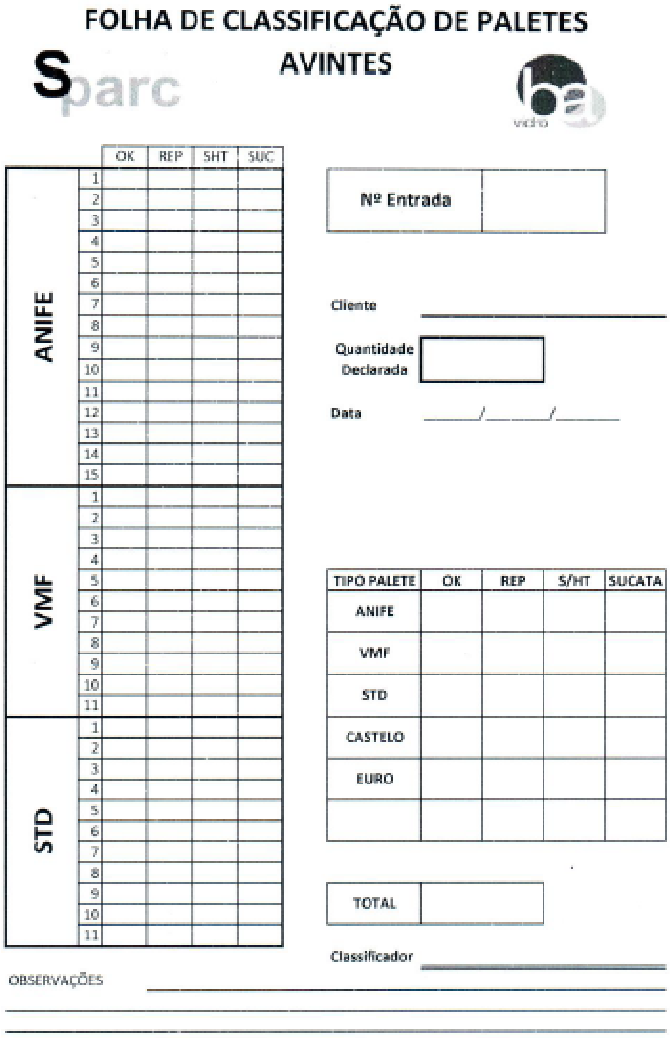


Figure 2: Operational sheet used in the Recovery Operator - before



FOLHA DE CLASSIFICAÇÃO DE PALETES

AVINTES

		OK	REP	SHT	SUC
ANIFE	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				
	11				
	12				
	13				
	14				
	15				
VMF	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				
	11				
STD	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				
	11				

Nº Entrada	

Cliente ______________________

Quantidade Declarada

Data ____/____/____

TIPO PALETE	OK	REP	S/HT	SUCATA
ANIFE				
VMF				
STD				
CASTELO				
EURO				

TOTAL	

Classificador ______________________

OBSERVAÇÕES ______________________

Figure 3: Operational sheet used in the Recovery Operator - after

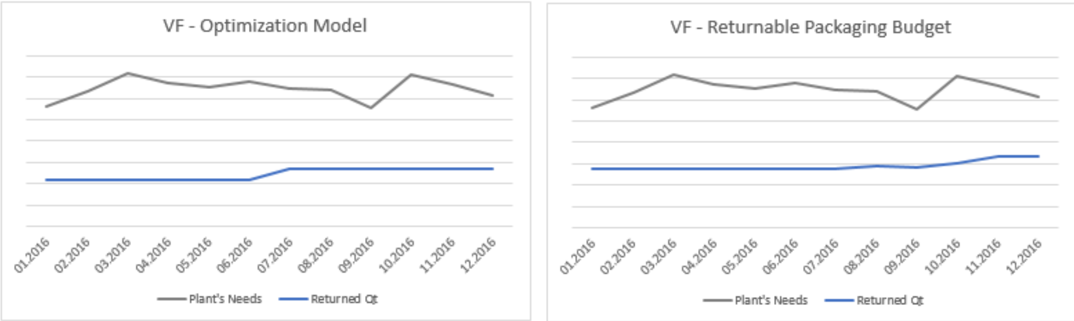


Figure 4: Forecasted Production Needs and Returns in VF plant

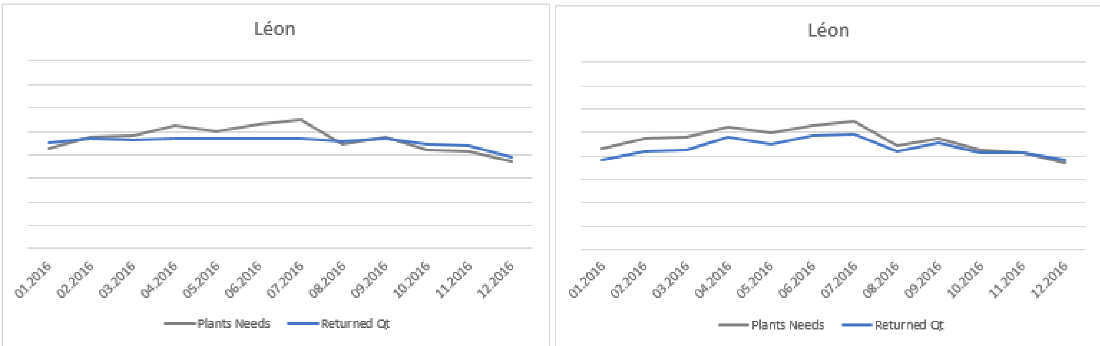


Figure 5: Forecasted Production Needs and Returns in LE plant

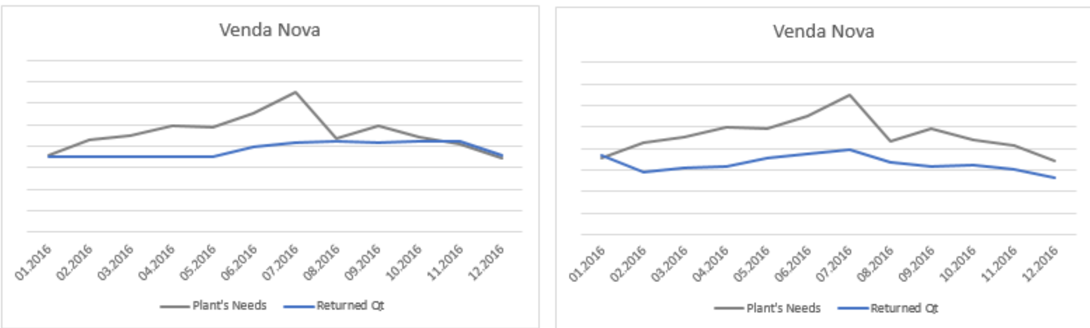


Figure 6: Forecasted Production Needs and Returns in VN plant

The returns to Villafranca de los Barros (situated close to Badajoz) were depicted in Figure 7. Sevilla (ES41) represents a little bit over 25% of the total returns, followed by regions in the south of France, Catalonia and Valencia.

Lastly, Venda Nova, systematically represented in 8 with a quarter of the returns coming from the metropolitan region of Lisbon (PT31), a great number coming from the central regions of

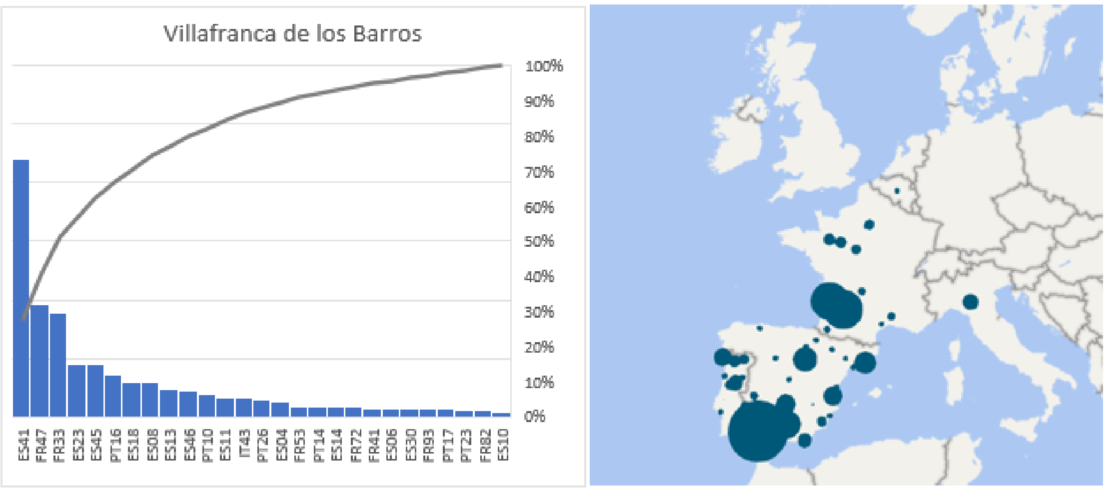


Figure 7: Pareto chart and heat map representing the proposed yearly returns to VF plant

Spain and the rest divided between Portugal, France, Italy and Belgium.

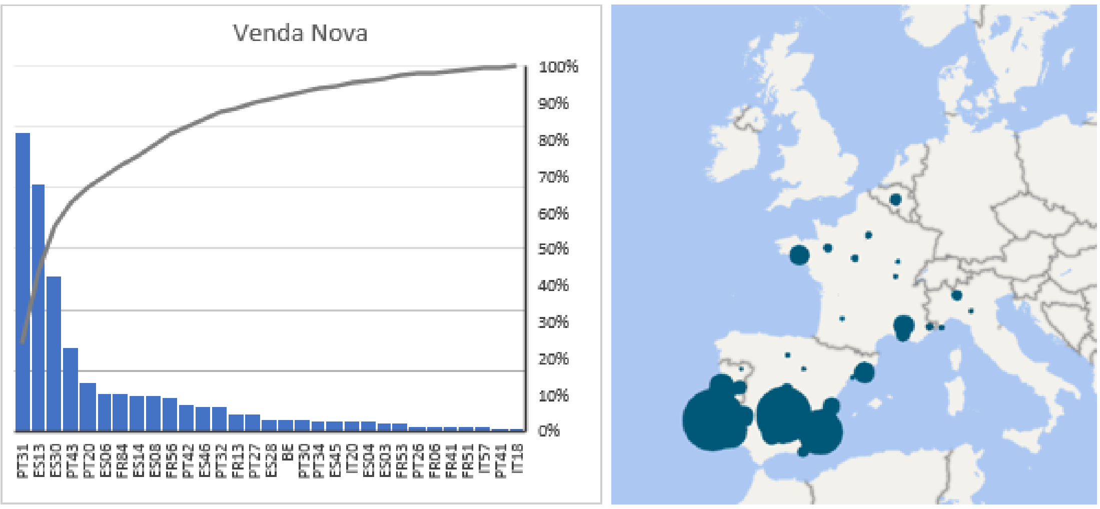


Figure 8: Pareto chart and heat map representing the proposed yearly returns to VN plant

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